INTERNATIONAL CONFERENCE ON SUSTAINABLE DEVELOPMENT IN CIVIL ENGINEERING (ICSDC - 2023)

16th - 18th February 2023

ICSDC 2023

CONFERENCE

FULL PAPERS PROCEEDINGS

Organized by:
Department of Civil Engineering
Mehran University of Engineering & Technology, Jamshoro

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PROCEEDINDS BOOK

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"Integrating Innovative and Sustainable Developments in Civil Engineering"

This theme is exclusively designed to attain the goal of integrating innovative developments in the discipline of civil engineering which is a major attraction of present time. The aim of ICSDC-2023 is to provide a platform to present and discuss all the cutting-edge research and scientific results related to Civil Engineering.

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Preface

Mehran University of Engineering and Technology (MUET), Jamshoro is known for producing high quality engineering graduates for many years. This university is now considered a distinguished public sector engineering university at the national & international level.

The Department of Civil Engineering is the largest department of the University in terms of infrastructure, student enrollment and faculty. It provides essential and advanced engineering education according to the requirements of the field. The vision of the Department of Civil Engineering is to become an institution that provides state-of-the-art education to aspiring civil engineering graduates, and to evolve as a research-based solution provider to the civil engineering industry.

Department of Civil Engineering in collaboration with Higher Education Commission and Pakistan Engineering Council, organizes 3rd International Conference on Sustainable Development in Civil Engineering (ICSDC-2023) in Mehran University of Engineering and Technology, Jamshoro Pakistan from 16 to 18 February 2023. This time the conference is being organized with a novel theme of "Integrating Innovative and Sustainable Developments in Civil Engineering". This theme is exclusively designed to attain the goal of integrating innovative developments in the discipline of civil engineering which is a major attraction of present time. The aim of ICSDC-2023 is to provide a platform to present and discuss all the cutting-edge research and scientific results related to Civil Engineering. This conference provides opportunities for the delegates to exchange novel ideas and experiences to establish research and business relations and to catch global partners for future collaboration.

The conference encourages collaborators from academia arena as well as industry professionals to present their original research of top-notch quality. The forum assembles keynote speakers, authors and participants from educational and industrial sectors to present and debate on various challenges faced by the stakeholders in the domain of Sustainable Civil Engineering.

ICSDC 2023 has been triumphant in attracting National and International participants and speakers from public and private organizations.

Acknowledgement

The organizing committee of ICSDC 2023 acknowledges the collaboration and support of Higher Education Commission (HEC), Pakistan Engineering Council (PEC), DHA City Karachi, Sardar Muhammad Ashraf D.Baluch (Pvt.) Ltd. The Palm Builders and Developers, MM Pakistan, Sumaya Builders, MUET FM, and MYHC Construction Company to make this event successful.

The active participation of the National and International Keynote Speakers, Authors, Participants, Session Chairs and Co-Chairs, Organizers, and Teacher Coordinators are highly appreciated who made the event eminent. High gratitude for the rigorous efforts of conference organizing committees.

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International Keynote Speakers

Prof. Dr. Douglas Barreto

Prof. Barreto is an Adjunct Professor at the Department of Civil Engineering at Federal University of Sao Carlos, Brazil. His core research emphasizes on Constructive Systems responsible for the discipline of Building Installations. He has wide experience in Civil Engineering construction especially in "Building Systems", "Sustainable Built Environment" with a focus on rational use of water in buildings and alternative energy. He has conducted numerous studies on pathology solutions in building systems in addition to technical work of restoration of historic sites. He has authored several national and international articles on building systems and is also a member of Regional Council of Engineers.

ABSTRACT

EFFICIENCY OF CITIES AND BUILDINGS – MAIN ASPECTS FOR ACHIEVING THE UN SUSTAINABLE DEVELOPMENT GOALS (SGDs)

Considering that in the last decade the world as a whole has been dedicating itself to the issue of sustainability in cities and buildings as a way of mitigating the environmental impacts resulting from human activities. The UN Sustainable Development Goals are of the greatest importance in this sense, enabling a systemic view of various aspects that influence the dynamics of Cities and Buildings, with three SDGs directly related to cities and buildings respectively SDG 6 Clean Water and Sanitation; SDG 7 Affordable and Clean Energy; and SDG 11 Sustainable Cities and Communities.

According to information contained in "UN - The Sustainable Development Goals Report - 2021, it is observed that for SDG 6, 2 billion people lack safely managed drinking water, 3.6 billion people lack safely managed sanitation, 2.3 billion people lack basic hygiene. For SDG 7, 759 million people lack access to electricity and accelerated action on modern renewable energy is needed — especially in heating and transport sectors. The indicators for SDG 11 show that the majority of the more than 1 billion slum dwellers reside in three regions: 370 million in Eastern and South-Eastern Asia; 238 million in Sub Saharan Africa; and 226 million in Central and Southern Asia.

Thus, it is of great importance to understand and discuss ways and actions to improve these indicators, which have not yet reached uniform levels in countries, especially in developing countries, which are far behind, and needing actions to reach adequate levels. Is urgent implementing efficiency instruments related with energy, water and others that results in a displacement of these indicators, making cities and buildings more efficient and sustainable? Some energy efficiency actions in buildings can be mentioned, such as the adoption of environmental certification, the use of more economical equipment, rational use of water and others. In cities, the trend is for the concepts of smart cities to be incorporated, which monitor various parameters, such as traffic and pollution level, public lighting and others. It is noteworthy that environmental issues affect the world indiscriminately and affect all countries, so acting in order to achieve these goals is a matter of priority order for all.

Prof. Dr. Norwati Jamaluddin

Dr. Norwati Jamaluddin is an Associate Professor in department of Structural and Material Engineering, Faculty of Civil & Environmental Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia. She has completed Masters of Structural Engineering from Universiti Teknologi Malaysia (UTM), Malaysia (2003) and PhD from University of Leeds, United Kingdom (2011). She has also served as a Structural Engineer (as part of Industrial Attachment) in HLA group of Companies. Her research interests include Steel Structural, Composite Steel Concrete Structures, and Finite Element Modeling. Moreover, she has been part of following professional societies: CSM, IAPS, MSSA, BEM, & MPA. She also has vast experience in the field of Management while serving in Fakulti Kejuruteraan Awam dan Alam Sekitar.

ABSTRACT

RESEARCH AND DESIGN DEVELOPMENTS IN CONCRETE FILLED STEEL TUBE COLUMN STRUCTURES

Composite columns possess many significant advantages over conventional reinforced concrete and steel structures. Its growing use in the case of structural and architectural applications is predominantly owing to the significant advantages of the structure, such as high load-carrying capacity owing to the blend of properties of differing materials in the structure (Ellobody et al. 2006; Wang et al. 2004). Steel is the most versatile traditional construction material and well known to provide high reliability in terms of its consistent quality and full efficiency when placed under tension whereas the concrete is efficient in compression. Concrete-filled tubes column, hereafter referred to as CFT, are being increasingly used as a structural element, especially in seismic zones, as it offers a number of significant advantages. The structure exploits the characteristics and overall configuration of the structure elements; steel offers high tensile strength, ductility and construction speed, whereas the concrete provides high compressive strength, stiffness and cost reduction. Another notable advantage associated with the use of composite columns is construction cost saving, as the steel tube can serve as a formwork to the concrete core. With the concrete-filled column profile, the opportunity to erect the steel frame after filling in the concrete material provides the advantage of saving both time and cost. The concrete infill can be from various concrete types, the normal weight concrete (NWC) and now with the concern of structure weight, the presence of light concrete weight concrete seems to be the choice. Another form of concrete which is the self-compacting concrete (SCC) adds more advantages to the CFT columns. The lightweight concrete, with the main characteristics in decreasing the weight and density of the material has significant changes that improve properties of concrete, both in placement and application. Since the lightweight concrete in form of SCC, same basic constituent materials for conventional concrete can be used but with the addition of various admixtures or fine materials with the objective to increase the cohesiveness and required rheological properties for SCC. Recent development of foam concrete as concrete structures has attracted the interest among the researchers due to the sufficient durability, excellent fire resistance and good thermal conductivity and it is categorized as a sustainable material. It is also the most popular lightweight material in the construction and industries. Nowadays, there are many formulations of concrete which provide various properties with the main ingredients which are aggregate, cement, and water. Recently, interest has developed all over the world in using a variety of wastes to make concrete more environmentally friendly. Cement production incorporated with waste materials compared to natural resources provide significant impact in term of reducing the carbon dioxide emitted and energy used for the production. It is also a practical solution to the pollution problem. The usage of waste material such as bottom ash and fly ash could be seen as brilliant way to minimize the use of natural sources for fine aggregate in concrete as well as preventing pollution. The production of bottom ash and fly ash from coal fired electric power plants; generate tons

of combustion waste every year, mostly lightweight "fly" ash and heavier "bottom" ash that settles on the floor of the boilers and the bulk of this ash goes straight to landfills. The bottom ash is coarse, angular and its size ranging between fine gravel to find sand. The particle size distributions shown that bottom ash composed of relatively well graded and coarse angular particles ranging in sizes that corresponds to the sizes of small gravel to fine sand. The development of the CFT column structures now has evolved in various aspects, the types of the tube and the types of concrete infill. These developments have been made to improve the structure performance, especially in terms of strength and workability of the structures.

Prof. Dr. Nasir Shafiq

Dr. Nasir Shafiq is currently working as a Professor in Structural Engineering and Sustainable development at Universiti Teknologi PETRONAS, Department of Management & Humanities. Apart from research and academics, he is actively involved in administrative positions. His current portfolios include Director of Sustainable Resources Mission Oriented Research (MOR), Chairman Innovation Committee and Chief Editor of the Research Bulletin RESINEX. The administrative positions main KPIs are research management at MOR level, strategic and business planning, monitoring of IP filing, Research Commercialization and Technology Licensing. His areas of expertise are Environmental Humanities, Social Ecology, Education for Sustainable Development, Higher Education Teaching & Learning, Sustainability Communications.

ABSTRACT

HOW COULD CONSTRUCTION INDUSTRY IN PAKISTAN EMBRACE CIRCULAR ECONOMY

The global statistics show that a tremendous amount of solid waste from multiple sectors is being generated every year; the 2020 data estimated that about 2.24 billion tons of solid waste were generated. It is calculated that on an average per person per day, footprints of 0.74 kilograms vary from country to country. Europe, Australia, North America, and other developing countries have established many programs for waste management to protect the global environment. Despite all these efforts, more than 50% of the generated solid waste is mismanaged and dumped into landfill areas, creating pollution and other environmental impacts. With the implementation of 17 sustainable development goals (SDG) in Paris 2015, many governments have pledged to strategize the deep carbon reduction agenda in their respective economies. In this respect, the concept of circular economy is embraced in business strategies, and all industrial sectors collaborate in solid waste trading. The construction industry is highly resource-consuming and has much potential to valorize waste from other industrial streams. Pakistan is facing many challenges in managing its urban expansion within the SDG framework. Therefore, the admiration of the circular economy through industrial symbiosis for the construction industry will not only facilitate the tremendous amount of solid waste management, particularly in Karachi, but it will create many tiny industries and jobs. This talk will discuss a framework that could be helpful for policymakers and construction professionals to bring the construction industry towards circular economy.

Dr. Jamal Thaheem

Muhammad Jamaluddin (Jamal) Thaheem is a Senior Lecturer of Construction Management at Deakin University, Australia. Previously, he was an Assistant Professor of Construction Engineering and Management at the National University of Sciences and Technology (NUST), Pakistan. He has a PhD in Cultural Heritage with research focus on project risk management from the Polytechnic University of Turin, Italy and a Bachelor of Civil Engineering in Civil Engineering from Mehran University of Engineering and Technology, Pakistan. He has research interests in risk management, construction engineering and management, sustainable development, and behavioral and decision aspects of the built environment. With over 100 indexed publications, based on Scopus citation data, over 2% of his publications have been ranked in the top 1% most cited publications worldwide, 9% of his publications have been ranked in the top 5% most cited publications worldwide and over 17% of his publications have been ranked in the top 10% most cited publications worldwide. He was awarded the "Best Teacher" at NUST and received merit scholarship for his PhD from the Higher Education Commission, Pakistan

ABSTRACT

CIRCULAR BUILT ENVIRONMENT – A NEW PARADIGM FOR SUSTAINABLE CONSTRUCTION

The impact of construction industry on the global resource base is phenomenal. From consuming resources to providing basis for development, the construction activity is at the core of human development and global resources consumption. The typical linear take-make-dispose model has been since long the modus operandi of the construction industry. Despite efforts at minimizing the impact of this model through better waste management, this model is inherently not sustainable. In an effort to learn from the nature and applying the tenets of circular economy, the built environment's journey to adopting circularity is promising – in spite of the apparent challenges and barriers. In this talk, we'll discuss the evolution from the linear to circular model, possible advantages and challenges to its adoption, and the sustainable way forward.

Prof. Dr. Nur Izzi Md Yusoff

Dr. Nur Izzi is currently working as Associate Professor in Department of Civil Engineering, Universiti Kebangsaan Malaysia. He is a committee member for Transportation Science Society of Malaysia (TSSM) and a member of some other professional bodies such as the Board of Engineers, Malaysia (BEM), Road Engineering Association of Malaysia (REAM), Road Engineering Association of Asia and Australasia (REAAA) and Association of Asphalt Paving Technologists (AAPT). His main research interest is on pavement materials, construction, design and rehabilitation and road safety. Dr. Nur Izzi has published more than 100 technical papers and supervised more than 30 postgraduate students. He also serves as a regular reviewer for more than 400 papers submitted for high and reputable journals. In addition, he is serving for an editorial member for International Journal of Pavement Research and Technology (IJPRT), and Journal of Engineering and Shock and Vibrations.

ABSTRACT
RECENT DEVELOPMENT OF SUSTAINABLE ASPHALT TECHNOLOGY

A sustainable pavement can be defined as a pavement that minimizes environmental impacts through the reduction of energy consumption, natural resources and associated emissions while meeting all performances conditions and standards. Realizing the importance of this issue, sustainability elements of each material used in construction of flexible pavement will be discussed. This session starts with a brief introduction on historical background of ancient and modern highway worldwide, followed by the discussion on sustainable term in the context of pavements. Tips for improving sustainability from various types of materials such as aggregate, bituminous binders and asphalt mixtures' point of views also will be discussed, together with some real examples in selected areas/regions. It cannot be denied that sustainable pavement certainly requires more capital to build, but on the long run it is economic, friendly to the environment and better for the society. Other two interesting topics that gains interested among paving scientists and researchers; namely perpetual pavement and innovative asphalt technology will also be discussed towards the end of this session.

National Keynote Speakers

Prof. Dr. Naveed Ahmad

Dr. Naveed Ahmad, currently working as a Professor in Department of Civil Engineering UET Taxila. He has done his PhD and Post-doctorate from the University of Nottingham, UK. Dr. Ahmad has worked as a key member for the development of "Taxila Institute of Transportation Engineering (TITE)" at CED UET Taxila. He also has worked as a Focal Person in various International Research Collaboration between TITE, UET Taxila and Hasselt University Belgium. He remained Member in joint consortium (NHA, NUST, UET Lahore, and UET Taxila) for improvement of asphalt mix design technology for Pakistan and delivered several invited talks/lectures to organizations like NHA and FWO on the subject of Transportation Engineering. He remained a member in Panel of Experts for Government's five-year action plan for technical co-operation in Highway Engineering between China and Pakistan. His areas of expertise are: Study of surface properties and interfacial adhesion, characteristics of pavement materials, effects of material modifications on their adhesive bond strength, and moisture sensitivity of these materials.

ABSTRACT
DURABILITY/MOISTURE SUSCEPTIBILITY OF ASPHALT CONCRETE

Asphalt mixture is mainly used for the construction of roads throughout the world. Large amounts of capital are spent for construction and maintenance of roads. Water is one of the major contributors towards the damage of road structure. It is considered as the worst enemy of a pavement structure by directly causing a distress or indirectly magnifying a distress and hence damaging the road structure. Asphalt mixture loses its strength in the presence of water either through loss of cohesion within the bitumen or loss of adhesive bond between bitumen and aggregate. All the conventional techniques that are used for the determination of the moisture susceptibility of an asphalt mixture assess the material as a whole by using some mechanical testing technique without taking into account the individual physicochemical characteristics of both the bitumen and the aggregates. The surface energy properties of the materials, which are used to quantify their interfacial adhesion, play an important role in the final adhesive bond strength between these materials. Similarly, it is important to understand the effect of presence of air voids in asphalt mixture. Percent air voids in the asphaltic concrete are specified for two stages; air voids for the mix design (Job mix formula), and air void in the field (in-place air voids after the final compaction/construction of the pavement). The air voids/pores in an asphalt mixture are generally divided into three categories; permeable pores, dead end pores, and isolated pores. Selection of right amount of air voids is of great significance for an asphalt mixture to survive. Right understanding and combination of the highlighted durability parameters can greatly contribute towards the development of a powerful material screening protocol/tool for selection of bitumen-aggregate combinations and gradations that are less susceptible to moisture damage.

Prof. Dr. Rizwan Farooqui

Prof. Dr. Rizwan Farooqui is serving as Professor and Co-Chair at the Department of Civil Engineering, NED University, Pakistan. He has a Ph.D. degree in Construction Engineering and Management from Florida International University USA; an MS degree in Structural and Construction Engineering from National University of Singapore; and a B.E. degree in Civil Engineering from NED University. Prof. Farooqui has over 20 years of research, teaching and construction industry experience in the USA, Pakistan, Singapore, Dubai, Qatar and Ethiopia. Few of his major accomplishments include: Development and implementation of a construction process re-engineering model for Ethiopian Construction Industry; Development of a strategic model for improvement of construction project management education, research and practice in Pakistan (a Pak-US collaborative grant), development of the M. Eng. Program in Engineering Management (with specializations in construction management and industrial engineering management) for NED University; and development of the B. Eng. Program in Construction Engineering for NED University.

ABSTRACT
CONSTRUCTION 4.0 – CONCEPTS AND EMERGING TECHNOLOGIES

Construction 4.0 is the counterpart of industry 4.0 in the AEC industry since 2013. In a nutshell, it's the Digitization, Automation, and Integration of planning, design, execution construction processes in all phases of a construction project. In recent years, due to the rapid development of the fourth industrial revolution and new platforms of information technologies, intelligent systems have received widespread attention in many industries and have brought the potential to improve the efficiency of the construction industry. These facts led to the appearance of a new concept in the construction industry called Construction 4.0. Construction 4.0 – the reality of connecting the owner and contractor, the field to the office, and the physical aspects of a project to the digital side of the project. The last decade has witnessed unprecedented changes in the technologies and processes involved in the construction industry. The philosophies associated with Industry 4.0 now reverberate in construction 4.0. Digitalization and interconnectivity in the cyber-physical systems of the sector are at the heart of such transformation. Construction 4.0 brings to the table a plethora of technologies and associated processes over the construction project lifecycle. This keynote will deliver an address on Construction 4.0: Concepts and Emerging Technologies. The keynote will provide insights into the meaning of construction 4.0, and the different aspects of its successful implementation in the construction sector. Overview of key technologies with sample applications in Construction will be discussed such as BIM, Digital Twins, AR/VR, Sensors, Drones, IoT, AI etc.

Prof. Dr. Khan Zaib Jadoon

Prof. Dr. Khan Zaib Jadoon is currently working as a Professor and Head of the Department in Civil Engineering at International Islamic University Islamabad, Pakistan. He received his PhD in the field of Water Resources Engineering from Université Catholique de Louvain, (UCL) Belgium. Dr. Jadoon is leading the water resources engineering research group and supervising a research team focuses on interdisciplinary cutting-edge research and innovation in surface and groundwater hydrology. His areas of special interests revolve around groundwater and hydro geophysics, from unsaturated zone hydrology to aquifer storage and recovery, and use of non-invasive geophysical methods to monitor subsurface flow and transport processes. He remained an active team member in different internationally funded research projects. Dr. Jadoon worked in different capacities including PI, Co-PI as well as collaborator in projects involving HEC funded NCGSA, NRPU projects and international funders such as BMBF Germany, Forschungszentrum Juelich, Germany, LBNL USA and Saudi national grant. Dr. Jadoon is a member of Environmental and Engineering Geophysical Society (EEGS), European Association of Geoscientists and Engineers (EAGE) and as a senior Program Evaluator (PEV) of Pakistan Engineering Council for Outcome-Based Education (OBE). He has published more than 70 peer-reviewed articles in journals and international conferences proceedings, having cumulative impact factor of around 100 with h-index of 15.

ABSTRACT
IMPLEMENTATION OF SMART GROUNDWATER MONITORING SYSTEM FOR SUSTAINABLE GROUNDWATER MANAGEMENT

Groundwater has consistently offered a dependable source of high-quality water for human use. In terms of global groundwater consumption, Pakistan ranks fourth. The situation in Pakistan has worsened as a result of the government subsidizing power for agricultural use, which allowed for the development of numerous tube wells around the nation and the ensuing high groundwater depletion. There are two main challenges for sustainable groundwater management. First, considerable groundwater depletion has been caused by rising withdrawals to meet growing human needs, which is typically not observed due to the high expense of the monitoring system. Data limitations and the application of regional groundwater models for future prediction is the second issue. To track the in-situ real-time dynamics of groundwater depletion, a smart groundwater monitoring system with Internet of Things (IoT) capabilities has been created and tested in this study. Each groundwater monitoring sensor is coupled to an integrated module that comprises of a wireless transceiver using Long Range Radio (LoRa) technology and a microcontroller. The readings from each LoRa-enabled module are combined at one (or more) gateways, which are then linked to a central server—typically over an IP connection by the centralized server. The smart groundwater monitoring system's sensors were calibrated in a lab setting using changes in water levels in a 3-meter water column. To enable a remote real-time assessment of groundwater level monitoring, a network of low-cost groundwater sensors was installed in the region. In order to achieve social benefits (promote equity among groundwater users), economic benefits (optimize pumping, which reduces energy costs), and technical benefits (better estimates of groundwater abstraction)

for sustainable groundwater management, the smart and resource-efficient groundwater monitoring system helps to reduce the number of physical visits to the field and also enhance stakeholder's participation.

Prof. Dr. Khan Shahzada

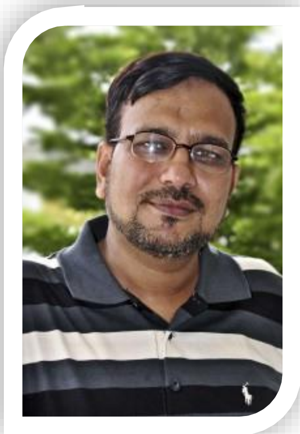
Prof. Dr. Khan Shahzada is currently working at the Department of Civil Engineering, University of Engineering & Technology, Peshawar. He has done his Ph.D. in Structural/Earthquake Engineering from the same university. His specialization is Seismic Risk Assessment of Buildings, Vulnerability Assessment of unreinforced and confined masonry buildings, Hazard assessment, Development of fragility curves for different types of buildings, and risk assessment of existing buildings. He has published a book on SEISMIC RISK ASSESSMENT OF BUILDINGs also.

ABSTRACT

SUSTAINABILITY-BASED INNOVATIONS IN CONSTRUCTION MATERIALS AND STRUCTURES

Shelter is one of the most basic rights of humans. For a comfortable and relaxed living, the shelter should be sustainable, strong, and safe. For the achievement of these goals, the material evolution era produced ample improvements at material and structural levels. Further, Pakistan lies in one of the seismically active regions where earthquakes in the past caused catastrophic damage to structures and human lives. To cope with this, competitive masonries like brick, dry stack, cellular lightweight concrete, solid and hollow concrete masonry are seismically evaluated using different structure typologies including unreinforced, confined, and retrofitted structures. Most of these results are validated numerically. Moreover, some of the masonries are assessed for blast loading both numerically and experimentally. RC frames and infill walls are assessed through quasi-static and shake table loading and proposed effective ways for its improvement. Strengthening of different structures is performed using different techniques including ferrocement overlay, engineered cementitious composite, external steel elements, and other Indigenous materials. Additionally, significant work is done at the material level using different additives to replace cement in concrete which includes wheat straw, bagasse ash, bentonite clay, rice husk ash, silica fume, waste glass, and marble powder. Based on the above experimentations, different materials are commercialized at the country level and improved based on the recommendations extracted from these studies.

Prof. Dr Muhammad Javed Iqbal



Associate Professor Dr. Muhammad Jawed Iqbal is currently working as Director Academics and Head of Transportation Engineering Department at National Institute of Transportation, a constituent institute of National University of Sciences and Technology (NUST), Pakistan. Dr. Jawed has more than 25 years of experience in various disciplines of Civil Engineering. His research interest includes Traffic Safety, Transportation Master Planning, Mass Transit Planning, Transportation Management, Congestion Management, Highway Design and Road Safety Audit. Dr. Jawed has taught traffic engineering and geometric design courses at MS and PhD level and carried out research to more than 25 students. He has number of publications to his credit, published in journals of international repute. Dr Jawed also attended postgraduate course in Disaster Management from AIT, Thailand. He is member of various professional engineering bodies.

ABSTRACT

ESTIMATING THE COST OF A ROAD TRAFFIC ACCIDENT IN PAKISTAN USING HUMAN CAPITAL COST APPROACH

Road safety is one of the leading causes of deaths in Pakistan and situation of road safety in Pakistan is worrisome. Thousands of people died, and millions got injured due road traffic accidents every year in Pakistan. The road traffic accidents not only cause physical losses, but economic losses and emotional losses are also associated with it. The survival of a family is questionable whose bread earner died or severely injured in RTA. The main objective of this study is to estimate the average cost of a road traffic accident using Human Capital Cost Approach at each severity level (fatal, major and minor accident) in Pakistan. For this purpose, accident data was collected from rescue 1122 and National Transport Research Centre (NTRC). Reported RTA data, population data and data of registered vehicles were obtained from Pakistan Bureau of Statistic. Collect Questionnaire survey was conducted to collect the data on medical cost, vehicle damage cost, vehicle downtime, judicial system cost and ERS. The RTA data depicts that 4% fatal, 23 %% major and 73% minor RTAs occurred in the study area. It also depicts the major cause of RTA is over speeding and carelessness. The average age of death in RTA is 32.54 years and 65% of death victims of RTA are of less than 40 years of age. The morning peak of RTAs is 7:00 a.m. to 9:00 a.m. and evening peak of RTAs is from 4:00 p.m. to 7:00 p.m. The cost estimation using human capital cost approach shows the average economic losses of Rs. 6.2 million, 1.4 million and 0.039 million occurred in case of fatal, major and minor RTA respectively. The analysis of data as per Islamic laws show the average compensation cost in case of RTA (Katal-e Khata) is Rs. 12.6 million in terms of camels and Rs. 17.45 million in case of Dinar (gold coins). While iRAP method shows the average loss in case of fatal crash is Rs.12.3 million and in case of non-fatal RTA the losses are Rs 3.074 million. The analysis shows the total losses incurred in Punjab due to RTAs is Rs 188.5 billion that is more than 1 % of the GDP of Punjab and 11.21 % of the budget of Punjab.

Prof. Dr.-Ing. Saqib Ehsan

Prof. Dr. Saqib Ehsan is a prominent expert and research scholar in the domain of Water Resources Engineering, currently rendering his services as Professor (Civil Engineering) at NFC Institute of Engineering & Fertilizer Research, Faisalabad Pakistan (affiliated with the UET Lahore). After graduating in Civil Engineering from UET Lahore in April 2002, he completed his MSc in Water Resources Engineering & Management in November 2004 and PhD in Civil Engineering (with specialization in Hydraulic Engineering) in March 2009 at Stuttgart University, Germany. He has valuable experience of teaching and research both at undergraduate and postgraduate level. He has total teaching/research experience of more than 20 years including more than 13 years' experience at post-PhD level. His areas of interest/expertise are Risk Analysis of Hydraulic Structures, Disaster Management, Water Resources Management, Hydraulic Engineering, Hydrology, Hydrogeology/Groundwater Management, Flood Control, Floodplain Management, River Engineering, Numerical Modeling and Rehabilitation of Structures. In addition to his multiple research papers in refereed/indexed journals and conferences/workshops, he has also published a Book (International Edition) titled as: "Evaluation of Life Safety Risks Related to Severe Flooding". He is reviewer of many national and international journals. He is also member of various national and international professional organizations/associations. Currently he is actively engaged in various collaborative research projects in the domain of Civil Engineering funded by foreign institutions.

ABSTRACT

DETAILED STUDY TO INVESTIGATE POSSIBLE GROUNDWATER RECHARGE OPTIONS FOR CITIES IN PAKISTAN

This research involves a detailed study to explore the possible groundwater recharge options for cities in Pakistan. It highlights the significance of storm runoff for groundwater recharge in urban areas. Due to excessive withdrawal of groundwater in urban areas, the groundwater table is significantly depleting each year. A proper storm water drainage system should be functional in order to collect the storm runoff from different parts of an urban area. As Case study, the Gujranwala city in Pakistan has been taken into consideration. The city has strong potential for a storm water drainage system. Each year a significant amount of storm runoff in Gujranwala city is not utilized due to unavailability of a proper storm water drainage system. Different aspects of hydrology and hydrogeology of this city have been thoroughly studied and using the available information about deep confined aquifers in the city area, the design considerations for tube wells have been elaborated. Various options for groundwater water recharge in the city area have been investigated and a typical design of an inverted well in the city area has also been proposed. This study strongly recommends the concerned authorities to first provide a suitable storm water drainage system in Gujranwala city and to investigate the feasible options of groundwater recharge. This research is intended to provide useful guidelines for studying the feasibility of groundwater recharge techniques in urban areas of Pakistan and also other parts of the world.

Dr. Shamsher Sadiq

Dr. Shamsher Sadiq is an alumnus of the MUET and currently serving as Assistant Professor at Department of Civil Engineering, Mirpur University of Science and Technology (MUST), Azad Kashmir. He earned Ph.D. degree in Civil Engineering (Major: Geotechnical Engineering) from Hanyang University, South Korea and B.E. degree in Civil Engineering from Mehran UET Jamshoro. He is currently working in range of areas: Energy Geotechnics, Soil-Structure-Interaction, Geotechnical Earthquake Engineering, Numerical Modeling in Geomechanics, Seismic Hazard Analysis and Ground Response Analysis, Tunneling in Soil and Rock and Landslide Hazard Assessment. He has also been involved in various R & D projects in South Korea, US and Pakistan. Currently, he is a PI and Co-PI of two HEC funded projects involving the development of seismic site amplification factors and amplification model for shallow bed rock sites of Pakistan.

ABSTRACT

EVALUATION OF SEISMIC SITE AMPLIFICATION CHARACTERISTICS OF SHALLOW BED ROCK SITES CONSIDERING PAKISTAN'S LOCAL PROFILE DATA

Current seismic provisions in Pakistan, seismic site classifications, and corresponding site amplification factors (BCP 2021) refers ASCE/SEI 7-05, which are based on the local site conditions of Western United States with low impedance contrast, deep sites, and high seismicity conditions. The use of these deep sites-based amplification factors to the shallow sites may not be appropriate to capture shallow sites' response. This study performed a non-linear site-specific response analysis suite to compute the amplification characteristics for the six (06) representative shallow bedrock sites generalized from 457 datasets of Islamabad, Pakistan. The computed amplification factors are compared with code-based design estimates; it is found that code-based guidelines underestimate amplification factors at a short period whereas overestimating at an extended period. Further, this talk shares the way forward for developing amplifications factors for Pakistan considering local geotechnical site profile database.

Sustainable Construction and Project Management

ID 34: Adaptive and Sustainable Design for Building Construction Considering Climate Change

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A B S T R A C T

The two most crucial factors that are constantly taken into account while developing or building any new infrastructure in this day and age are sustainability and resilience. In a similar manner, this project centers on the same idea of sustainability and resiliency in order to construct a 10-story structure that served the function of a multipurpose community center equipped with cutting edge technology and carefully selected construction materials in order to lessen the number of harmful emissions and to keep a balance in both the structural strength and the environment. The design process has involved choosing the primary building material, the type of construction used, the building plans, and the carbon footprints the selected building materials are generated. The building's planned design also assessed for structural soundness, environmental sustainability, and resilience. The outcomes are compared to an existing structure in the same domain for the critical evaluation and effective decision-making. As a result, this compilation also includes a complete and in-depth analysis of how the suggested construction is more robust and sustainable. The preface also includes information on the building parts, such as the materials used to contrive the structural as well as the nonstructural members. In the end, the suggested design is monitored based on its structural qualities to ensure its stability and resilience. In order to successfully propose a sustainable and resilient design for the building of a multipurpose 10-story community center, a comprehensive and optimal set of recommendations is provided.

K E Y W O R D S:

Sustainability, Resiliency, Construction, Climate Change

1. Introduction

An adaptive and sustainable design plays a vital role in the prevention of buildings from climate changes observed in the dynamic world. The concept of sustainable and resilient design is explored in multi-directions, including the social, economic, health, building performance and other environmental factors as well. Sustainable principles daunt the practice of non-renewable natural resources, which are helpful in enhancing resource conservation. The multi-structured building considered for climate change, including structural and non-structural members, need in-depth assessment for material, strength, harmful emissions, environmental sustainability, and resilience.

In sustainable and resilient building design, the role of climate change is vital, which includes several seasonal and non-seasonal natural phenomena like humidity, wind, rain and other temperature changes. Based on record, the expected increase in temperature falls between 1.8°C to 4.0°C at the end of 2tst century [1].

Climate change increases global warming and affects building performance which has become a constant pressure in the construction industry. Developed countries have proper building policies and standards which help in reducing carbon footprints and temperature to have control over diseases. Selection of building material according to revised building codes is important and regular maintenance also increase the resilience of the building. Passive building designs also help to deal with difficult situations [2].

Carbon footprints need to be controlled during the construction phase by having an appropriate timeframe and good consumption of material to decrease operational energy. The study has shown an increase of 5 million tons of carbon footprints from 2005 to 2009 [3]. Carbon footprint control techniques like recycling products and materials have worked well. Also, sustainable and resilient buildings are one of the best options to get over ecology stress.

2. Research Methodology

2.1 Data Collection

The data presented in this paper was gathered through the consideration of various research approaches specifically linked with the design of buildings with 10 stories and calculations of carbon emissions. After it has been designed, the building with ten stories judged against another structure of a comparable size in order to determine how well it performs in terms of its resilience and sustainability. The flow of methodology is shown in Figure 01.

2.2 Design Approach

The community centre that housed in the designed ten-story structure state-of-the-art and feature separate areas for administrative tasks, social and public gatherings, cafes, recreational activities (games, rides, etc.), and also included a swimming pool. The structure was designed in accordance with all applicable building codes as well as the general requirements outlined in design standards. All of the structural elements are designed using appropriate calculations that take into account combinations of dead load and live load, in addition to other requirements.

2.3 Calculations of Multiple Aspects

The following is a list of the computations that are going to be included in this research paper:

- The total volume of concrete that was used in the construction of each floor's structural members.
- The total amount of wood that was used in all the structural members, floor by floor.
- Calculating the associated levels of carbon emissions (based on construction materials).

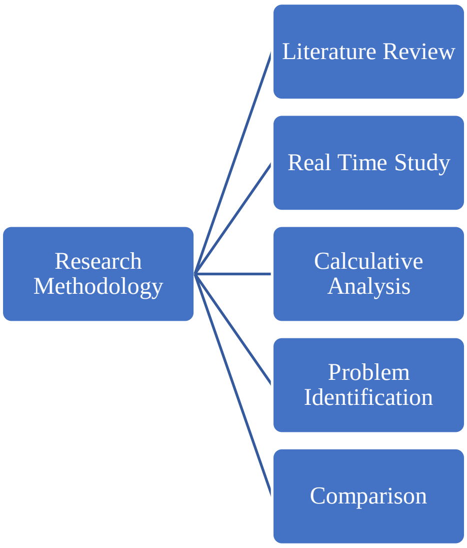


Figure 01: Research Flow

3. Result and Discussion

3.1 Selection of Material

For the building's construction, the following two concrete proportions are selected:

3.1.1 M15 (1:2:4) Concrete Mix

In the M15 concrete mix, 15 MPa(N/mm2) is the compressive strength of the cement which is 2175 in psi. Compression strength defines the ability of a material to resist after the application of compressive force. The proportion of 1:2:4 represents cement, sand and aggregate, respectively. In terms of percentage, it becomes 14.28%, 28.57% and 57.14%, respectively. Furthermore, the quantity of steel is considered for building construction, which cannot be finalized based on concrete grade, but the type and dimension of structural members, including the total area of a 10-story building and the concrete amount for holding reinforcement, is supposed to be determined. The water-to-cement ratio for M15 ranges between 0.4-0.6, while steel% for slab, beam, column and foundation are 0.7-1, 1-2, 0.8-6 and 0.8, respectively, for a 1-meter cube of concrete.

3.1.2 M20 (1:1.5:3) Concrete Mix

In M20 concrete mix, 20 MPa (N/mm2) is the compressive strength of concrete which is 2900 psi, and the proportion of 1:1.5:3 represents cement, sand and aggregate, respectively, which makes 18.18%, 27.27% and 54.54% in the same order. The water-to-cement ratio is 0.42, and the %steel for structural members like slab, beam, column, and foundation have ranges 0.5-1.5, 1-1.5, 2-3 and 2-5, respectively [4].

While making a comparison between M15 and M20, it is finalized that M20 is better in terms of compressive strength, stability under tension with a 13.33 modular ratio (modulus of elasticity of steel/modulus of elasticity of concrete) and strong binding, but the main problem is with the environment. M20 produce CO_2 and increases global warming, which is not suitable for climate change. While M15 has 15 compressive strength, 18.86 modulus ratio and 14.28% less cement content as compared to M20, causing fewer oxides of cement, it is eco-friendly, which produces less air pollution and is considered best for climate changes and is budget-friendly too.

3.2 Concrete Construction Techniques

3.2.1 Precast Concrete

Precast concrete is one of the types of concrete which is prepared in a rebar framework away from the original site, but the conditions remain the same. After the curing and hardening, it is transported and assembled into the structure under construction. The precast concrete method is suitable for a multistory building having prefabricated structural members as per standards. It can be a Large Panel system (Multistory buildings) and a Frame System (Beam-columns assembly for multistory buildings).

3.2.2 The sustainability of precast concrete

Precast concrete can work on all structural members of the building, but it makes relatively heavier members. It offers good elasticity and quality with more durability of members. The use of material makes it cost-effective and eco-friendly, with no on-site construction. On the other hand, it subsidizes chamber formation of structural elements (columns and beams). Also, it is costly in terms of member transportation, including the connections and joints [5].

3.2.3 Cast-in Concrete

The preparation of framework, curing, hardening and filling of concrete is ensured on-site for cast-in concrete. It is suitable for load-bearing walls and foundations made by a certain grade and by taking the shell out or by filling the driven metallic shell, which is cured till the desirable durability and compressive strength are obtained. Also, the vibrator is used to make concrete consistent in the framework along with reinforcement.

3.2.4 The Sustainability of Cast-in Concrete

Cast-in concrete offers a variety of shapes, sizes, surfaces and textures, along with easy connections for a 10-story building. At the same time, the heavy machinery, more labor and time-consuming fabrication of reinforced framework are tricky to handle. Furthermore, consistent and standardized quality is challenging to retain. While making a comparison between precast concrete and cast-in concrete, precast concrete is recommended based on the consistency and homogenous quality of the structural members of a multi-story building. Also, the carbon footprints are reduced by eradicating harmful pollutant yield at the time of concrete production. The overall procedure results in the maintenance and sustainability of the environment while constructing a multi-story building. Precast concrete is friendly in terms of eco, economics, material quality and resilience. The optimal curing, labor efficiency, short-time hardening and resistance against climate change make precast concrete sustainable and a good option to consider for the construction of a 10-story building.

3.3. Calculative Analysis

3.3.1 Volume & Steel Weight Calculations

The calculations are mentioned in the following Tables from Table 1-8, moreover, the cross section is illustrated in Figure 02.

Table 1: Column Calculations

Slab calculations	**Slab Thickness (m)**	**Slab Size (m)**	**Concrete Volume in Slab (m^3)**
(One Floor)	0.150	33 x 33	33 x 33 x 0.150 = 163.35

Table 2: Slab Calculations

Table 3: Beam (One Floor)

Column calculations	**Column Height (m)**	**Column Size (m)**	**No of Columns**	**Volume of 1 Column (m^3)**	**Volume of concrete in 25 Columns (m^3)**
(One Floor)	3.850	0.750 x 0.750	25	0.750 x 0.750 x 3.850 = 2.16	2.16 x 25 = 54

Beam (One Floor)	**Length (m)**	**Width (m)**	**Depth (m)**	**No of Beams (m)**	**Volume of Concrete in 1 Beam (m^3)**	**Volume of Concrete in 20 Beams (m^3)**
Beam Type -01	7.125	0.750	0.450	20	7.125 x 0.750 x 0.450 = 2.4	= 2.4 x 20 = 48
Beam Type -02	7.50	0.750	0.450	20	= 7.50 x 0.750 x 0.450 = 2.5	= 2.5 x 20 = 50

Table 4: Total Concrete Volume

Total Concrete Volume (cum)	1 Floor (cum)	10 Floor
	Column + Slab + Beam-01 + Beam-02 = 54 + 163.5 + 48 + 50 = 315.35	Column + Slab + Beam-01 + Beam-02 = 315.35 x 10 = 3153.5 cum = 80 x 3153.5 = 252,280 kg = 252.28 tons

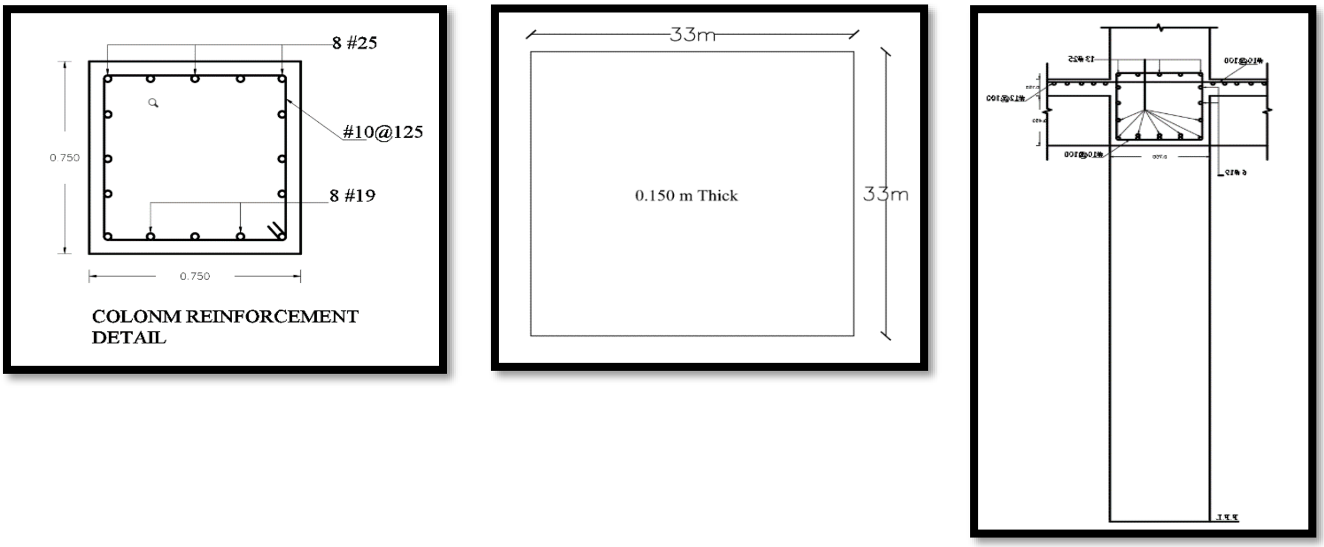


Figure 02: Cross sections of elements

Table 5: Carbon Emission from Concrete

Carbon Emission Calculation from concrete of Designed Building	**Total Volume of Concrete (cum)**	**20MPa Concrete (per cum) emits CO2 (kg)**	**Total Emissions**
Carbon Emissions from Concrete For All Floors	3153.5	328	= 328 x 3153.5 = 1034348 kg CO_2 emissions

Table 6: Carbon Emission from Steel

Carbon Emission Calculation from steel of Designed Building	Steel bar emits CO2 (kg)	**Total Emissions**
Carbon Emissions from Steel (Columns + Slabs + Beams) For All Floors	2.1	**= 2.1 x 252,280 = 529788 kg CO_2 emissions**

Table 7: Carbon Emission from Glulam Floors

Carbon Emission from Treet Building	**4 floors Volume**	**1m^3 Glulam**	**CO_2 emission**	**Volume Concrete Slab (5)**	**Concrete Slab Emissions**
Glulam Floors	550 m^3	1718 kg CO_2 e	= 550 x 1718 = 944900 kg	1250 m^3	= 5 x 1250 x 328 =2050000 kg CO_2 e

Table 8: Carbon Emission from Remaining 10 Floors

Carbon Emission from Treet Building	CLT Volume for 1 Floor	CLT Volume for Floors	1 m^3 CLT emits CO_2	CLT CO2 emissions
Remaining 10 Floors	385 m^3	=10 =385 m^3 x 10 =3850 m^3	645 kg	=3850 x 645 =2483250 kg

Proposed 10 Story Building	**Treet Building**
Total CO_2 emission for the concrete = 1034348 kg CO_2 e	**Total CO_2 emission for glulam** = 944900 kg CO_2 e
Total CO_2 emission for the steel = 529788 kg CO_2 e	**Total CO_2 emission for Concrete Slab** = 2050000 kg CO_2 e **Total CO_2 emission for CLT** =2483250 kg CO_2 e
Total CO_2 emission = 1564136 kg CO_2 e	**Total CO_2 emission** = 5478150 kg CO_2 e

3.4. Discussion based on Results

It has been determined through these calculations and the results obtained that the Treet building emits a greater amount of carbon than the designed building. In comparison to the Treet building's use of Cross laminated timber and glulam as its primary building materials, the proposed design for the fifteen-story building, which uses reinforced cement concrete as its primary building material, is the more environmentally friendly option [6].

4. Evaluation of The Design's Long-Term Sustainability and Resistance to Failure

The standard building has a heat recovery installed ventilation system, district heating system, timber as primary and concrete as secondary material. In contrast, a 10-story designed building has a heat recovery proposed ventilation system, heat exchanger system, and concrete as primary and timber as a secondary building material. There are three stages of construction for a typical high-rise (levels 1–5, 6–10, and 11–15), while a custom-designed structure has only two (levels 1–5, and 6–10) [7]. Comparatively, the designed building has sliding windows with triple glazed low emissivity glass, load bearing framework in only the seventh floor, a single hinged swinging door made from oak wood with stainless steel frame, and concrete slab on the seventh level, while the standard building has windows with low emissivity glass with an aluminum frame, load bearing framework at every fourth floor, wooden doors, and concrete slab on the ground, fifth, tenth, thirteenth, and fourteenth floors. Standard buildings in this area of Hordaland, Norway (which has a coastline) have an underground parking system and several refreshment points, but the designed building has ground parking on all four sides and features a swimming pool, fitness center, and restraint on its roof. The total construction area is 7140 square meters. For long-term viability and defence against severe weather, there is metal cladding at the left, right and back sides to protect concrete from extreme weather conditions and steel plates with dowels as joints. In comparison, designed multi-story building have metallic cladding on the 10th level because of concrete as a primary material in construction, including anchor bolts to join columns, beams and slabs; steel plates and dowels are used to make timber connections [8]. The required graphical representations are as follows (Figure 03-12)

Figure 3: Treet Building [10]

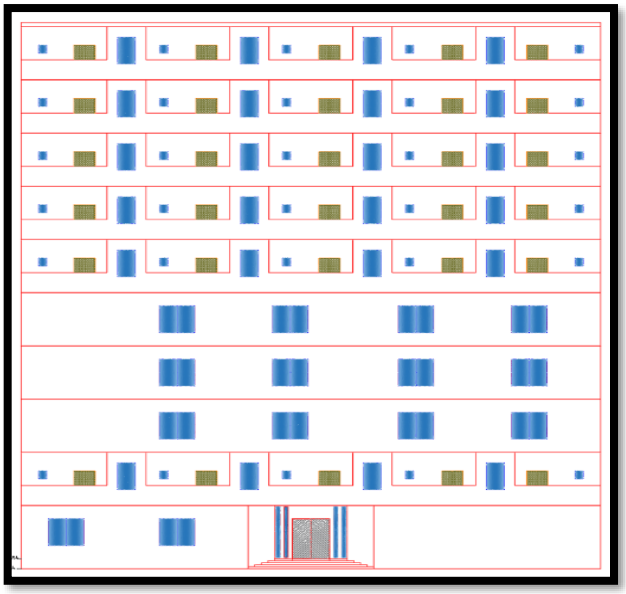


Figure 4: Plan of Building

Figure 5: Proposed Ground Floor Plan

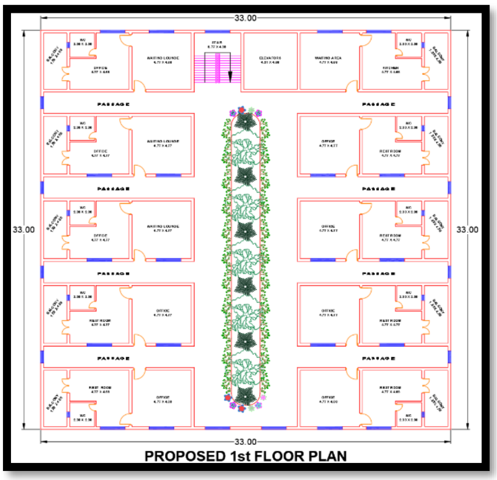


Figure 6: Proposed 1st Floor Plan

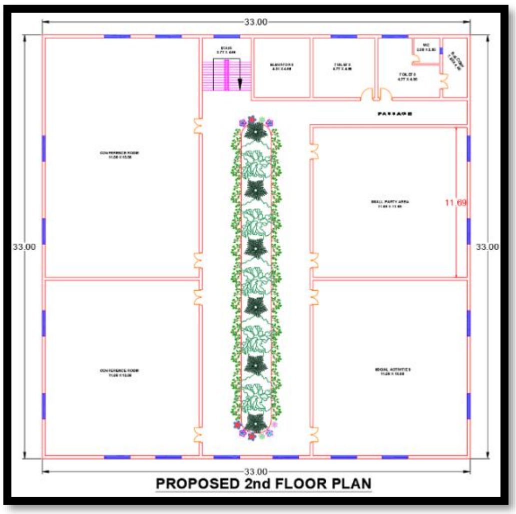


Figure 7: Proposed 2^{nd} Floor Plan

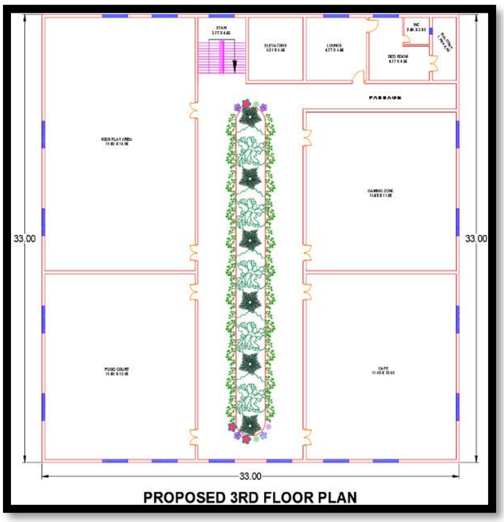
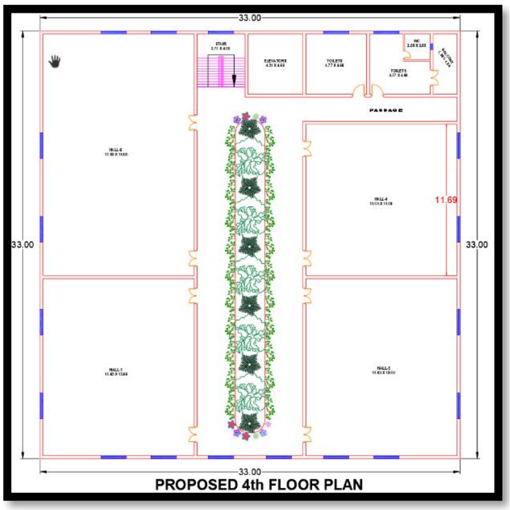


Figure 8: Proposed 3^{rd} Floor Plan



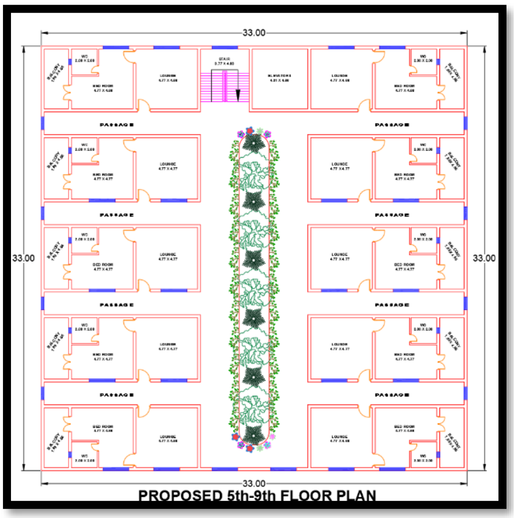
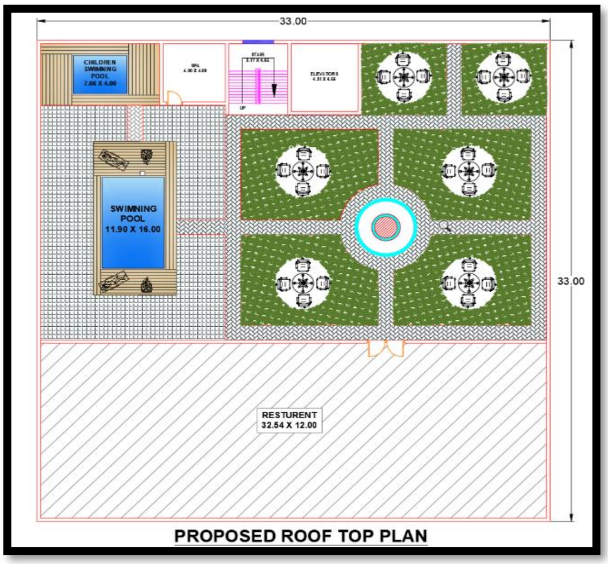


Figure 9: Proposed 4th Floor Plan

Figure 10: Proposed 5th-9th Floor Plan



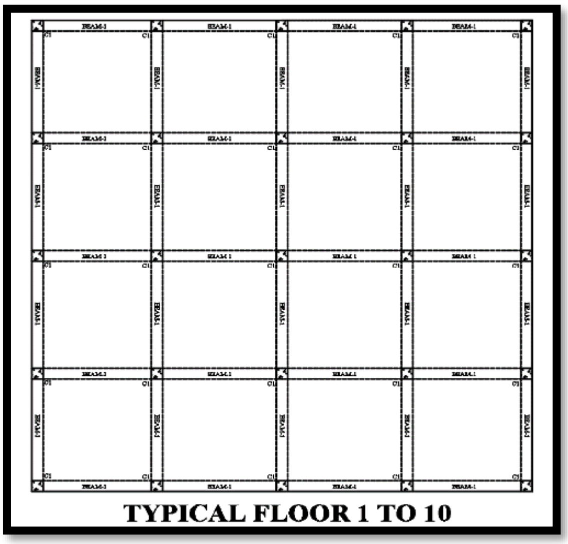


Figure 11: Proposed Roof Top Plan

Figure 12: Typical Floor 1 to 10

5. Conclusion

This research was to put forward the study of sustainability and resilience of 10-story building design as per the standard criteria. Sustainability is associated with environment-friendly structures emitting less carbon emission footprints, and resiliency is the tendency of a building to sustain against disaster with redundancy and robustness. Sustainability is achieved through advanced techniques to undertake CO2 emissions from materials, while resiliency is obtained by making the right selection of material type, reviewing soil characteristics, and studying reinforcement.

The design procedure includes analysis of topography and construction area, which leads towards the drafting of floor plans with necessary components and elevations were made. After that, M20 grade concrete with S-355 grade steel is selected as the primary construction material for structural members (column, beam, slab etc.), while timber is a secondary material for building elements (doors, windows and frames). Furthermore, aluminum and stainless steel for framing, low emissivity glass with triple glazing for windows, hybrid ventilation system, heat exchange system, condenser boiler, glazing and insulation are ensured to reduce the CO2 emission [9]. Apart from that, a well-thought-out analysis was made to select techniques of concrete construction (M20, M15, precast concrete, cast-in-place concrete) with a type of foundation. The calculation for volume and quantity of concrete is also made. Lastly, the comparison of designed 10-story building is made with a standard Treet building in Norway, having all details of components highlighted in the designed building, and it is concluded that the designed is more resilient and sustainable.

6. Acknowledgment

We are highly thankful to the whole team of International Conference on Sustainable Development in Civil Engineering 2023 for making this work possible. We are extremely thankful to Engr. Fida Hussain Siddiqui, and Engr. Moazzam Mughal for their assistance during this work. Finally, we are gratified to Almighty Allah, who is ever graceful to us.

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ID 57: Building Information Modelling (BIM) based Approach for Waste Estimation and Management in Building Demolition

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A B S T R A C T

Construction and demolition (C&D) heave a lot of attention nowadays. All over the world, ways are being discovered that generate less waste. A renowned principle in this regard is to reduce, recycle and recycle waste generated in construction industry. Initial requirement for performing any of such activities is to have a basic estimate of that amount of waste. Currently our construction industry is marred by weak and inaccurate methods of waste estimation. Considering this anomaly, this research is conducted to develop a BIM based system, for better waste estimation. The system is expected to give an estimate of the waste that would be produced if we perform the building demolition. It is also required to output the amount of waste that should be recycled and the amount of waste that should be sent to land fill sites. The methods of waste estimation that are already mentioned in literature are reviewed in first part of this research. Subsequently the model is verified by applying the waste estimation on an example residential building. Successively, the data from Revit is input to a software programmed in C++ language to get estimates of waste. As a result of this research, we get an approach that can be used to estimate building waste. The framework has capability of estimating amount of total waste generated as well as the amount of recyclable and disposable waste. Along with that, the framework gives an estimate of the cost of total amount of waste produced, specifying amount saved on recycling/reusing.

K E Y W O R D S:

Construction Industry, BIM, Waste Management, Sustainable Development, Sustainable Construction.

1. Introduction

Construction and demolition activities have increased a lot nowadays. There has been an unprecedented increase in construction of new buildings and renovation of older structures. Where this culture helps our industry to thrive, it also causes many problems. Due to such trends, C&D (Construction and Demolition) activities have expanded to worrying levels. This high level of construction activity makes construction unsustainable. Where it helps improve economics and employment in the industry, at the same time it is causing negative impacts to the environment and depletion of construction materials. More alarming is the forecast of further increase in C&D activities. Recent studies have drawn our attention towards the impact of these activities on the surroundings. Construction industry no leverage, as it faces negative comments from critical analyst over harmful effects on the environment due to construction and demolition activities. The community awareness on this matter has forced modern researchers to work out ways to make construction industry more environmentally friendly. This could help us keep construction industry away from the radar of critics.

1.1 Construction & Demolition Waste

One of the hazards of construction industry that pose a risk for the environment is the C&D waste. Any waste that is produced in the process of construction and demolition can be called as C&D waste. The larger proportion of construction waste is generated in the demolition process instead of construction, Poon [1]. The types of construction materials that are most common, are most common in C&D waste as well. These include concrete, steel, bricks, glass etc. In general practice these materials are just dumped or incinerated causing multiple pollutants, Hamidi [7]. In current era it carries a lot of significance to pay heed to construction waste management. Construction waste management can be described as the more effective and efficient way of managing construction and demolition (C&D) waste to protect our environment from harmful effects.

There are several reasons for generation of C&D waste. Demolition process can be highlighted as the biggest culprit here. The waste generated in demolition process is generally just dumped in landfills that causes land pollution. Demolition of buildings is an important part of th e industry and cannot be avoided. In avoiding demolition process we stand at risk of causing safety issues for the residents and causing lack of space to build. A strong reason for C&D waste is the use of steel reinforcement which is very popular nowadays. Steel reinforcement needs to be cut for use. The cutting of steel causes unwanted small pieces formed by shaping the edges of the steel that are wasted. The use of premixed concrete is also an issue. In premixed concrete there are many supply chain issues, to deal with them a larger amount is usually made which causes wastage. Sometimes lack of communication also causes difference in demand and supply of premixed concrete. As lower culprits, pipes and wires also cause waste. Inaccurate sizing and unusable residual parts, common in such equipment, get wasted in the process.

Although air pollution always takes away the limelight. It is not the most significant effect in every case. One of the important effects is also land pollution which is caused by the dumping of C&D waste. Piles of waste gathered in large open areas cause wastage of land. The heaps of waste collected in any area causes bad aesthetics of that area as well. The problem become more severe if the dumping is being done in urban area. Usually urban areas are avoided, but logistic waste can lead to urban dumping. This causes expensive land to be utilized in unnecessary waste causes scarcity of land and housing. The second most ill effect is the depletion of construction material. Good quality construction material is not available in abundant quantity. The unregulated use of the material would slowly lead to its depletion. Unless we find alternatives or encourage recycle, we may face scarcity of construction material in future. It may start with simply increase in prices of such materials. Third most important effect is the economic loss. Waste being generated due to inefficient methods determine waste of materials that is purchased from funds of the project. More material required due to wastage leads to cost overruns and missing of budget targets. The overall project is completed at a higher cost and the time is also wasted.

To find a solution in this situation, we need to find new ways of construction and demolition. Our new methods should minimize waste generation and should encourage recycling of the material that is already used. This should reduce chances of inflation in construction material's prices in future. There is a chance of establishing habits of construction and demolition that are less harmful to the environment and more sustainable. According to research from 2009 by McGraw-Hill Construction in United Kingdom, 80% of contractors involved in the field of construction in United Kingdom have responded that sustainable waste management will become an important practice by 2014, McGraw [3]. This is an unusual increase of 19%, when it is compared to 5 years ago McGraw [3]. With this discovery, construction, and demolition (C&D) waste problem has amassed astonishing attention from both practitioners in the field and researchers around the world Lu [4].

1.2 Building Information Modelling

Perhaps, one of the most advanced tools adopted for the purpose is BIM. BIM cannot e defined as a software, rather it is a technology. BIM can be defined as a methodology of making process of construction linked through portable digital representation. It is a collection of many tools that allow this process. As compared to previous such attempts, BIM has led to discovery of various new advancements in this field. BIM encourages various types of analysis of the project through model in addition to data. BIM has various components of function. Its various functions include visualization, clash detection, quantity take offs, surveying and machine guidance, scheduling, and cost estimation. The last two features are one of the most notable features from the perspective of a construction manager. BIM has bigger role in sustainable construction. Through its planning and designing capabilities, it has allowed advanced analysis and change of methodology to cuts costs and emissions in very initial stage. The use of such technology has made it faster and more accurate to estimate material used and produced in C&D. This area is the most imperative part of solutions to waste management in construction and demolition activities.

2. Literature Review

C&D waste is any unwanted material produced in the course of construction and demolition process. Pakistan roughly produces twenty million tons of physical waste annually, with an approximate yearly growth rate of nearly 2.4%, Racheal [6]. Largest city of our country, Karachi generates more than nine thousand tons of physical waste each day, Iqbal [5].

2.1 3r (Reduce, Reuse & Recycle) Policy

It is a popular theory used for better waste management. The policy focuses on reducing the waste generation altogether as first priority. Then to find best solution of any waste that is unavoidable. The first and the most important part of the theory is “Reduce”. It is the most important part due to the benefit it holds. It is way easier to handle the situation when waste isn’t produced at all in the process. The second part is “Reuse”. This part encourages direct use of a component of one building by replacing it to other building. This method is only in use in some cases due to problem of synchronization. The construction products are unique, unlike manufactured products. This makes it difficult to reuse any component. When applicable, this method does save time, money, and waste accumulation. It saves time and money because no process is required to be done before using that material again. The third part is “Recycle”. This part of the policy instructs to recycle the material wasted in the process. This can be done in different ways. The concrete can be crushed and used as aggregate again. Steel can be taken out and cut in smaller size to be used again in structures requiring lower length.

2.2 Review of Available Waste Estimation Systems

A waste estimation system was developed by in Portugal by Poon [1], that used waste index for the estimation of amount of waste produced. The index is multiplied with the GFA (Gross Floor Area) to find amount of waste produced on demolition of that building. This method is very inaccurate due to difference of waste produced in different projects. The index is found by estimations and calculations which don’t give a magic number to be used for each project. At best it gives somewhat accuracy when used for just that specific region. It needs lot of verifications and revisions according to the conditions. The method gives inaccurate results because of the change in nature of construction as well. Residential, commercial or industrial buildings all have difference in amount of waste that would be produced. This can be observed in the field that certain components of building produce more weight than others. This renders average calculation method as inaccurate.

Another effort in the pool was done by Jalali [2] in Portugal. This method is similar to Poon [1] method, but it is more precise. In this method component indexes are calculated using similar methodology. The component index is found for each component and used to find waste for only that specific component. This method improves accuracy, but the generalization still haunts its calculations. The components of various buildings also yield different amounts of waste. The method also has gross estimation and thus this method gives inaccurate result as the gross floor area doesn't define the actual amount of material used in the building.

Further in 2008, a method was developed by Lau [10] in Malaysia. This method requires specific work to be done in the field before calculations. The waste when generated in the field is made to the shape of a pyramid. This is done by making heaps of waste in the shape of a pyramid. Then the dimension of that pyramid of waste is found like length, width and height. Then using the mathematical formula for calculation of volume of a pyramid, V=1/3(L x B x H). This method is very inaccurate due to the reason that in field it is not possible to make a shape of pyramid each time. The pyramid made would have non straight edges which would mean that the estimate is wrong. The waste that is piled in this method is not categorized into different types. This leads to very vague level of waste estimation and management. This is because of the different effects that each type of waste has the amount of waste generated needs to be categorized into different types.

In 2014, research was conducted by Behzad Hamidi [7] in Virginia tech university USA. The research resulted in formation of a tool for waste estimation. This method employs BIM for the purpose of waste estimation and partial management. The estimates are later used for a cost benefit analysis of the whole demolition process. The BIM estimated waste is classified into the type of waste that can be reused or recycled. The cost saved by reusing and recycling is compared with the cost of demolition. This estimate helps us to know the financial standing of our demolition process. The framework formed has a lot of inaccurate estimation and human effort requirement. To keep things simple, researcher has kept the material setting same for all components. This harms the accuracy level of the waste estimate, because of the difference in the waste produced in each component. There is no program to input estimate data which leads to a requirement of a lot of work required by the user.

Extraordinarily strong research was done by Jack C.P Cheng [8]. This research involved making a framework for the waste estimation. The waste estimated is then distributed into different categories. The further calculations are done by a software programmed in C# language. The framework here then outputs number of trucks required for the transport of that cargo. But this method is extremely specific to Hong Kong's local industry. The reason being the type of model, the size of cargo trucks and the recyclable material selected. The type of residential model used here is very strictly typical to the construction industry of Hong Kong. This restricts it to be used only for the construction industry of Hong Kong.

An excellent attempt at waste estimation was done by Beatriz C. Guerra [9]. This research aimed at solving a problem in waste estimation methods currently used. The methods in use usually overestimate the quantity of material in a model. This is because the amount of difference due to use of steel reinforcement is not considered in the estimate. This is due to the error in commonly used software of BIM. The research found such factors and used new algorithm to make changes in methods. The new methods after use algorithm subtract the amount of volume used up by use of steel. This makes the estimates more accurate than earlier. Although it helps in this regard, the research done is based on forming algorithms. This research does not actually produce a framework to work on waste production. This research does provide a new field to work on to get more accurate results.

After doing this review of available literature it was observed that the research conducted by Jack C.P Cheng [8] was an advanced step towards waste estimation and involved better tools for the purpose. It still lacked, in nature the effect that Pakistan's conditions would have on the framework. Considering this research gap, it was decided to work according to Pakistani conditions in a framework like that research in Hong Kong. To devise a framework for waste estimation. This devised method contains additional features as well.

3. Research Methodology

3.1 Reviewing Available Waste Estimation Systems in Literature

The first step of this research was to review literature and analyse various waste estimation systems developed (Refer Fig 01.). The waste estimation systems that were analysed were currently in use in some part of the world. In some other cases the frameworks were just proposed by some researchers and were not used as of now. The methodology and result structure of all such systems were critically analysed to find deficiencies in those systems and find new gap to work on. The result of this review should give guideline to follow for making a new and improved system for waste estimation and management.

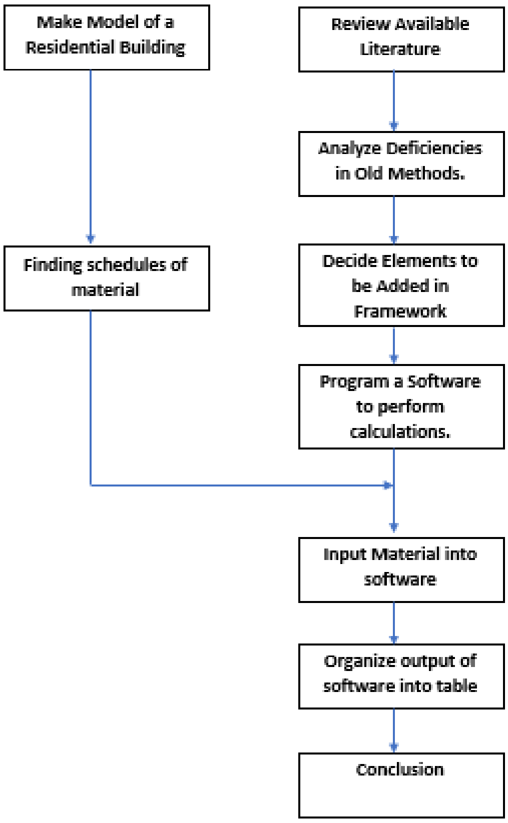

Fig. 1. Flow chart of methodology of this research

3.2 Making Revit Model of the Building

The research further advanced with design of a BIM based model of a building for the estimation. The model is made in Revit structures software. It is a common software for BIM programmed by Auto Desk inc. The model of the building has exact dimensions of 92 ft by 52 ft. The model has an area of 4968 square ft. The model of this building can be seen in Fig. 2. The model is made to represent a typical residential building in Pakistan. This model depicts construction over an area of five hundred square yards. The model contains 5 rooms and a kitchen. The building has 3 ft ground level and then double storey structure of 10 ft height per floor. Such building can be found in most residential areas of Pakistan.

3.3 Finding Quantity of Material for the Model

Now that the model is already made, the amount of waste can be calculated. The Revit software due to its setting always store such data for the model. While we design the model, the software records a lot of stuff like the volume of material used in the model. There are some tools like quantity take off and material take off etc used for finding out the amount of material in the model. This material basically is the amount of waste that would be generated on performing the demolition process. In our case schedule of the various components of the model were found. The schedule outputs many types of data that were of our use. The quantities of dissimilar materials used in the building were found by evaluating quantity take-offs of various components of the building. The volumes found were later used to find mass of materials in those components.

3.4 Coding of C++ Software

Once the volume-based quantities of material were found. It was required to do some calculations. For the calculations to be done without effort a software was made part of the framework. The software is programmed in C++ language and is written using code blocks console. The software inputs volume data and outputs quantity of material in terms of mass. The software then calculates the amount of material that could be sent to reuse or recycle facility and the amount of material that needs to be sent to sorting and dumping facility. In this research material containing concrete and steel is considered fit for reuse/recycle. Other materials such as plastic and wood are sent to sorting and dumping facility. The software initially finds out each type of material produced. The logic behind this step remains the fact that all material in the building should be produced in the field on performing demolition. The estimate specifies the amount of material that would be wasted and the amount that could be used for good. The software in addition output number of trucks required for transportation of this cargo. The software in its last output stated the approximate cost of the material being sent for reuse/recycle. This tells us the cost that could be saved by us on reusing or recycling that product for future construction use.

4. Results and Discussion

4.1 The Model of The Building

The model of the residential double storey building can be seen in Fig. 2. The figure shows model in Revit software with one floor and open slit roof. The Revit software screen shows the perspective of the view of this model. The open roof allows observance of the model's interior Our typical structures consist of an area of six hundred square yards and construction is done on 500 square yards leaving remaining area open for lawn.

4.2 Calculating Quantities of Material

The quantities of the material were found using the schedule tool. This tool allows finding out volume of each component separately. The schedules, in addition give location of every component present in the model as well, providing more usable data. The result of schedule for the column can be seen in Fig. 3. This type of result gives a better idea of the data for the model. It also gives location of every component in the model. The schedules are found for various components of this model such as floors, windows, doors, columns, beams, walls etc. The heads of this sheet are selected by judgement to know the quantities of type of data that would be useful for the research. The volume part was of the most use to us. The software itself adds all the volume and gives us a total for all the elements of the same category of components. For suppose schedule of columns would include all columns and a total volume for all the columns can be found directly from Revit. This feature was used to get the total volume. A special type of schedule was required for the quantity of rebar. That requirement for different schedule was due to non-availability of rebar volume option in Revit. For the purpose special field had to be created.

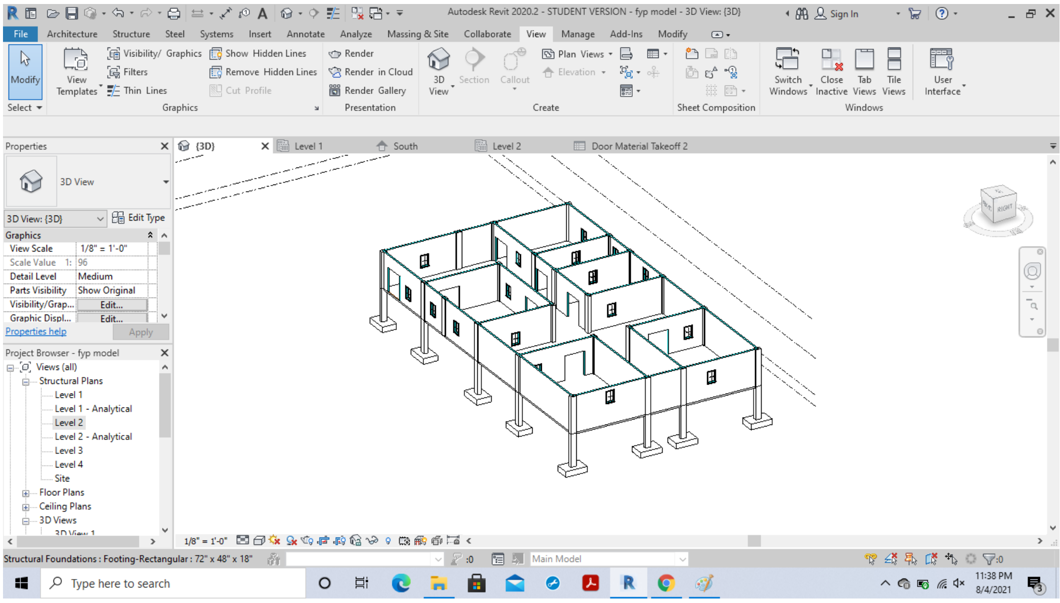

Fig. 2. Model of the building in realistic perspective

The process included finding out unit weight for a bar. As the bar number was in our knowledge so the unit weight was found, and it was multiplied with the bar length that the software calculates itself. This outputs us the weight of steel in total. The total volumes of the components were noted down for each of the component for future use. Table 1 shows volumes (weight only for rebar) of different components of the model building. These volumes are recorded from the schedule generated for each of the component.

Table 1. Volume/Quantity of all the components

COMPONENT	Quantity / Volume of Material Used
Column	636.33 cubic feet
Wall	5454.45 cubic feet
Foundation	864 cubic feet
Door	106.63 cubic feet
Window	26.47 cubic feet
Rebar	47780.72 pounds
Floor	6054.65 cubic feet

4.3 Running the Program

The software is run, and results are found after successful running of the program. The software on boot asks number of components to be analysed, as can be seen in Fig. 4. On selecting the number, program runs instructions on loop for as many times as stated in initial input. As can be seen in Fig. 4, 7 was entered as number of components. Once the volumes of those materials are added, the software itself does the calculations and outputs the end results, which can be found in Fig. 5. The program has outputs total weight of each component. This gives the amount of waste that would be generated in total. The total weight of each component output can be seen in Fig. 5. The software also outputs weight of each type of material that would be produced on performing this demolition. This is important in making decision of whether the material would reused/recycled or would be disposed. The software outputs total weight of material (general), that would be produced because of this demolition. The total weight of each material generated can be seen in table 2.

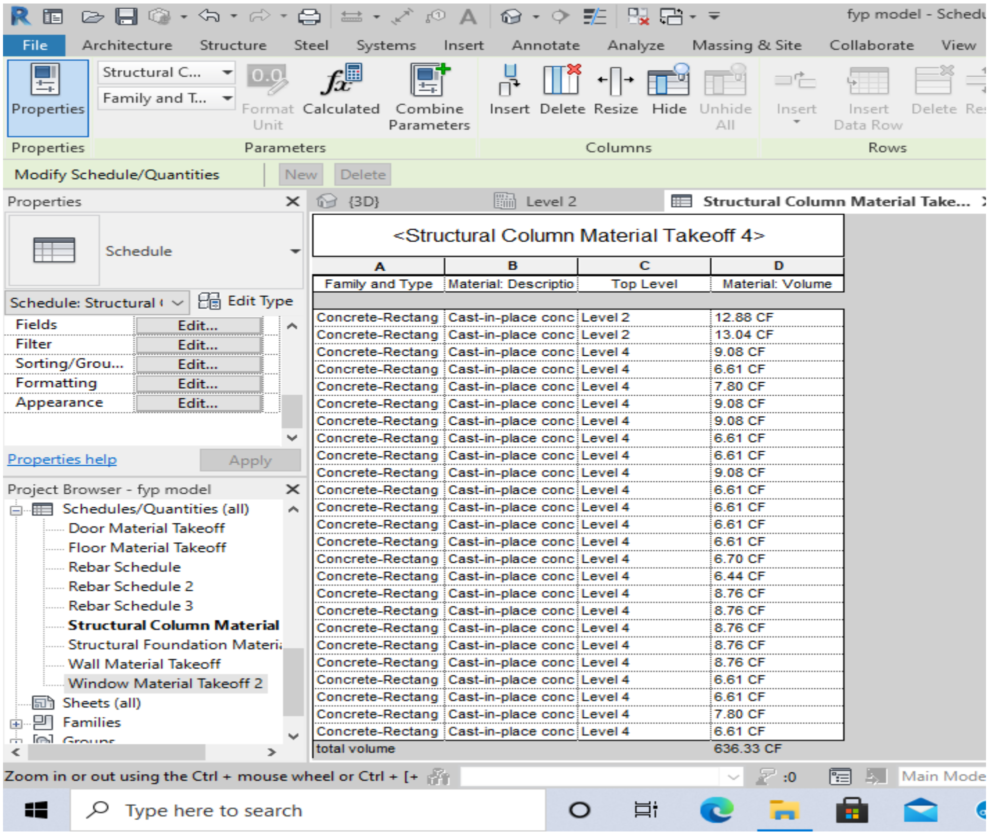

Fig. 3. Schedule/Material take off for columns

For efficient construction management, the software calculates (by simple addition) the amount of material to be sent to reduce and reuse facility and the total amount of material that needs to be sent to sorting and dumping facilities.

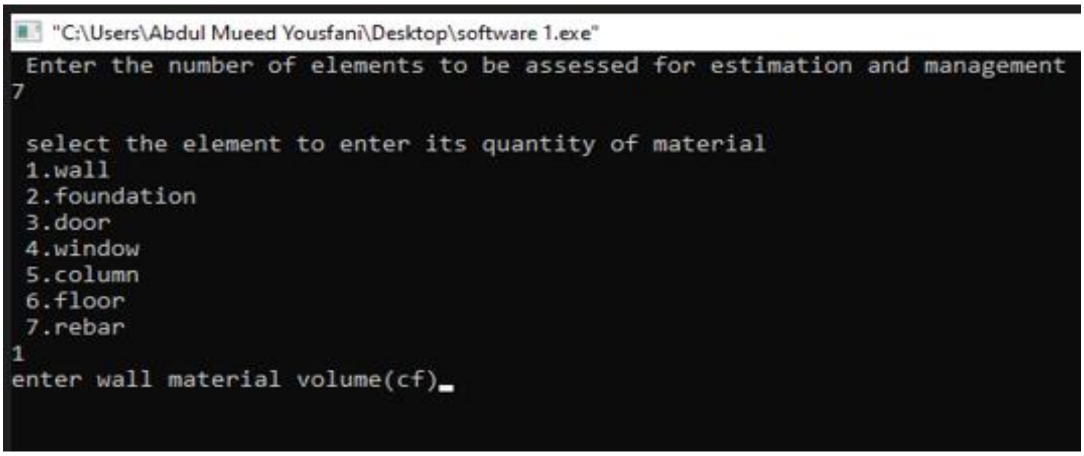

Fig. 4. Software asks for volume of wall material.

The software has done it by categorization. It sends all material but concrete and steel to sorting and dumping facilities. An additional output by the software is of finding out the number of trucks (pre-selected capacity of 4000 pounds) that would be required to transport all the cargo. The size of truck is selected by finding the usual size of truck that are used in Pkaistan. The material for different destinations as estimated by the program can be seen in Table 3.

Table 3. Weight and number of trucks of materials

Category	Weight Of Material (Kilo-Pounds)	Number Of Trucks Required (4000 Pounds Capacity)
Reuse/Recycle	2094.64	523.661 (almost 524)
Sort/Dump	13.8584	3.46459 (almost 4)

At last, the program outputs cost of all material. The significance of this output is that we get to know the amount (in PKR) that we on average would save by reusing/ recycling all this material. The output of the software for cost of all the materials that can be saved, is given in the Table 4.

Table 4. Total cost of different materials

Type of Material	Total cost (Rs)
Concrete	2428950
Metal (Steel)	3770450
Glass	18529
Wood	298564

The results of this table are found by multiplying the quantity of each material with the per unit cost of that material. The per unit cost if found by gathering information from local market at that time. Although it may be noted that this amount is an estimate and practically the amount in field could be a bit different.

Table 2. Weight of several types of materials

Type of Material	Weight of Material (Pounds)
Metal (Steel)	47780.7
Concrete	2046860
Glass	4261.67
Wood	9596.7

5. Conclusion

The research is successful in completion of its goals. The research results in the formation of a methodology for efficiently estimating the amount of waste generated by performing a building demolition. The estimation of the amount of material depending on its destination is also found which confirms the objectives have been accomplished. The system is verified by testing it on an example model of a building which is common in Pakistan. The program that was coded, gave a facility to do such calculations without need for any work from the user and without the need of setting an excel sheet each time for the work. The framework developed can be used by our agencies and institution for better estimation and management work. The research in the end did contribute to our industry. Although the research was comprehensive, and it covered various spheres. There are still features, lacking in this research. The first limitation of this research could be the need for using different software for calculation. Future research could include one click direct calculations from Revit software through use of plug ins. Another limitation could be the research based on just one type of building. Future research can include more than one type like commercial buildings as well. To improve the values of estimates, future research could include MEP (Mechanical, Electrical and Plumbing) elements in the model and the schedule as well.

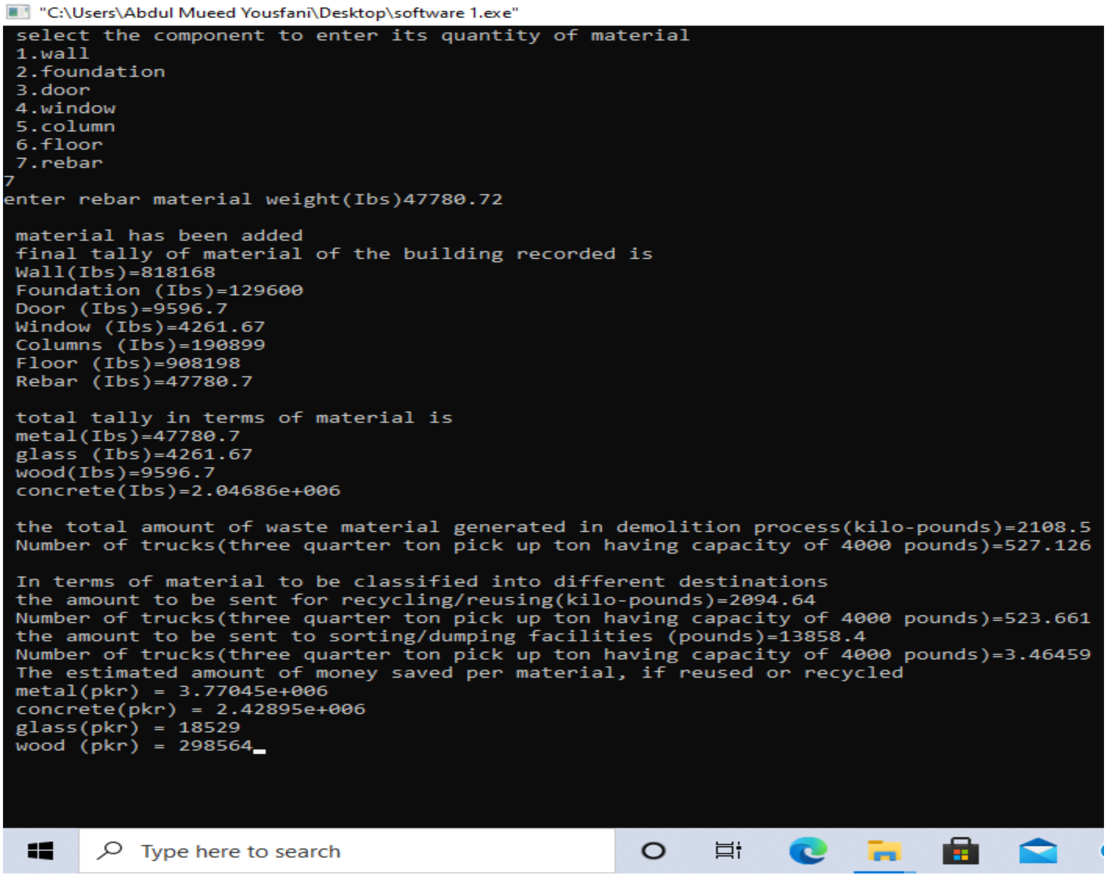

Fig. 5. Final results from software

6. Acknowledgment

Authors are thankful to Almighty Allah, who is ever graceful on us.

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ID 62: Utilising Prefabricated Concrete Structures in Building Construction: Cost Analysis and Economic Viability

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A B S T R A C T

The majority of organisations still use traditional methods of building and are not yet prepared to arm themselves with cutting-edge methods that would enable them to complete their projects more quickly and effectively. Prefabrication is expanding quickly in the construction industry, and prior studies have found a variety of benefits for projects. Prefabricated building, however, is not as popular in Pakistan as conventional building techniques. Because of this, a comparison between a normal RCC building and a prefabricated (precast RCC construction) building is necessary to identify any possible savings from using prefabrication on the entire project cost. Autodesk Revit is used to create a BIM-based multi-dimensional model of conventional and prefabricated buildings in order to do this. The advantages of prefabricated building over conventional construction were obvious after a thorough comparison of both techniques of construction in terms of materials, labour, transportation, and time. The prefabrication technique of building is 84% quicker and costs roughly 13.46% less than the traditional way. This thorough comparison will aid in understanding and motivate the building sector to use prefabricated construction.

K E Y W O R D S:

RCC Structures, Prefabrication, Concrete Structures, Economical Suitability, Building Information Modelling (BIM).

1. Introduction

Two of the main consequences of the building sector on a country are the growth of the economy and the sustainability of the environment. Prefabricated components are clearly used in modern architecture since all the delicate and perfectly formed aesthetic components are constructed off site and then installed. Engineers are restricted in what may be created using conventional methods since it is not possible to make precise and accurate pieces using standard procedures. The use of modular construction, which also provides choices for long-term economic and environmental sustainability, eliminates all of these restrictions. [1].

To demonstrate why prefabrication is superior to conventional construction, a comparison between a typical RCC building and a prefabricated building is necessary. Using Autodesk Revit, a multidimensional model of a traditional and prefabricated building is created for efficient comparison. The model compares the costs of labor, materials, and transportation. Prefabrication targets the issues with massive waste production in conventional construction methods, and it also significantly shortens the construction period, saving time and labor costs [2]. It is a developing step toward reducing environmental difficulties since owners may streamline the construction process and reduce waste in this controlled, safe setting. It is an economical construction technique. The purpose of this study is to promote prefabricated construction in Pakistan's construction industry. [2] [3]

2. Literature Review

Prefabricated construction is another name for modular building. According to study conducted by Y.Chang in 2018, prefabricated construction is one of the most economically secure and ecologically friendly techniques of building construction currently accessible. This method fills the potential gap for contractors both economically and environmentally [1]. The limitations of material waste and building longevity are removed by prefabricated construction [5]. Engineers can easily increase the serviceability of a built structure with prefabrication. Off-site construction is the idea behind prefabrication [5]. Building components used in prefabrication are made away from the construction site and then transported and installed there. Prefabrication is done to control costs and timelines [6]. Building quick homes for people affected by disasters like war or earthquakes is made possible by prefabrication [7].

The advantages of prefabrication include cost savings, flexibility in the design model, and speedier construction. When Shu Wang compared the costs of prefabricated construction and traditional construction in 2019, it was found that prefabricated construction was more effective and cost-effective than traditional methods, with the exception of China's strict building code regulations, which made prefabricated construction slightly more expensive [7]. The maintenance of the project becomes easy because of prefabrication and the future repairs become easy to deal with hence it increases the return on investment as compared to conventional method of construction [6].

3. Methodology

In the methodology section, we have discussed about the tools that we have used to design our building model. We have used multiple programs for different types of work, such as AutoCAD for plans, Revit for structures, and Lumion 10 for visualization. In traditional construction, the casting of components is done onsite using conventional methods and for prefabricated construction, the casting of components is done off-site in steel moulds as steel is opted for this method of construction because according to American Iron and Steel Institute, steel is a 100% recyclable material [10].

Hyderabad, Sindh, Pakistan's main Phase-1 Qasimabad is where the planned building examined is situated (Figure 1). The structure is 240 square yards in size and has four apartments on two separate storeys in addition to a bank on the main floor.

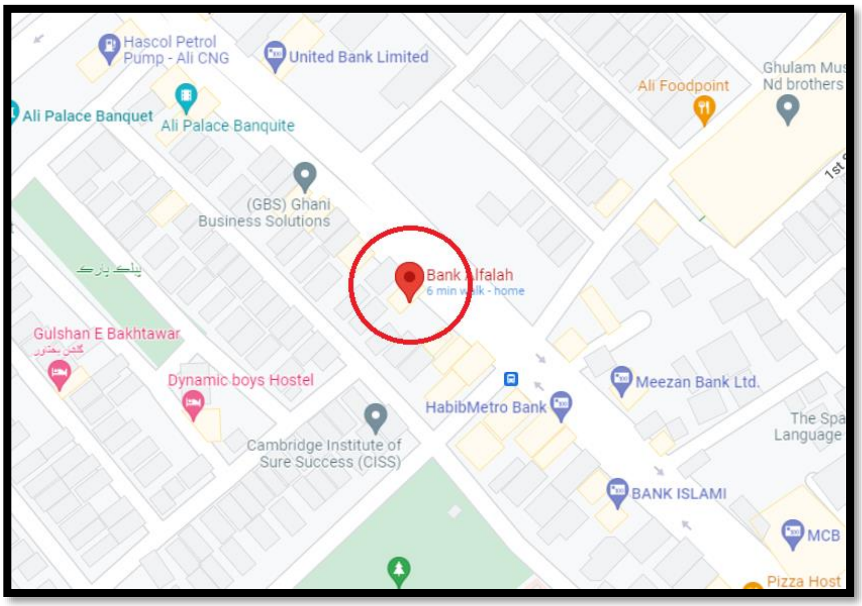

Fig 1: Building Location on Google Maps

3.1 Material Identification

The connection of two prefabricated members may result in a small gap between them; this type of gap is typically filled with grout [7]. There would not be many gaps and some connections will be made with grout in the bolted connections. Peikko, a renowned provider of engineering solutions, created the bolted connections that we will use in our prefabricated structure, see Table 1.

Table 01: Material Identification

	PPM HIGH STRENGTH ANCHOR BOLTS & INSTALLATION TEMPLATE
	HPKM COLUMN SHOE
	PRESTRESSED HOLLOW CORE SLAB
	LIGHT WEIGHT HOLLOW CORE WALLS

3.2 Material Rates

These rates have been taken from the Government of Sindh's Basic and Composite list of schedules enforced from 7th July 2022 and are shown in Table 2. [9]

Table 2: Rate of Materials

Name	Unit	Cost
OPC (Ordinary Portland Cement)	50 KG	Rs. 1000/-
Fine Sand Haro	Cubic Feet	Rs. 37.7/-
Stone crushed graded 3/4"	Cubic Feet	Rs. 53.83/-
M40 Grade Steel Rebar	KG	Rs. 252.52/-
Bricks 9" x 4 1/2" x 3"	-	Rs. 16/-

3.3 Calculation Formulae

Foundation cost is calculated using the volume of concrete and amount of steel used in foundation which is automatically calculated within software. The formula for total cost is:

$$Total\ Cost = (Volume\ of\ Concrete\ X\ Unit\ Rate) + (Total\ Weight\ of\ Steel\ X\ Unit\ Rate) \qquad (eq.1)$$

The brickwork for conventional building is calculated using the following formula, in which material volume is automatically calculated within the software:

$$Total\ Cost = (Material\ Volume\ in\ CFT\ X\ No.of\ Bricks\ in\ 1\ CFT)\ X\ 16 \quad (eq.2)$$

M20 (1:1.5:3) Grade concrete volume calculation for conventional building is done automatically within the software, the volume of cement, sand and aggregates is calculated with the help of quantity estimation book by BN DUTTA. The cost is calculated using following formula:

$$Unit\ Rate = (Cement\ Bags\ in\ 1\ CFT\ X\ Cost\ of\ 1\ Bag) + (Sand\ Vol\ X\ Cost\ Per\ 1\ CFT) + (Aggregates\ Vol\ X\ Cost\ Per\ 1\ CFT) \quad (eq.3)$$

$$Total\ Cost = \ Material\ Volume\ in\ CFT\ X\ Unit\ Rate \quad (eq.4)$$

The cost of steel is calculated by considering the unit weight of steel, the total bar length is automatically calculated within software and the final formula is:

$$Total\ Cost = (Total\ Bar\ Length\ X\ Unit\ Weight\ of\ Steel)\ X\ 252.52 \quad (eq.5)$$

The cost calculation for prefabricated beams and column members is done using the following formula:

$$Total\ Cost = Unit\ Rate\ of\ Component\ X\ Total\ Length \quad (eq.6)$$

The cost of curtain walls and hollow core slabs are done using the following formula:

$$Total\ Cost\ of\ Slab = \ Total\ Area\ SFT\ X\ Unit\ Rate\ of\ Floor\ Panel \quad (eq.7)$$

$$Total\ Cost\ of\ Wall = Total\ Area\ SFT\ X\ Unit\ Rate\ of\ Wall\ Panel \quad (eq.8)$$

The cost of connections is calculated using the following formula:

$$Total\ Cost = Connection\ Count\ in\ 1\ Section\ X\ Total\ Sections\ X\ Unit\ Cost \quad (eq.9)$$

The grouting cost is calculated by determining the wall to wall panel connection and slab to slab panel connection and the formula for those are:

$$Volume\ of\ Grout\ Required\ for\ Panel = \ Panel\ Perimeter\ X\ (Thickness + 1"\ Spacing) \quad (eq.10)$$

$$Numeber\ of\ Beam\ \&\ Column\ Components = total\ lenght\ of\ component\ /12 \quad (eq.11)$$

Size of wall panel is (10x10) ft., size of slab panel is (10x15) ft. and size of members are 12ft.

3.4 Unit Rate Calculation for Traditional Building

The unit rate calculation (excluding reinforcement) is done by taking the M20 graded concrete under consideration, see Table 3.

Table 3: Unit rate calculation for traditional building

M20 GRADE MIX DESIGN	**RATE**
0.35 Bags of Cement	Rs. 350
0.42 Cft of Sand	Rs. 15.834
0.84 Cft of Aggregates	Rs. 45.217
Total Unit Rate Rs.411.05	
1:6 MORTAR	**RATE**
0.179 Bags of Cement	Rs. 179

1.319 Cft of Sand	Rs. 49.72
Total Unit Rate Rs.228.72	

3.5 Unit Rate Calculation for Prefabricated Components

The unit rate calculation of materials used in prefabricated components is mentioned in the table below with the exclusion of waste factor since prefabrication benefits in minimizing waste by precisely using the material. The rates of additional components are taken from GOVT'S Schedule of Rates published on 7th July 2022, see Table 4. [11]

Table 4: Rate of prefabricated components

COMPONENT	DESIGN	UNIT RATE
C1 (9"x24") & C2 (6"x12")	6 #4 bars | #3 ties @9"c/c	Rs.1391.2/ft & Rs.1160.29/ft
B1 (9"x24") & B2 (9"x18") & B3 (6"x18")	6 #4 bars | #3 ties @9"c/c	Rs.1391.2/ft & Rs.1179.9/ft & Rs.851.306/ft
Slab	Pre-stressed hollow core slab	Rs.150/ Sq.ft
Wall	Hollow core wall	Rs.80/Sq.ft
Base Connection	Baseplate Anchor	Rs.1267 /piece
Screw	Screw 8"	Rs.253.75. /piece
Grout	Grout (1:4)	Rs.236./CFT
Formwork	Steel Moulds	Rs.15000/piece

3.6 Labor Cost

The labor cost for traditional construction is calculated using the method provided in the book of quantity estimation by BN DUTTA [8]. The cost of prefabricated construction labour is determined by carrying out a pilot study in which ten construction firms are contacted and asked to provide interviews of their skilled labourers. Following this, the average labour requirement to install a single component is estimated, and the amount of work that needs to be done in a single shift is multiplied by this estimate. It is important to note that expert labour is necessary due to the intricate bolted connections used in prefabricated construction.

4. Data Collection & Analysis

The data for hollow core wall and prestressed hollow core slab is collected from the manufacturing plant "HUMECRETE CONCRETE MATERIALS" located in the site area of Hyderabad, Sindh region. The data for steel moulds which are to be used in prefabrication, are also provided by "HUMECRETE CONCRETE MATERIALS". The total number of moulds required are 349 in two phase precasting [9]. The data for bolted connections is taken from Piekko Engineering and the data for construction timeline is provided by "HUMECRETE CONCRETE MATERIALS".

4.1. Cost Sheet for Traditional Method of Construction

The cost sheet for traditional method of construction is generated by calculating the values using equations 1,2,3,4 & 5. Table 5 contains the data which is calculated:

Table 5: Total cost of traditional construction

CATEGORY	COST
Structural Floors + Columns + Beams	Rs. 1525803/- + Rs. 600844.32/- + Rs. 486024.04/-
Structural Foundation + Reinforcement	Rs. 406035/-
Total Reinforcement (Excluding Foundation) (Total Weight Including Foundation = 17.69 Tons)	Rs. 4239933.94/-
Brick Work + Mortar + Labor + Formwork	Rs. 2198419/- + Rs. 2574239/- + Rs. 1858948/- + Rs. 810431/-
TOTAL COST	**Rs. 1,47,00,677/-**

Total cost of construction is Rs.14.7 Million and total area of construction is 6480 Sq.ft. and for that, the rate of construction is calculated to be Rs.2269/Sq.ft. only.

4.2. Cost Sheet for Prefabricated Construction

The cost sheet for prefabricated method of construction is generated by calculating the values using equations 6,7,8,9, 10 & 11. Table 6 contains the data which is calculated:

Table 6: Total cost of prefabricated construction

CATEGORY	COST
Beams & Columns + Onsite Labor & Machinery	Rs.3154199/- + Rs.799569/-
Curtain Wall & Hollow Core Slab	Rs.5443220/-
Bolted Connections + Grouting	Rs.1017268/- + Rs.349575/-
Plant’s Profit (10% of Material)	Rs.996426/-
Steel Moulds + Salvage Value	Rs.5235000/- + Rs.-4711500
Transportation (Two Shifts) + Foundation Cost	Rs.40000/- + Rs.406035/-
TOTAL COST	**Rs.12729792/-**

The total cost without salvage is calculated to be around **Rs.17.44 Million** and by considering the salvage value, the total cost of the prefabricated project is about **Rs.12.72 Million**. The unit rate of the prefabricated construction considering salvage value is calculated to be **Rs.1965/Sq.ft**. Only.

4.3 Construction Duration

We conducted ten separate construction company interviews in Hyderabad, Sindh, Pakistan, and using the results of the pilot study, we came to the conclusion that the conventional method of construction takes an average of 192 days to complete as shown in the figure 02. Prefabricated construction project will take a total of 30 days to complete as shown in figure 03.

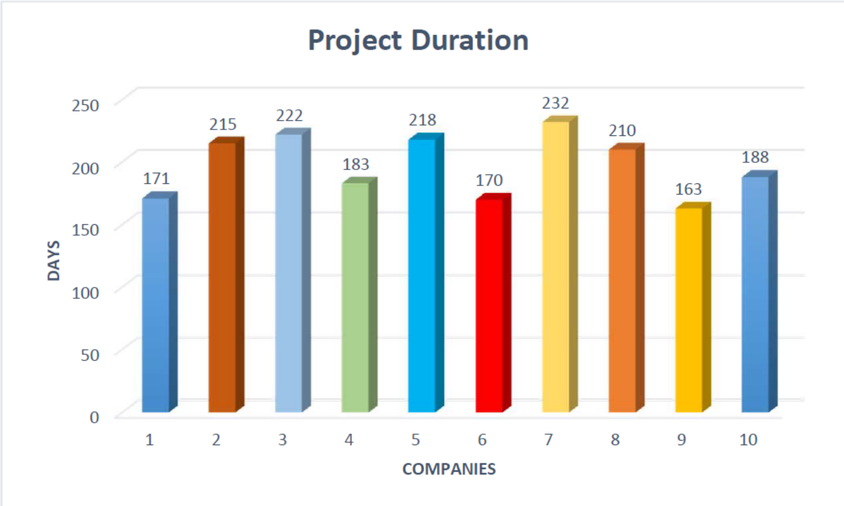

Fig 2: Traditional construction duration

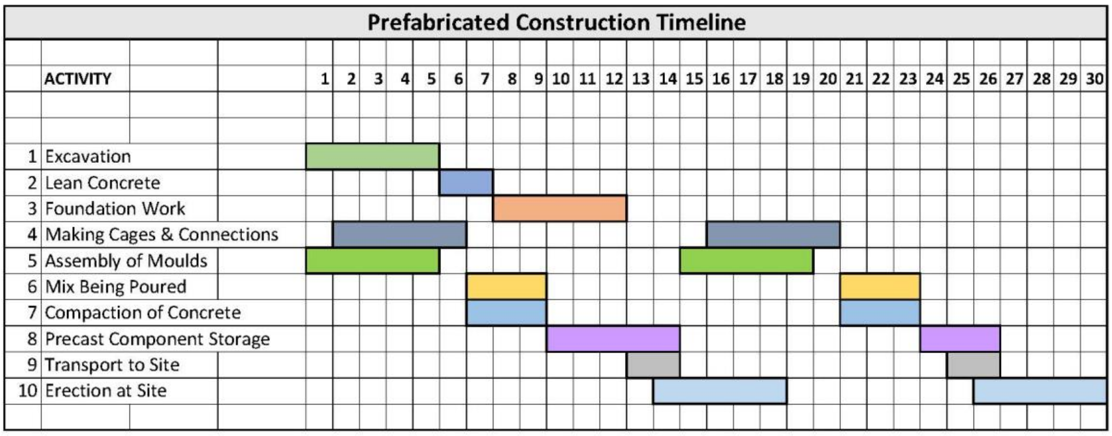

Fig 3: Prefabricated construction timeline

5. Conclusion

According to the research and analysis the prefabricated method of construction is therefore quick and affordable. The prefabricated construction is also environmentally friendly according to the environmental impact assessment performed by Miran Seo [14]. Prefabricated buildings cost **13.46%** less to construct than conventionally built buildings, and they also take about **84%** less time. A margin of error of 1–2% is taken into account when estimating various costs and components.

6. Acknowledgement

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ID 71: Framework for Enhancing the Adoption of Green Buildings Construction in Pakistan

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A B S T R A C T

The world is adopting green buildings to increase the efficiency of buildings and curb rapid climate change. However, Pakistan is facing a series of challenges in the adoption of green buildings. This research work aims to assess the barriers inhibiting the adoption and propose remedial measures followed by developing a suitable framework to mitigate the barriers. To find the barriers, research work from prominent past studies was conducted. Multiple surveys were conducted with field experts, construction professionals, and concerned government officers for data collection. Further, semi-structured interviews were conducted to propose possible remedial measures. The research findings suggest that currently, the adoption of green buildings in Pakistan is at a low level. Moreover, this study investigated 35 barriers after validation from construction practitioners. The SPSS program generated results were evaluated, and 20 barriers were observed as critical. A few of the top barriers were observed to be: lack of awareness among people about green building practices, a lack of green building codes and regulations, and high initial investment. Therefore, to eliminate barriers, literature-based adoption measures were analyzed and results suggested that maximum involvement of clients, government, and institutions is required. The proposed framework consists of each of the barriers examined during this research work and remedial measures for those barriers. The framework will help institutions, policymakers, and construction practitioners to enhance the adoption of green buildings in Pakistan. This will also benefit the readers and researchers for their research work in green buildings.

K E Y W O R D S:

Green Buildings, Framework, Construction industry, Adoption, Barriers, and Pakistan.

1. Introduction

Green building (GB) construction or sustainable construction refers to salubrious construction that serves positive impacts on the people and mother earth.[1] Green structure is the act of making designs and utilizing processes that are naturally capable and asset viable through a structure's life from an idea to existential, development activity, sustenance, remodel, and deconstruction[2]. There is no question that individuals have begun deciding on making their way of life and well-being better. In each industry organizations are inclining increasingly more toward manageable choices. Be that as it may, with the advantage of maintainability, the reception of green structure rehearses accompanies plenty of difficulties and impediments[3]. These difficulties make it hard to embrace economical work during the development of a structure completely. However, the underlying interest in green structures development can be reasonably contrasted with regular ones, the getting-through benefits making it an amazing long-haul speculation for the two purchasers and designers. These days, reasonable structure rehearsal is acquiring notoriety because of their popularity as individuals are more disposed towards climate-agreeable structures[4]. The operation will be carrying positive impacts on every individual and for surroundings as well, keeping the strategy that, it will not interrupt the land and resources around the structure. Moreover, the standard green building would be a building task that would let you conserve most of the natural environment around the building land site. While, still being able to bring on a building that is going to serve an intent that's why green building is also known as high-performance building. In addition, green buildings support ecosystems by utilizing the resources efficiently. Using renewable energy is well thought out as well as enabling the system to recycle and reuse the waste and materials (non-toxic). The total importance of going green is; bringing down the trash, dust, and erosion of environment, Efficiently using energy, water, and other resources, and Preventing the occupant's health and providing comfort, etc.[5].

Normally, traditional construction uses resources that are directly responsible for the negative impacts on the planet. Compared to other sectors in infrastructural development, the construction sector is one of the largest consumers of natural as well as artificial resources that cause environmental degradation and is responsible for a large portion of energy consumption, biodiversity loss, waste generation, and pollution. Ordinary construction of buildings contributes 23% to air pollution, 50% to climate change, 40% to drinking water pollution, and 50% to landfill wastes[6]. To cope with the climate change situation, developed nations and many developing nations of the world are adopting green buildings at a rapid pace. Pakistan is lurking behind in this field, although the construction industry of Pakistan contributes approximately 2.53% of its GDP. Therefore, to combat the situation there is a dire need to adopt green construction in Pakistan.

At present, in the construction industry of Pakistan, there exists a number of barriers that refrains green building adoption[7]. Barriers depend on how the system of construction works in different countries. In Pakistan, barriers differ to a certain extent from other countries. Barriers can be related to the lack of awareness among the clients and the organizations, government and its policies regarding building construction, etc. However, different studies suggest different factors. There is a need to investigate appropriate factors creating barriers, more importantly, to mitigate those examining remedial measures.

2. Literature Review

2.1 Green Building and Development

There are various definitions of Green building, one of them being, "the practice of building structures, implementing design procedures, landscape selection that is responsible towards the environment and resource-efficient for the better lifestyle and natural resource preservation throughout the life cycle of the building"[8]. The Green building idea extensively integrates many interests and aspects of sustainability emphasizing the reduction of environmental impacts through a holistic method of land and constructing usage and production techniques[2]. As per the World Commission on Environment and Development (WCED),– Our Common Future (1987), such as (Green) buildings are structures that are designed to promote efficient use of resources and to reduce the adverse effects of buildings on the environment. Such types of buildings are known as Green Buildings because they strive for more environmental-friendly and sustainable buildings. They are eco-friendly more energy-efficient less polluting and provide with healthier lifestyle and environment for the end-users[9]. Figure 1 shows a green structure in Singapore.

Fig. 1. Green Structure (Phys.org)

All gatherings, from policymakers to modelers, designers to worker, and laborers, need sufficient information and abilities for green structure development. One of the main pressing issues turning into a boundary to the reception of green structures is a greater expense and costly maintainable development materials. The government of Pakistan has done nothing to incentivize or encourage green building construction. In addition, the government-affiliated National Energy Efficiency Conservation Authority (NEECA), has even prepared a Pakistan Energy Provision 2011 but it remains unimplemented. In Pakistan green building construction is not likely to accept by people as the lack of awareness is one of the leading causes of halting green construction, however, for construction building codes and regulations are required which are lacking in Pakistan.

2.2 Barriers to the Adoption of Green Buildings

Bringing change in something faces hindrances/challenges. Green building is the modern-day innovation-filled initiative to bring change in construction[7]. Green building adoption is an important step to mitigate/cope with climatic atrocities. The world is already shifting towards sustainable development and the adoption of green buildings, whereas Pakistan is lurking behind to adopt green buildings at a rapid pace. The number of barriers refrains the adoption of green buildings in Pakistan. Prominent scholars have also worked on the barriers, after investigating past works of those scholars, for instance, resistance to culture change, financial problems, and technology-related barriers. In total there were 37 barriers selected and relevant to the construction industry of Pakistan.[10], [11].

2.3 Adoption Measures

Identification of barriers has forced it to decrease its impact on the adoption of green buildings. Therefore, around the world, there is several studies have been carried out to identify and investigate the remedial measures to combat these barriers. Promoting green buildings through advertisements in media[7], successfully implementing laws and legislation of green buildings by the government[12], developing a wide range of rating tools and codes, and also spreading awareness of existing incentives and codes and regulations[13]. There were 14 measures identified from past research works, and are well documented in table 4.2 with an analysis of on collected through the structured survey.

3. Research Methodology

This study investigates barriers to the adoption of green buildings and measures to mitigate those barriers. The investigation process follows a specific research methodology. The preliminary study and literature review were already achieved by exploring the prominent scholar's past research work on green buildings. The questionnaire was prepared from barriers found in the literature review and used to solicit professional's opinions. Figure 2 represents the process of research methodology that was carried out.

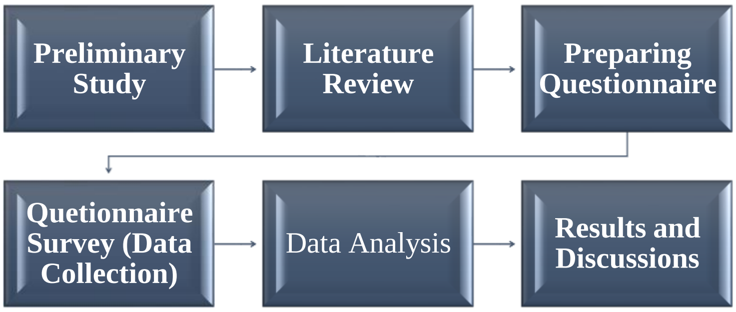

Fig. 2. Flow chart of research methodology

3.1 Data Collection

The designed questionnaire was discussed and interviewed repeatedly by conducting a semi-structured from four experts in the construction field; one Assistant resident engineer, one university professor, one senior site engineer, and one project manager. They all have more than 10 years of experience in the construction industry of Pakistan. The sample size in line with the design of the questionnaire was calculated by the formula shown below, the calculated sample size was 52. Therefore, to conduct a structured survey the designed questionnaire was distributed among 52 professionals within the construction industry of Pakistan, who have considerable experience in green construction. From the total distributed questionnaires, 43 responses were received, from which 41 were considered reliable after discussion with the supervisor. The Likert scale from 1-5 (1 for Not significant and 5 for extremely significant) was used to get the appropriate answers from the respondents, 41 responses were received from professionals include; 4 project engineers, 6 design engineers, 4 resident engineers, 3 assistant engineers, 3 assistant resident engineers, 2 planning engineers, 2 LEED project managers, 1 assistant director civil, 3 site engineers, 2 manager procurement, 1 principal architect, 3 junior researchers, 2 lab engineers, 3 assistant managers, and 2 surveyors.

$$S = \frac{Z^2 \times P(1-P)}{M^2}$$

3.2 Data Analysis

The collected data were further analyzed using IBM SPSS v20 software. In the SPSS software, the reliability tests were conducted and the results generated in the form of mean value, standard deviation, and Cronbach's alpha were represented in the results section. However, the collected data were subjected to descriptive statistics, and from the obtained results mean item value was used to rank the barriers. The standard deviation value was used to rank the barriers in case two or more of the barriers bore identical mean values.

4. Results and Discussion

4.1 Results of Semi-Structured Survey

The barriers extracted from the literature review were further evaluated and subjected to the semi-structured survey. In the survey, discussions were carried out with four experts in the construction field for validation of the barriers. The results are represented in table 1.

Table 1. Details of respondents collected through semi-structured interviews

Designation	Experience	Remarks
Assistant Resident Engineer	13-16 years	From the literature review some barriers were selected from other countries' construction industry and then were evaluated from local professionals. Barriers like political issues exist in other countries, but it has little significance in Pakistan. The political issues and lack of green building skilled labor barriers were remarked by construction practitioners that, these are not the barriers to the adoption of green buildings in the construction industry of Pakistan. Because, in the construction industry political involvement is very low, and the skilled labor depends on other factors like demand and providence of education related to the GB. Other barriers were considered valid in the construction industry of Pakistan.
Senior Site engineer	09-12 years	
Project Manager	09-12 years	
Professor	10 years	

4.2 Results of Structured Survey

This survey was conducted to know the significance level of the validated barriers from the construction field experts in Pakistan. A questionnaire of 35 barriers, questions was based on the Likert scale of 1-5, and were asked to know the significance level of barriers. Further results of analysis on barriers and the demographics of respondents are represented in the subsections.

4.2.1 Demographics of the Respondents

The questionnaire of the structured survey included two parts, in part one information of respondents was asked to know the relevance and acceptance of the responses. The basic and important information about respondents' experience and their organization information is graphically illustrated in figures 3, 4, 5, and 6.

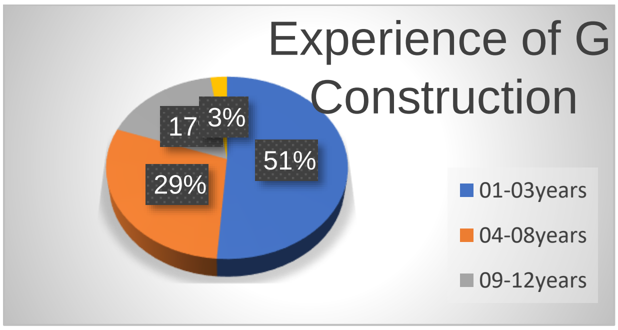

Fig. 3: Experience in the general construction field

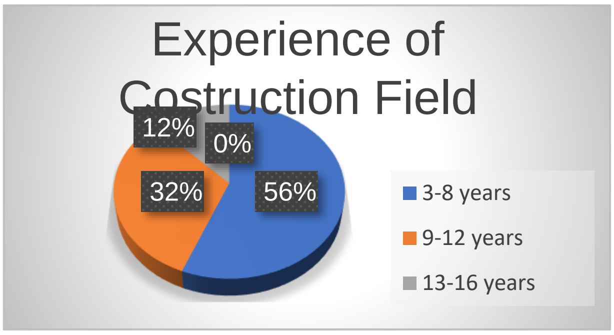

Fig. 4: Experience in Green construction field

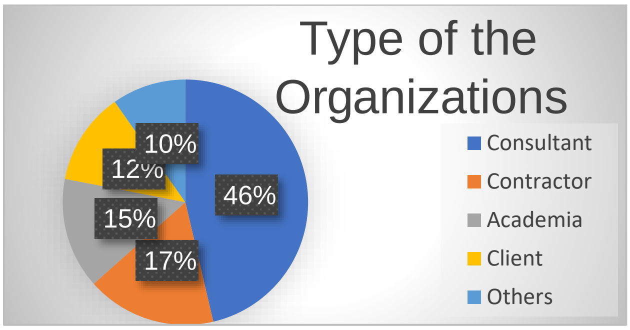

Fig. 5: Type of the organization

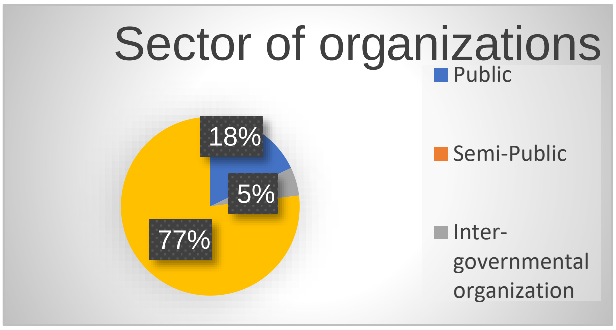

Fig. 6: Sector of the organization

4.2.2 Results of Analysis on Barriers

The data collected through a structured survey was subjected to descriptive statistics to undermine frequencies, and also reliability test was performed to know Cronbach's alpha value. However, in both the analysis mean item value and standard deviation of the barriers were evaluated. All the results were extracted from SPSS software by conducting above mentioned methods of analysis. The tests were performed category-wise, which results in the mean item values and standard deviation of each barrier in each category. All the results of analysis are represented in the table 2. From each category, the top barriers were observed to be: FCB1 'the high initial investment' (MV=4.07, SD=.932), GPB2 'Lack of green building codes and regulations (MV=4.37, SD=.662), AKB2 'Lack of awareness among people about the importance and advantages of adopting green building practices' (MV=4.49, SD=.675), TPB12 'Lack of Supply chain management process' (MV=4.12, SD=.954), OB7 'Insufficient green building rating systems and labeling programs available' (MV=4.15, SD=.910). Among all the results of 35 barriers, AKB2 was the most significant one, which indicates that people are not aware of green building in its advantages and it is the major barrier that is creating a lot of hurdles in the adoption process. The reliability test was also conducted through SPSS software, the program generated results in the form of Cronbach's alpha for each category. The Cronbach's alpha value for each category was observed to be: Finance/Cost related barriers (0.727), Government and Policy related barriers (0.705), Awareness and Knowledge related barriers (0.791), Technology and Local Professionals related barriers (0.805), Organization related barriers (0.776). The acceptable significant value of Cronbach's alpha is considered to be between 0.7-0.9 all the categories have more than 0.7. Therefore, it is considered to be significant.

Table 2. Results of the analysis of collected data on barriers through SPSS

Categories of Barriers	**Code**	**Barriers to the Adoption of GB**	**N**	**Frequency**					**Mean**	**Std. Deviation**	**Rank**
				1	**2**	**3**	**4**	**5**			
Finance/ Cost related Barriers	FCB1	The high initial investment	41	0	4	4	18	15	4.07	.932	1
	FCB2	Long payback period	41	1	8	9	14	9	3.54	1.120	6
	FCB3	Higher functioning costs for green buildings	41	1	6	11	14	9	3.59	1.072	5
	FCB4	Higher maintenance costs for green building	41	2	6	6	16	11	3.68	1.171	4
	FCB5	Low market demand	41	2	3	10	13	13	3.78	1.129	3
	FCB6	Lack of financial resources	41	1	5	5	13	17	3.98	1.129	2
Government and Policy related Barriers	GPB1	Lack of incentives and support from the government	41	2	3	4	13	19	4.07	1.149	3
	GPB2	Lack of green building codes and regulations	41	0	0	4	18	19	4.37	.662	1
		Negative impacts of public policy (e.g. subsidies for	41	1	4	7	18	11	3.83	1.022	4

Categories of Barriers	Code	Barriers to the Adoption of GB	N	Frequency					Mean	Std. Deviation	Rank
				1	2	3	4	5			
	GPB3	domestic materials, the inappropriate tariff system									
	GPB4	Lack of technical training/education in green building design and construction	41	0	4	3	16	18	4.17	.946	2
	GPB5	Poor implementation of laws and legislation	41	2	7	7	13	12	3.63	1.220	5
Awareness and Knowledge related Barriers	AKB1	Disbelief regarding the benefits of green building	41	0	3	10	13	15	3.98	.961	4
	AKB2	Lack of awareness among people about the importance and advantages of adopting green building practices	41	0	1	1	16	23	4.49	.675	1
	AKB3	Lack of awareness of existing incentives	41	0	1	8	19	13	4.07	.787	2
	AKB4	Lack of Credible Research on the Benefits of Green Buildings	41	0	6	8	9	18	3.95	1.117	5
	AKB5	Lack of environmental awareness among developers and consultants	41	1	2	8	15	15	4.00	1.000	3
Technology and Local Professional related Barriers	TPB1	Lack of information and databases on green technologies	41	1	3	8	17	12	3.88	1.005	5
	TPB2	Lack of professional knowledge	41	1	5	7	11	17	3.93	1.149	4
	TPB3	Technical level and innovation among architects, designers, and engineers are less than desirable in terms of environmental issues	41	2	5	7	14	13	3.76	1.179	6
	TPB4	Challenges of innovative equipment in design and construction methods	41	0	4	6	13	18	4.10	.995	2
	TPB5	Poor management and/or lack of staff time for implementing green practices	41	2	4	8	14	13	3.80	1.151	7
	TPB6	Lack of advanced technology	41	1	4	7	11	18	4.00	1.118	3
	TPB7	Lack of technical expertise in green building	41	3	3	8	15	12	3.73	1.184	8
	TPB8	Lack of communication and collaboration	41	2	4	10	14	11	3.68	1.128	9
	TPB9	Problems with existing technologies	41	1	6	10	15	9	3.61	1.070	11
	TPB10	Reluctance to introduce it by Firm owners/managers	41	2	6	7	16	10	3.63	1.157	10
	TPB11	Lack of Communication and Interest among Project Team Members	41	5	7	6	18	5	3.27	1.245	12

Categories of Barriers	Code	Barriers to the Adoption of GB	N	Frequency					Mean	Std. Deviation	Rank
				1	2	3	4	5			
	TPB12	Lack of Supply chain management process	41	0	3	7	13	18	4.12	.954	1
Organization related Barriers	OB1	Lack of end-user support	41	1	4	9	14	13	3.83	1.070	3
	OB2	Lack of availability of environmentally sustainable materials and products	41	1	9	11	10	10	3.46	1.164	4
	OB3	The risk associated with implementation	41	6	7	10	12	6	3.12	1.288	7
	OB4	The complicated design than the traditional one	41	0	3	4	21	13	4.07	.848	2
	OB5	On-time completion of the project/delays in the project	41	2	9	9	11	10	3.44	1.226	5
	OB6	Competing stakeholder interests	41	3	9	10	12	7	3.27	1.205	6
	OB7	Insufficient green building rating systems and labeling programs are available	41	0	3	5	16	17	4.15	.910	1

4.3 Ranking of Categories of the Barriers

After analyzing the barriers category wise critical barriers were investigated and remedial measures were proposed. Critical barriers were examined as per the mean item value, from 35 barriers total of 20 barriers were observed to be critical as they have a mean value of more than 3.80 range, that means more than 31 (75% of total respondents) respondents agree on a barrier to be critical and needs to be signified. The categories were ranked considering the average mean values of all barriers in each category. Therefore, they were ranked as Awareness and knowledge-related barriers (4.10), Government and policy-related barriers (4.01), Technology and local professional-related barriers (3.80), Finance and cost-related barriers (3.77), Organization related barriers (3.63). Ranking imitates that awareness-related barriers are most critical and are majorly halting the adoption of green buildings in the construction industry of Pakistan.

4.4 Results of Analysis on Adoption Measures to Promote Green Buildings

Through SPSS descriptive statistics test was run, the program generated results in the form of the mean item value, standard deviation value, and frequencies of the respondents' answers on the Likert scale 1-5 (were in the form of Strongly disagree = 1 to strongly agree = 5). Table 3 represents all program-generated results. The mean item value of all the adoption measures was observed to be more than 4.0, which indicates that the measures are relevant and applicable to promote green building adoption and, are rightly remedial measures of barriers to the adoption of green buildings. From the results of the measures, the top measure was observed to be 'Publicity of green building through advertisement on television and social media (MV=4.54, SD=.635). Therefore, green buildings should be promoted and publicized through advertisement to spread awareness and hence increase demand, which will ultimately increase the adoption in return.

Table 3. Results of the analysis of collected data of the adoption measures through SPSS

Code	Adoption Measures for Green Building Construction in Pakistan	N	Frequency					Mean	Std. Deviation	Rank
			1	2	3	4	5			
AM1	Financial awareness of green buildings for clients	41	0	2	6	8	25	4.30	.861	10
AM2	Training on modern green buildings technologies	41	0	2	6	5	28	4.44	.791	4
AM3	Education in institutions on green building adoption and construction	41	0	1	5	10	25	4.42	.809	6
AM4	Formation of public awareness toward green initiatives through seminars, workshops, and discussions	41	0	1	5	13	22	4.36	.883	8
AM5	Easy access and education on a green buildings rating system	41	0	1	5	8	27	4.49	.676	2
AM6	Organizational belief in the long-term benefits of green building practices	41	1	4	3	7	26	4.29	.937	11
AM7	Availability of a variety of green building codes and regulations	41	0	3	3	6	29	4.46	.694	3
AM8	Easy financial incentives and penalties from the government (e.g. low taxes, soft loans) for green building practices	41	1	1	4	9	26	4.43	.701	5
AM9	Publicity of green buildings through advertisement on television and social media	41	0	3	2	6	30	4.54	.635	1
AM10	Availability of comprehensive training and education in green building technologies for engineers, developers, and policy-makers	41	0	2	5	11	23	4.37	0.860	7
AM11	Involvement of government in the adoption of green buildings by providing funding and subsidies to organizations and institutions	41	1	4	7	8	21	4.25	.982	13
AM12	Government should provide funding and regulatory incentives for green construction development	41	0	3	6	10	22	4.36	.892	9
AM13	Availability of institutional frameworks for the effective implementation of green building guidelines	41	0	4	3	15	19	4.19	1.001	14
AM14	Providence of green building education for case study and research work	41	0	1	3	9	30	4.28	.963	12

4.3 Discussion

Based on the evaluated results from data collected through surveys, 20 recurring barriers from 5 categories extracted from the literature review are discussed here. From the first category of finance and cost 2 barriers; lack of initial investment and lack of financial resources were considered more significant. As in the Pakistan construction industry individuals and organizations, due to insufficient financial coverage and or from government or other entities unavailability of financial incentives create hindrances. From the subsequent category government and policy related barriers ineffective government involvement such as lack of; availability of codes and regulations, incentives or support, negative impacts of public policies, proper training and education are need being adopted to absorb the needs of locals. In the third category awareness and knowledge related barriers almost all 5 barriers are prevalent as people have minimal or no knowledge of benefits that green buildings provide. Also there is less research is being carried out in the academic institutions and the detailed information of the existing incentives is not recognized at the adoptive level. The technology and local professional related barriers are modern day barriers, as technology is enhancing and taking over on other hand it is also creating barriers where lack of knowledge and expertise is common. This is exacerbated when technology is not easily available in the local market or is not known by the local professionals. It also creates cost related barriers, due to its expensiveness and import issues. When government and other entities will promote, educate, and regularise the green practises, more access to financial and other incentives will be easy for the industry builders. Therefore, demand in green construction, technology adoption and professionalism will increase. The final category is related to organizational barriers. Insufficient GB rating systems and labelling programs is most significant one in this category, as Pakistan has no individual systems it only follows other systems. Therefore, it turn out to be the root barriers which supports other barriers like implementation risks, design problems, supply chain insufficiency, and or sustainable materials availability issues.

To counter these barriers, there were remedial measures investigated and analysed with collected data from experts. The results are shown in table 3, from where the top adoption measure was analysed as promoting green building adoption publicity through advertisements on televisions and or social media. The graphical illustration of the barriers and their measures are depicted in the below framework.

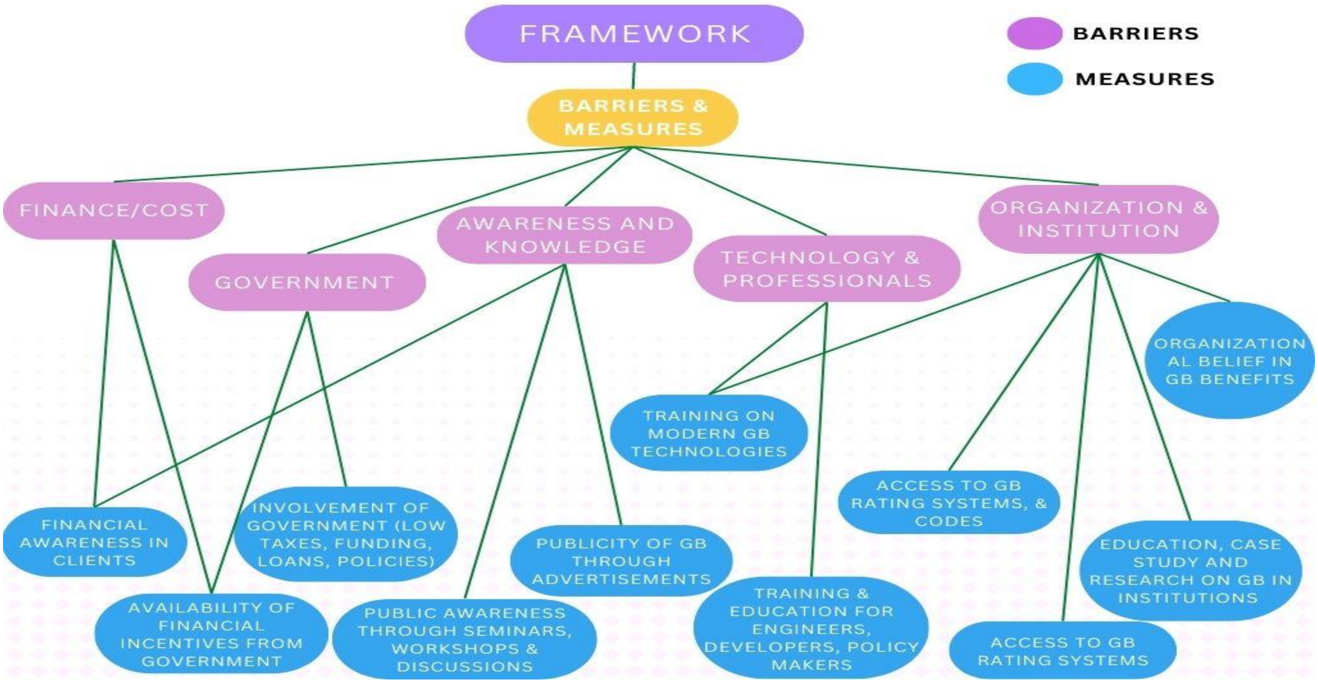

Figure 7: Overall Framework for Enhancing Adoption of the Green Buildings in the Construction Industry of Pakistan

5. Conclusion

From an exploratory examination of the past research on barriers to the adoption of green buildings, it is inferred that towards the alternative of ordinary construction, that is green construction, in the construction industry of Pakistan, there exist several barriers. Even though that green construction is of great importance for the social and natural environment the development process of green construction in Pakistan is efficaciously low. After conducting different surveys and analyzing the received data from the respondents, the results were quite evident and helpful. The investigation comprehensively manifests that the most critical barriers to the adoption of green buildings in the construction industry of Pakistan are; Lack of awareness among people about the importance and advantages of adopting green building practices, Insufficient green building rating systems and labeling programs available, Lack of advanced technology, The High Initial Investment and others which are halting the adoption of green buildings in the construction industry of Pakistan. The adoption measures were also extracted from past work and analyzed, the results were quite evident all of the 14 measures were significant to reduce the barriers and promote the adoption of green buildings. Publicity of green buildings through advertisement and spreading awareness through seminars, public gatherings, and discussions were top measures to mitigate the barriers in the awareness and knowledge category. Availability of incentives from governments, easy access to rating tools, and codes and regulations are also major measures to promote green building construction in Pakistan. In the end a conceptual framework was proposed, which will help in enhancing the adoption of green buildings in Pakistan and will be of help to researchers, organizations, institutions, government, and the public for awareness.

5. Acknowledgment

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ID 109: An Expert System for Disputes Avoidance in Highways, Public Sector Projects of Pakistan Construction Industry

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A B S T R A C T

Construction industry "a term that includes activities associated with the construction of physical infrastructure and associated activities" plays a vital role in the economy of the country. The international construction industry (ICI) (14 April 2022) published a report which was estimated that global construction industry valued US$13.6 trillion last year, and anticipated to reach US$15.2 trillion in 2022. The ICI also evaluated the major economic significance on Gross Domestic profit (GDP) contribution 14.3% in 2021 and expected 14.8% at the end 2022. The contribution of ICI globally labor force is 7%. Its contribution in Pakistan labor force almost 30% to 35% participating directly or indirectly. This researched is focusing on identifying the issues and their root causes that are giving rise to disputes in Pakistan's construction industry road development projects. Expert System (ES), a piece of intelligent computer software, employed in various technical fields nowadays. The purpose of this study is to create a framework for an expert system for suggesting appropriate and controllable actions to prevent disputes during road construction projects was founded by unstructured interviews and questionnaire survey form most experiences stakeholders. Therefore, the KBES will aid in the avoidance of disputes in road construction projects. The created KBES will aid clients in proposing appropriate measures for controlling significant problems and their underlying causes that result in disputes. Therefore, the KBES will aid in the avoidance of disputes in Pakistan road construction projects.

K E Y W O R D S:

Disputes, Highway/Road projects, Construction Industry, Avoidance Strategies/Controlling Measure and Knowledge Based Expert System.

1. Introduction

The construction sector, defined as "activities involved with the construction of physical infrastructure and related activities," plays a crucial part in the nation's economy. It was anticipated that this sector's production would contribute significantly to gross constant capital creation. In addition, research investigations have suggested that the expansion of the construction industry is linked to the growth of other businesses. As an important modern business, the construction sector has a substantial impact on the economy and labor force of any nation [1]. The construction industry is regarded as being crucial to the development of any nation's economy, and investments made in this industry have a significant impact on all other economic sectors. While this industry is engaged in the preparation of lands and building of real estate throughout the nation, the participants in the construction industry have a variety of perspectives, talents, and high levels of knowledge in the construction sector. In addition to developing an expert system for dispute avoidance in public sector road construction projects, this research study is focused on identifying important issues that are, contributing to disputes connected to road projects in Pakistan's construction industry [3].

1.1. Conflict

Conflicts are simply described as opposing participant interests in the execution of a project contract. Conflict was defined by Edmonds and Kennedy as disagreements over a project's execution, frequently the consequence of discussions concerning how differently two or more people perceive the circumstances. Conflicts arise when one person's actions obstruct or interfere with those of another [4]. Conflicts around interests are commonly regarded as the primary motivator of disagreements, and there may be differences in method, behavior, or even time or location among the participants [5].

1.2. Claim

The Canadian Law Dictionary says. The claim is described as a "statement to the right to remedy, comfort, or property" or a "failure to meet obligations under the agreement" [6]. Additionally, the definition of "claim" in the Oxford English Dictionary is "a demand for something as due, an action of right to something," which is derived from the old French word "clima" [7]. A request, demand, application for payment, or notification of anticipated entitlement that the contractor, correctly or erroneously at this point, thinks himself entitled to with recognition that a settlement has not yet been established was characterized as a Claim in their reference "claims in attitude" [8].

1.3. Disputes

A dispute is defined as a specific disagreement over a matter of fact, law, or policy in which a claim or assertion is rejected and that rejection is not accepted [9]. Any contract question or argument that needs to be resolved outside of the jobsite control group of workers is a dispute, according to Baloch, SA et al, (2018) definition [10]. Yeu and Cheung (2007). Characterized disputes as a difference between the parties following the use of the internal system [11]. Due to the complexity of the construction industry, some difficulties will occasionally arise for the stakeholders. The different perspectives of the stakeholders, including the sponsor, function Object and engineer, on the development issues. As a result, whenever there are issues and disagreements, a confrontation over that something is unavoidable [12]. Elziny, A. et al. (2016) noted that the construction business has developed into one of the most unfavourable and trouble-prone, with claims and disputes on projects and construction jobs being the norm rather than the exception. Because of the enormous risk that disagreements present, rational decision-making is necessary [13]. Figure 1 shows dispute occurrence flow diagram.

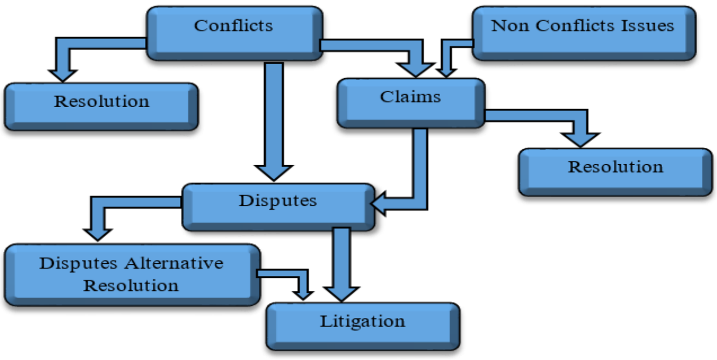

Fig. 1: Flow diagram of dispute occurrence

2. Literature Review

Arcadies [16], Construction disputes in Asia continue to rank highly according to studies. Customers and sponsors are the primary suppliers of resources in the construction development industry. All problems, their causes, and their effects are interconnected with customers [16]. Planning, design, drawings, conduct, building technique, significances, and order exchange are a few examples of the various types of conflicts that can result in claims and disputes in the construction industry. The primary reasons of arguments among members of the creation enterprise are issues from the outside world, delays in delivering drawings, billing, design errors, procurement, and handing over the website to the client [17]. Therefore, disagreements are the primary factors that lead to project delays, disruption of the construction schedule, an increase in the challenge cost at a high level, and negative impacts on the relationships between the project participants. It is widely accepted that disagreement is one of the major factors impeding and preventing the successful culmination of any creativity projects [18]. A professional-level intellectual computer software programmer application to a few particular areas for coding the facts is called a "knowledge-based expert system" (KBES). The purpose of using this precise method is to solve issues at the level of human capabilities [19]. Irlayc [21] also looked at the disputes in the Turkish construction sector. This study examined the issues and root causes of disagreements in building projects. This study came to the conclusion that the risk to participants, the time constraints, the intended cost, and the proper quality are the main sources of conflicts. If they are not managed effectively, projects won't be completed successfully [21]. Demirkesen [22] concentrated on time, cost, and quality as well as regulating measures to reduce disputes in the construction sector through the use of integration management. The development of a project's character, integrated knowledge, staff integration, process management, and supply chain management are the major elements of integration management. Clients and contractors are accountable for minimizing disagreements in the building sector, according to the project management dimension [23]. Akram et al. [24] recognized the important factor that contributes to time and cost overruns in building projects for the Pakistani construction sector and created a professional guide for managing measures for the major component time and cost overrun. Failures to perform have become a notable element of the building construction industry. This wide range of failures, from little fractures to complete collapse, are linked to a number of negative outcomes. Abbas Muhammad Burhan [25] additionally created an "expert system for investigation of failure in the construction business" [25]. El-Adaway and Ogburn [26] conducted a study to look into the cause-and-effect chain of disputes. The investigation concluded that risks, conflicts, and claims are the main causes. These issues eventually result in disagreements, and if they are not appropriately handled, they have a severe impact on the project's completion.

1. Data Analysis and Results

75 questionnaires from public sector road construction departments, 46% from the national highway authority (NHA), 31% from works and services, and 23% from Pakistan Works Department (PWD) of the country's construction industry were successfully collected from the respondents after 106 questionnaires were distributed to them (see Figure 2).

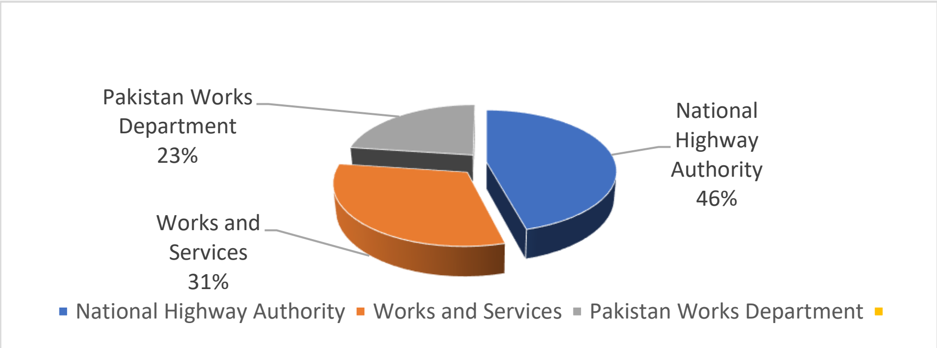

Fig. 2: **S**tatistics of questionnaire.

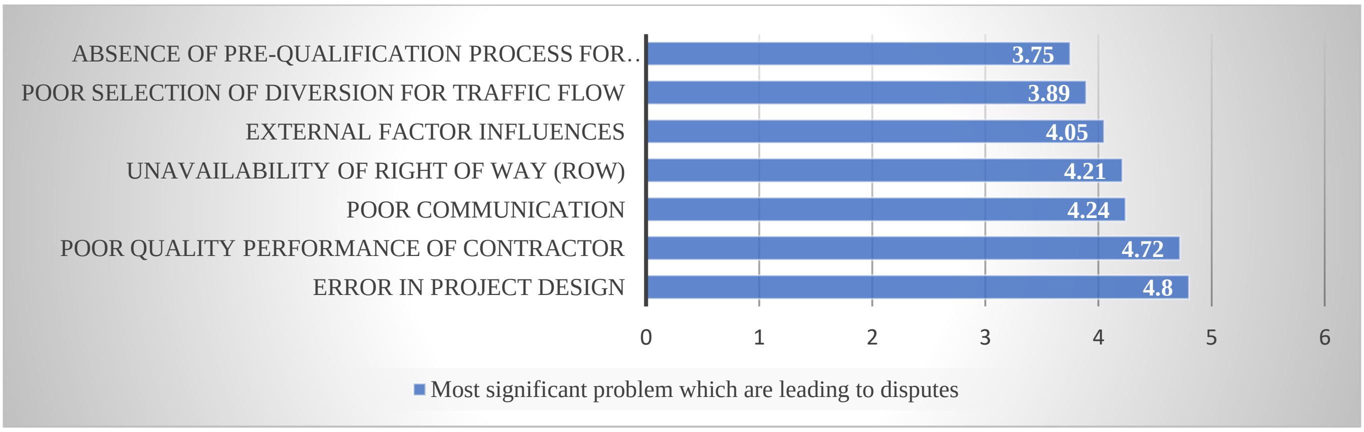

Fig. 3: Demonstrates the significance of the issues that are causing disputes

The problems were identified which are leading to disputes in road construction projects, see Figure 03. Furthermore, the causative measures of disputes are illustrated from Table 1-6.

Table 1: Show causes and controlling measure related to problem Error in project design

Causes of the problem	Controlling Measure
During survey activities, uncalibrated devices were employed	The consultant makes sure that every device seems faultless.
	conducting instrument error testing prior to the start of the survey
Incorrect design data	Before beginning design, the design data should be thoroughly analyzed.
	to confirm that all info is correct according to the site

Table 2: Shows causes and controlling measure related to problem Poor quality performance of contractor

Causes of the problem	**Controlling Measure**
Defects during the construction stage that become apparent during liability period	Before handing over the site, create a list of defects.
	The contractor is bounded to resolve all defects
Insufficient quality standard operating procedures by the contracting company	To make sure that the quality control mechanism is followed
	To appoint a quality assurance manager
Unsatisfactory labor productivity	Setting a self-imposed timeframe procedure
	Begin workshops, seminars, seminars and put the two mints rules into action.

Table 3: Shows causes and controlling measure related to problem Poor communication

Causes of the problem	Controlling Measure
Ineffective collaboration with other departments	To establish a committee to co - ordinate with multiple departments
	To cultivate effective leadership abilities and qualities within the organisation in order to achieve co – ordination
Intentionally delaying the flow of information	Create an efficient information process flow.
	Workshops and training should be held on a regular basis.

Table 4: shows causes and controlling measure related to Unavailability of Right of Way (ROW)

Causes of the problem	Controlling Measure
Land acquisition	The right to receive just compensation when land is acquired
	Disclosure of all relevant information regarding the acquisition of land under the rehabilitation or resettlement act.
Ethical/Holy places	Alteration to the blueprint for the motorways, highways and road construction.
	to reroute the road as much as possible in order to save the sacred places
land acquisition rewards are not given to the incentives	Establish a procedure for equitable compensation in the process of land acquisition.
	In order to acquire land through the adoption of a rehabilitation and resettlement act

Table 5: Shows causes and controlling measure related to problem external factor influences

Causes of the problem	Controlling Measure
Interference of political processes in construction	Dependencies on external parties
	Getting a response that can be considered reasonable
Delay in the process of obtaining a certificate of no objection (NOC)	management that works well with various stakeholders
	Obtain the NOC before placing any bids.

Table 6: Shows causes and controlling measure related to problem poor selection of diversion for traffic flow

Causes of the problem	Controlling Measure
Inadequate preparation in ahead of time	Carry out a pre-construction planning of the necessary activities and resources for the project.
	It is important to involve the project manager along with the rest of the team during the initial stages of planning.
Disruptions in the neighboring areas	Taking preventative measures to redirect high volumes of traffic away from construction/residential areas
	Plan for the Regulation of Traffic

4. Developing an Expert System for Disputes Avoidance in highways Construction Projects

The Purposes of developing of Expert System (DES) is to provide a user interface approachable system for defining the various causes of disputes performances in road construction sector. It will also able to suggest appropriate and controlling measure to avoid disputes during road construction project. The following tasks are involved in the development of an Expert system to overcome from disputes.

1. Identifying the issues that are causing the road construction project to be delayed and contentious.
2. Determining the significant level of causative factor which are leading to disputes through (SPSS).
3. Determining appropriate controlling remedial measure to overcome from disputes.
4. Establishing an Expert System for the Purpose of Suggesting Appropriate and Governing Measures to Prevent Disputes

Focus of this paper is the determination of the factors that contribute to disputes in highways construction projects, and it uses both qualitative and quantitative methods. SPSS is used to perform the analysis on the data. The primary contribution made by this study is the integration of expert systems (ES) with experience-based recommendations from the construction industry regarding appropriate and controlling dispute prevention measures for use during road construction projects.

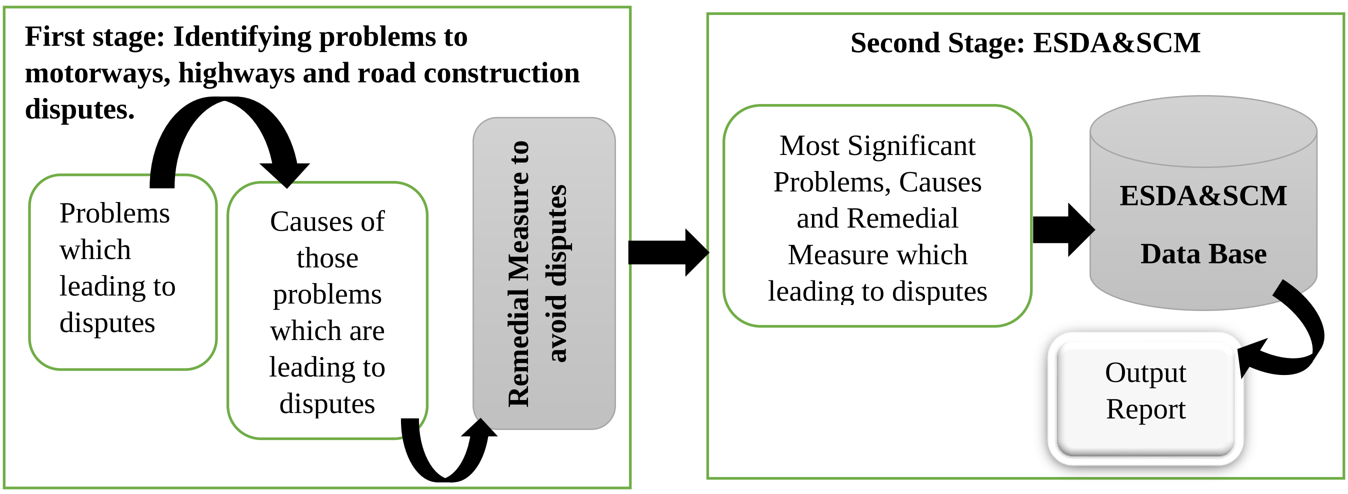

Fig. 4: shows the conceptual Frame work of expert system

4.1. The Conceptual Frame Work of Expert System for Disputes Avoidance in road construction project.

Expert system will provide a user interface approachable system for the determination of problems that lead to disputes in the road construction sector. This ES will also support the users in suggesting and appropriate controlling measures to avoid disputes during road construction projects, see Figure 4.

4.2 Figure: Conceptual Frame Work of ESDA & SCM

The Conceptual Frame Work of ESDA & SCM is divided in two different stages as defined bellow.

First Stage: Given a concise overview of the major issues causing highways construction disputes. A quantitative literature review using questionnaires and unstructured interviews with road construction experts completes this. From this point, users can identify the biggest issues causing road construction disputes and how to fix them.

Second Stage: A database and transformation layer based on dispute-causing issues. The expert system will suggest appropriate and controlling measures from the database to avoid disputes during highways construction projects.

4.3 Working Mechanism of Expert System

KBES for road construction dispute avoidance helps users step-by-step.

In the first step (Figure 5) of evaluating knowledge-based expert system input from users, when the user starts the programme, a new window will open on screen where the user will enter user name and password to get access and select the disputes-causing problems.

Fig. 5: Shows Screen shot to get access and selecting problem

After starting the program, than enter the problem, as illustrated in Figure 6.

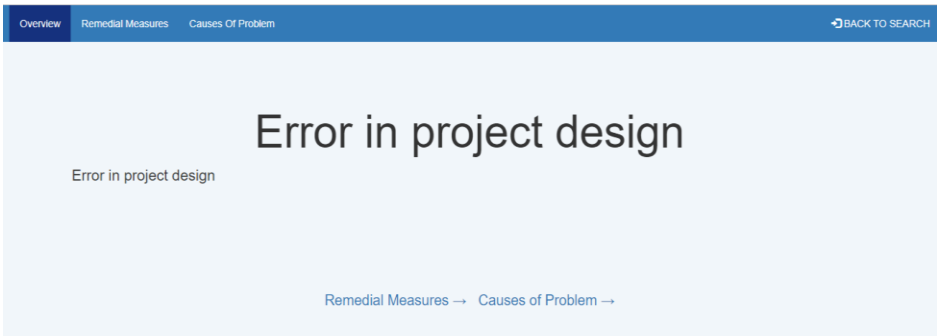

Fig. 6: Shows Screen shot of displayed Problem which is leading to disputes

The user will choose the most important problem causes as usual in roadway projects. To avoid construction disputes, the expert system will present control measures for each of the following causes (Figure 7 and 8).

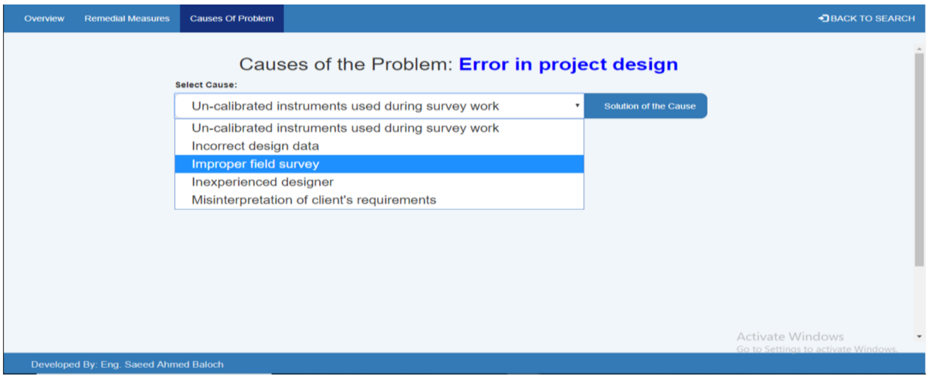

Fig. 7: Screen shot of displayed significant causes of the problem

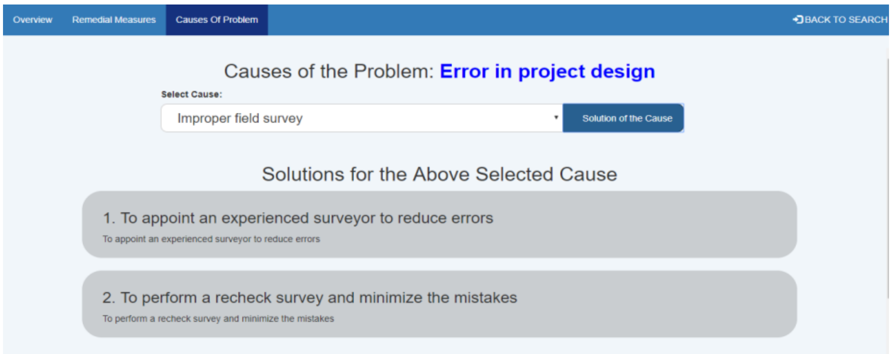

Fig. 8: Shows Screen shot of displayed controlling measures of causes to avoid dispute

5. Conclusion

This research paper proposes a conceptual framework for developing intellectual computer software (ES) to suggest and control construction industry disputes. As mentioned, most construction projects worldwide experience disputes. Significant issues and their causes are causing construction disputes that will delay project completion. The ESDA&SCM framework can identify major issues that cause disputes and suggest ways to avoid them in road construction projects to improve performance. This study also shows the most effective dispute avoidance methods. The knowledge-based expert system developed using structured query language (MYSQL) database, hypertext preprocessor (PHP) server site scripting, and HTML/Java Script user interface achieved the research's main goal. To avoid conflict, the system controls problems, causes, and their controls. If applied to road construction, the suggested controlling remedial measures will prevent disputes and finish the project on time and within budget.

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ID 110: Challenges in Implementing Constructability in Construction Industry–A Systematic Review

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A B S T R A C T

Constructability is an effective managerial strategy that has been employed in the construction industry that enables us to achieve earlier benefits concerned with cost, time, and quality. This novel concept facilitates the completion of overall success of project's desired goals. However, recent shifts in socioeconomic conditions and swift technological advancements have caused torsions in the construction industry. This comprehensive analysis investigates the various challenges and the application of constructability in the construction industry globally. A systematic review was conducted to address various issues including trends and more specifically the challenges & mitigations towards constructability implementation. The review found that constructability is of utmost prominence owning to recent advancements in the industry such as after the integration of Building Information Modelling (BIM) for more recent complex designs and growing environmental challenges in the construction industries. This review study would enable industry stakeholders to prepare for the industry in accordance with existing and future trends and also provide thorough future directions to mitigate challenges for the implementation of this novel concept.

K E Y W O R D S:

Constructability, Construction Industry, Buildability, Construction Management.

1. Introduction

Construction industry is a complex and dynamic sector that plays a critical role in the development and growth of economies worldwide. Over the years, the industry has undergone significant changes, characterized by rising complexity, project costs, and environmental considerations [1]. The traditional approach to construction projects has been to design and construct in a linear sequence, leading to unforeseen issues, delays, and increased project costs during the construction process. In response to these challenges, the concept of constructability has emerged as an effective managerial strategy in the construction industry [2]. Constructability refers to the degree to which the design of a construction project is optimized for the construction process, considering factors such as cost, time, and quality [3]. It involves integrating construction considerations into the design process to ensure that the construction process is efficient, cost-effective, and safe. This concept has gained prominence in recent years due to various socioeconomic and technological changes that have impacted the construction industry globally [4].

The need for constructability in the construction industry is increasingly crucial. By integrating constructability into the design process, construction professionals can optimize the construction process by identifying and addressing potential construction issues early on in the design phase [5]. This results in a more efficient construction process, reduces project costs, enhances project quality, and minimizes the potential for disputes and litigation. Furthermore, constructability enables construction professionals to consider environmental considerations and ensure that the construction process is sustainable and meets regulatory requirements. However, despite the potential benefits of constructability, there are challenges associated with its implementation in the construction industry. These challenges include a lack of understanding of the concept among stakeholders, inadequate communication and collaboration between design and construction teams, resistance to change, and a lack of appropriate tools and technologies to support constructability implementation [6, 7]. Thus, there is a need to identify and explore these challenges and to develop effective solutions to address them.

This systematic review paper aims to identify the significant and current challenges in constructability implementation and to explore available mitigations by reviewing various reputable publications. The study seeks to contribute to the current knowledge on constructability implementation and provide insights into ways that construction professionals can overcome challenges and optimize the construction process. The findings of this study are expected to benefit stakeholders in the construction industry by providing a deeper understanding of the challenges associated with constructability and potential solutions to address them.

2. Research Methodology

This study seeks to investigate the challenges associated with implementing Constructability within the construction industry by employing a comprehensive and structured approach. A Systematic Literature Review (SLR) method is utilized to ensure the examination of relevant studies addressing the research objective in a systematic manner. The SLR method encompasses several phases, including scoping, planning, searching, screening, eligibility, research synthesis, and findings presentation. To effectively execute the SLR method, the research topic statement is initially defined as the current challenges and trend of Constructability in the construction industry. This statement serves as the basis for the literature review process and guides the search for pertinent articles. Subsequently, a list of relevant search terms is generated by brainstorming, comprising "Constructability," "Buildability," "Challenges in Constructability," "Construction Industry," "Systematic Literature Review," and "Construction Management." The selected search terms aim to facilitate the retrieval of articles directly related to the research topic. Following the identification of search terms, recognized journals, and databases, such as Springer, Elsevier, Google Scholar, ASCE, and HEC (digital library), are searched. These databases are chosen based on their extensive collection of scholarly articles and their credibility within the research community.

This research identifies and categorizes search terms related to Constructability, Buildability, Challenges in Constructability, Construction Industry, Systematic Literature Review, and Construction Management. These terms are utilized to search for The SLR method enables the systematic identification of relevant studies, determination of the study's scope, and recognition of research gaps and previous work concerning the challenges of implementing Constructability in the construction industry. The research topic statement, focusing on the current obstacles in implementing Constructability within the construction industry, guides the search process and ensures adherence to the research objective. Articles connected to the research topic. Title, abstract, and keyword search parameters, as well as logical keyword combinations, are employed to search the selected journals and databases, maximizing the likelihood of discovering relevant articles.

The search results are processed using a systematic approach. A total of 142 records are identified through the searches. During the screening process, this process eliminate duplicates (51), non-English language entries (5), and articles based on abstract and title (27). Full copies of 83 articles are reviewed, and 46 records are eliminated based on inclusion and exclusion criteria. Ultimately, only 25 papers are included for the final review, ensuring a comprehensive analysis of relevant articles. By adhering to this detailed methodology, the research study systematically investigates the challenges of implementing Constructability in the construction industry, yielding valuable insights, and contributing to the existing body of knowledge on the subject. Figure 1 presents virtual representation of Systematic Literature Review.

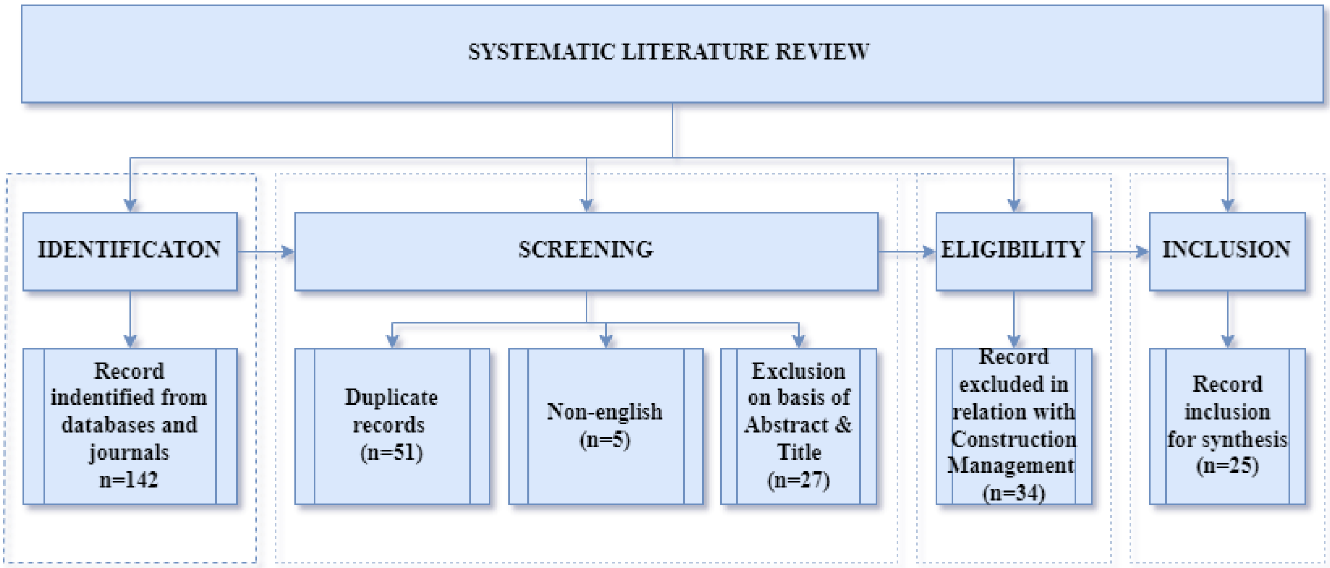

Fig. 1: Systematic literature review

2.1 Material Collection

A Systematic Review on Challenges in Implementing Constructability in Construction Industry material collection compiles 25 research articles published between 2013 and 2022 on constructability practices in the construction industry. The articles cover a range of topics related to constructability, including virtual prototyping, project delivery processes, sustainability indicators, BIM, ontology, blockchain, and safety.

The collection includes studies from various countries, including Nigeria, Indonesia, Sweden, Oman, and Pakistan, indicating the global relevance of constructability practices. The articles explore the challenges, benefits, and obstacles to implementing constructability practices in the construction industry, providing valuable insights for industry professionals, researchers, and policymakers.

3. Results and Discussion

3.1 Challenges in Constructability Implementation

Constructability implementation in the construction industry plays a vital role in enhancing project performance, reducing costs, and improving overall efficiency. Despite its importance, several challenges hinder the effective implementation of constructability practices. This finding aims to synthesize the key findings from various studies provided in the earlier parts, identifying the common themes and challenges in constructability implementation. By addressing these challenges through increased awareness, training, collaboration, technological adoption, and standardization, the construction industry can improve project outcomes and capitalize on the benefits offered by constructability practices. Based on the comprehensive review of the literature discussed in the previous sections, the following key findings can be derived concerning constructability challenges in the construction industry.

3.1.1 Communication and Collaboration:

A recurring theme across various studies [3, 8, 9] is the challenge of effective communication and collaboration among project stakeholders. The lack of proper communication channels and collaboration can lead to errors, inconsistencies, and delays, resulting in project cost overruns.

3.1.2 Lack of Understanding and Training:

Many studies such as [3, 6, 10, 11] have identified the lack of understanding of constructability concepts among project stakeholders as a significant challenge. Additionally, inadequate training and education on constructability practices contribute to the problem.

3.1.2 Limited Use of Technology:

Several studies such as [9, 12, 13] have highlighted the limited adoption of advanced technologies, such as BIM and VR, in the construction industry. This slow adoption rate hinders the potential improvements in constructability practices that could be achieved with the help of these technologies.

3.1.3 Resistance to Change:

The construction industry's resistance to change, as identified by [13], can be a significant barrier to the adoption and implementation of new constructability practices and technologies.

3.1.4 Lack of Standardized Definitions and Guidelines:

The absence of standardized constructability definitions and guidelines, as mentioned by [14] and [13], can lead to confusion and inconsistency in the implementation of constructability in construction projects.

3.1.5 Limited Integration with Project Management Tools:

[9] also identified the limited integration of constructability with other project management tools as a challenge, which restricts the potential benefits of constructability.

3.1.6 Limited Focus on Sustainability:

[15] pointed out the limited focus on sustainability in construction projects, which means that sustainable constructability practices are not always prioritized.

3.2 Mitigations for Challenges in Constructability:

In mitigation for the challenges faced by constructability practices are multifaceted and complex. The construction industry must overcome these challenges to achieve constructability goals effectively. The use of quantitative models, BIM, and adequate resources, experience, and open communication between designers and constructors are crucial in achieving constructability goals [16]. It is essential to increase understanding and adapt the concepts of constructability and implement comprehensive training and awareness programs to enhance stakeholders' knowledge and commitment to the adoption of buildability practices.

3.3 Trends in Constructability:

Constructability Implementation in the construction industry is towards the adoption of digital technologies, stakeholder cooperation, and the integration of sustainability and safety measures [17]. There is also a focus on comprehensive training and awareness programs for stakeholders and the development of quantitative models to improve the assessment and implementation of constructability practices [18].

4. Conclusion

The above findings underline the importance of addressing these challenges to improve constructability practices and their integration with other project management tools in the construction industry. Enhanced communication and collaboration among stakeholders, increased training and education on constructability concepts, and the adoption of advanced technologies can help mitigate these challenges. Moreover, fostering a culture of change and innovation, standardizing definitions, and guidelines for constructability, integrating constructability with other project management practices, and emphasizing sustainability can lead to better constructability outcomes in construction projects. Finally, considering local culture and standardization while adapting constructability concepts, as suggested by [6], can further contribute to improvements in the construction industry.

5. Acknowledgment

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ID 119: E-Procurement and Supply Chain Performance in the Construction Industry of Pakistan

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A B S T R A C T

E-Procurement is a crucial tool for reducing purchasing expenses and enhancing operational efficiency in business. In today's rapidly changing and competitive global economy, technology-based services are essential for both public and private businesses to meet customer needs and improve satisfaction. E-procurement has been widely adopted globally and has made its mark in Pakistan by being successfully implemented in various projects. Despite the growing interest in e-procurement in the construction sector, research in this area is limited and concentrated in specific regions. Despite numerous studies on the application of e-procurement in construction projects, the literature suggests that most of the research is limited to specific regions. The study utilized a descriptive design, collecting both quantitative and qualitative data through questionnaires and interviews with experienced workers. The data was analyzed using SPSS 25, and the results showed the significance of factors that impact supply chain performance, which were then ranked based on mean and standard values. The analysis results identify the top e-procurement factors that influence supply chain performance in the construction industry in Pakistan.

K E Y W O R D S:

E-Procurement, Supply Chain Management, Construction Industry, Pakistan and Productivity.

1. Introduction

E-Procurement is a crucial tool for reducing purchasing expenses and enhancing operational efficiency in business. It encompasses various electronic processes, including electronic advising, invoicing, bidding, payment, receipt, contract management, order tracking, shipping notification, payment, and inventory management. An efficient supply chain is essential for companies to remain competitive in today's challenging economic climate, as it enables coordination and Synchronization of all activity from end customers to suppliers across the whole supply chain. This has led to a transformation in the procurement function, which was previously viewed as a minor aspect of an organization's relationship with suppliers, but is now considered a critical factor [1].

Today, procurement work is more than just a support office feature that assists other sectors; it is a research area in and of itself that necessitates constant progress and digitalization to remain competitive. Digital economy, specifically electronic procurement frameworks, allows the buyer, providers, clients, and other purchasing process participants to form and maintain at least one association. As businesses expand globally, there is a greater need for electronic procurement frameworks to maintain control over tasks, maintain connections between buyers and suppliers, and reduce costs. Studies have shown that implementing electronic procurement in purchasing operations can result in a cost reduction of 8-12% compared to traditional purchasing methods [2].

Global Public Procurement has undergone a shift towards electronic procurement with the aim of optimizing productivity. The proliferation of e-marketplaces, internet-based supply chain management, and internet-based procurement through networks and hubs has been driven by the growth of the internet. The widespread adoption of e-procurement, which started in the late 1990s, has revolutionized the entire procurement process and supply chain by replacing conventional methods with this innovative system, resulting in improved efficiency in procurement and effectiveness while reducing procurement costs and maintaining the organization's quality standards. In comparison to traditional procurement, e-procurement through internet-based tendering is more efficient, saves time and money, and has become popular even among small and medium-sized businesses in developing countries [3].

Procurement has traditionally been a vital division in most industries, known for its high level of importance and professionalism. In this context, factors such as cost, available resources, expertise and specialized skills, and innovation have amplified the challenges of electronic procurement and an efficient supply chain cycle. Companies are still grappling with issues such as data management, data collection, processing, and storage. In contrast to the traditional paper-based and conversation-based procurement practices, today's procurement is electronic. This investigation reveals that poor record-keeping, inadequate documentation and reporting systems, insufficient procurement organization, ineffective post-contract management, inconsistent reporting to procurement management, and the lack of use of high-level requests are all signs of a failing procurement process [4].

Electronic procurement is now a core way to conduct all levels of acquisition and ensures system management between key, strategic, and functional acquisition, just as it does with suppliers and end users. In addition to this systems management, In addition to improved efficiency, electronic procurement offers other benefits such as better data organization across acquisition channels, cost and time savings for organizations and their agents, reduced paperwork, and similar advantages [5].

A single mistake in procurement can greatly affect a company's supply chain and performance. The main reasons for poor procurement practices stem from a lack of market awareness and expertise. The growth of e-procurement has made the procurement process more complex, leading to an increase in procurement disruptions and their corresponding impact in recent years. These disruptions can harm the organization's supply chain management and hinder its ability to respond in sync with its supply chain and procurement. A relevant example is a PC manufacturing firm that struggled with ineffective supply chain and procurement management, resulting in slow response times and dissatisfaction (Qrunfleh and [6].

Before the United States experienced severe monetary stagflation in 2000, e-commerce started to gain popularity. By the end of the 1990s, most states in the U.S. had already started conducting procurement transactions online through the organizational portal. Similarly, the Malaysian government issued a directive asking all service providers to consider using the electronic procurement system. Public procurement officials and other leaders play a significant role in evaluating suppliers and outlining details to ensure that public entities receive the best value for their money while serving their constituents. In Malaysia, the public sector is going through a lot of change and showing inconsistencies, especially in the acceptance of coordinated new developments to fix and close public procurement process gaps. Because the government responds rapidly to stop government authorities cooperating with malicious providers from stealing public resources, electronic acquisition and government gathering are conceivable in Malaysia. [7].

The goal of this research is to investigate the impact of electronic procurement factors on management of supply chains in Pakistani firms. The purpose of this study is to identify the electronic-procurement-related elements that have an impact on the performance of supply chain management in procurement activities within companies in Pakistan.

2. Literature Review

The focus of this research is to analyse the impact of e-procurement on improving supply chain management efficiency in Kenya's energy sector. The findings show that e-procurement factors such as electronic data exchange, electronic bidding, and integration of the supply chain have a significant impact in improving the effectiveness of supply chain management in Kenya's energy industry [5]. A positive relationship exists between EAPCC (the organization) and its suppliers due to the removal of a factor that causes differences between the two parties. Furthermore, the utilization of electronic procurement systems is claimed to decrease ordering expenses [6]. The advantages of adopting e-procurement have been highlighted. Cost Savings: Using e-procurement can result in cost savings of up to 65%, leading to increased deal volume by securing better prices from suppliers and enhanced bargaining power. Improved Communication: The internet's computer system and network can facilitate better communication between suppliers and customer organizations by directly interacting with suppliers to share information about products/services. Efficient Process: E-procurement streamlines the procurement process by eliminating intermediaries and enhancing communication with suppliers through the internet. Improved Inventory

Management: The e-procurement process can eliminate demand position or order errors, such as duplicated information. Better Customer Service: Improved communication between suppliers and customers results in better customer service. Faster Customer Service: The internet allows for faster information exchange between suppliers and customers [7]. The majority of studies on the adoption of IT at the company level are based on the DOI and TOE models, which are the most widely used frameworks [8]. Factors have a good and substantial impact on the adoption of electronic procurement such as support from the organizational structure, technological infrastructure, expertise in technology, B2B capabilities, perceived indirect benefits, perceived competitor performance, and ease of interaction with trading partners from the surrounding environment [9] and [10]. Electronic procurement is a technology-based system that streamlines the procurement process by integrating internal and external procurement components. This improves organizational efficiency by reducing costs and saving time in the procurement of goods. Additionally, as electronic procurement is based on IT, it is often up-to-date with the latest market trends [12]. Every modern business is faced with the challenge of avoiding unnecessary expenses in internal and external operations as every action incurs substantial costs in terms of money, time, and energy. However, organizations can conserve these resources by improving the efficiency and agility of their procurement and supply chain management processes [13] and [14]. The implementation of e-sourcing has helped companies reduce the costs associated with their supply chain, enhance the accessibility of important business information, and reduce the duration of procurement procedures. Despite this, certain systematic and specific weaknesses exist within various e-procurement components and there are limitations to the study, as it was not conducted in Pakistan [15]. E-procurement processes are much more crucial than other e-business processes in determining supply chain success. [8] and [9]. In order to reach a wide customer base globally, it is necessary to have a secure and trustworthy website. The website should be beneficial to both consumers and businesses, providing access to accurate information about goods and services. The most successful implementation of e-procurement is achieved when it is fully integrated into the business process and has the ability to adapt to the constant evolution of technology [10]. An e-catalogue, in essence, is an online platform that provides information about the products and services offered by a seller, thereby enabling online purchases and payments. This platform allows for two-way, real-time communication between the buyer and the seller, as well as expanding the customer's awareness of items they may not have been aware of previously. The traditional delay between a customer's request and the issuance of a purchase order is eliminated through online authorization. Email notifications and confirmations are also possible. Additionally, e-catalogues allow for quick price and packaging adjustments in response to market changes. [11]. The relationship between supply chain management partners reflects how customers treat their providers and the expectations they have of them. The continual contact between the buyer and the supplier creates an enabling mechanism in firms with long-term connections. With the help of this strategy, they can work together to develop strategies for the provision of requirements that are tailored to the needs of the customer. The collaboration should involve coordinated planning over a range of time periods. Tactic, operational, and short-term planning procedures all require a long-term strategic view. This is only possible with cooperation from all parties involved in the supply network. In the connections, various representatives from the buyer and selling organizations have conversations. Each participant brings to the collaboration particular personal traits, life experiences, and areas of skill [12].

The importance of this study lies in its contribution to providing guidelines for improving supply chain. The scarcity of research on supply in the Pakistani construction sector, and the lack of studies that specifically focus on the impact of e-procurement factors, make this study a valuable addition to the field. Other studies or literature reviews do not fulfill the research's intended objectives by providing the necessary information. As a result, the current examination was given a distinct place in the written form and fills a void. This context enhances the significance of the existing exploration. The current investigation generates exceptional information for its designated individuals, such as acquisition experts and business advisors. Furthermore, this investigation focuses on the building projects industry in Pakistan, the review has boosted to the industries in Pakistan. Furthermore, the current investigation has only focused on a few electronic acquisition factors and has purposefully ignored other factors that may also affect supply chain management achievement.

3. Research Methodology

3.1 Data Collection and Methodology

Data Following the approach by authors for e-procurement factors which effecting the supply chain performance, a multi-step methodology was adopted, as shown in Figure 1. In the initial phase, journal articles, conference proceedings, books, and reports to be attained from various scientific databases. Obtained documents were then be scanned for most influential factors of e-procurement. After the literature mapping of all these, unstructured interviews were conducted with the industry experts to verify their relativeness with Pakistan's CI. In the next stage, factors related to e-procurement and its impact on supply chain performance were compiled into a questionnaire format. The perspectives of construction sector professionals were gathered through this questionnaire, where they were asked to rank the factors on a five-point Likert scale from strongly disagree to strongly agree. Data analysis was conducted using SPSS version 24 to determine the most significant factors. A total of 135 questionnaires were distributed among the targeted respondents, with 110 being considered valid for analysis. Respondents were asked to provide feedback for each item listed in the questionnaire used the scale as X_1 = Strongly Disagree; X_2 = Disagree; X_3 = Neutral; X_4 = Agree; X_5 = Strongly Agree. The level of significance was determined using the AI (Average Index) method, which was calculated using the statistical software SPSS. The AI value was calculated using the following formula, which was adapted from.

$$AI = \frac{\sum(1X_1 + 2X_2 + 3X_3 + 4X_4 + 5X_5)}{\sum(X_1 + X_2 + X_3 + X_4 + X_5)} \qquad \text{(eq. 1)}$$

Figure 1. Research Methodology

4. Results and Discussion

4.1 Literature Review and Mapping

Following an extensive examination of relevant literature, 20 electronic-procurement factors affecting the supply chain of the construction sector in Pakistan were identified. Subsequently, structured interviews were conducted with experienced construction industry experts who had over a decade of working experience. The results of these interviews, as shown in Table 1, led to a reduction of the 20 factors to 15, which were then analyzed as affecting the supply chain.

Table 1: Unstructured Interviews

S. No.	E-procurement Factors	yes	No
1	E-Biding	10	03
2	E-Informing	09	04
3	E-Tendering	13	00
4	E-Payment	11	02
5	E-Sourcing	08	05
6	E-Market Sites	05	08
7	E-Data Interchange	12	01
8	E-Invoicing	11	02
9	E-Design	08	05
10	E-Reverse Auctioning	07	06
11	Web-based ERP (enterprise resource planning)	10	03
12	E-MRO (maintenance, repair and operations)	08	05
13	Spend Analysis	10	13
14	Indent Management	06	07
15	Catalog Management	13	00
16	Vendor Management	12	01
17	Contract Management	12	01
18	Purchase order integration	07	06
19	Order Status	08	05
20	Order Acceptance	05	01

The above mentioned 10 factors were then set up in a questionnaire, which contained 2 parts. The first part of the questionnaire contained the introductory questions about the responder; however, the second part of the questionnaire contained the above mentioned 21 factors that effected the labor productivity in public sector building projects of Sindh, ranked on a Likert's scale from 1-5,

Where:

1 = Strongly Disagree

2 = Disagree

3 = Neutral

4 = Agree

5 = Strongly Agree

135 questionnaires in total were distributed among industry experts, out of which 110 were returned and were found valid for analysis. The results obtained were then analyzed in SPSS software, which yielded following results as shown in Table 2.

Table 2 SPSS Results

Factors	Mean	S.D	Rank
E-tendering	2.412	0.765	**1st**
E-informing	2.303	0.938	**2nd**

E-sourcing	2.207	0.808	**3rd**
E-bidding	2.200	0.856	**4th**
E-payment	2.156	0.873	**5th**
E-invoicing	2.099	0.893	**6th**
E-design	2.001	0.953	**7th**
E-data interchange	2.000	1.135	**8th**
Contract management	1.983	1.046	**9th**
Catalog management	1.901	1.142	**10th**
Web-based ERP (enterprise resource planning)	1.881	1.156	**11th**
Spend analysis	1.782	1.213	**12th**
Vendor Management	1.712	1.258	**13th**
E-MRO (maintenance, repair and operations)	1.708	1.264	**14th**
Order status	1.652	1.265	**15th**

The above table clearly shows that E-Tendering was chosen as the most important factor due to its higher mean value. Because the factors in the building sector are not easily accessible, the industry's integration suffers greatly. E-Sourcing was identified as the second most significant driver of adoption in the construction industry due to its second higher mean value. Another critical component that has a significant influence on construction sector supply chain performance and for improved results in the construction business, project information must be transmitted electronically. The third factor that had an impact on the construction sector supply chain performance was discovered to be e-informing, which demonstrated higher mean values than the initial two factors. E-informing was found to be a crucial element in the integration of supply chain management in the construction sector and has a significant impact on its adoption. The fourth highest factor affecting supply chain performance was found to be e-payment, with high mean values. E-payment is considered important in Pakistan's construction industry as it enables secure online transactions between parties and organizations, reduces time waste, and improves construction sector supply chain performance. According to the research findings, e-bidding was identified as the fifth most important factor affecting supply chain performance in the construction industry, with a mean value that exceeded the top four factors. The factors were ranked based on their mean values, with those having the highest mean value considered to have the greatest impact.

5. Conclusion

The purpose of the current study was to investigate the impact of 15 e-procurement factors on supply chain efficiency in Pakistan's construction industry. The study used exploratory factor analysis to group these 15 e-procurement elements into three components: infrastructure, technology and system, and organization and management. This study builds upon previous research, which had not previously explored the role of e-procurement in effectively deploying procurement and supply chain management strategies and improving supply chain responsiveness. The findings of the study indicate that the implications of e-procurement in the construction industry are similar across countries. The primary factor that drives firms to adopt e-procurement over traditional paper-based systems is the perceived benefits. However, researchers and industry practitioners have different perspectives on what factors influence the decision to use e-procurement. For better research outcomes, it is crucial for construction researchers to connect with industry practitioners. The conclusion of the study highlights the importance for businesses considering e-procurement implementation to understand the benefits, availability, and cost of e-procurement technologies and solutions. For the wider acceptance and utilization of e-procurement in the construction sector, it is necessary to promote awareness through workshops, gatherings, and professional associations, and to provide e-procurement software and technologies at affordable prices.

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ID 122: Causes of Conflicts Due to Contractual and Technical Problems in Building Construction Projects

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A B S T R A C T

In the competitive and complex environment of the building construction industry, individuals with diverse perspectives, abilities, and building process expertise engage with one another. Due to the presence of such contentious circumstances, conflicts are inevitable. It is necessary to identify the root causes of construction conflict in order to establish an effective mitigation strategy. This research analyses the causes of conflict resulting from technical and contractual problems. Contractual duties bind professionals to work as a team to achieve the project's objective and construction industry is involve more contracts than other of industries. Due to the widespread use of contracts in construction sector, complexity and conflict are unavoidable. According to the results of this research, inadequate definition and specification of the precise scope of contract, the client's inability to pay according to the contract, and changes in the initial cost commitment under the contract are top three causes of conflicts due to the contractual problem. It is clear from previous studies that conflict due to technical problems directly affects construction project time and efficiency. So it is very important to determine and rank most important causes of conflict due technical problem. The study shows that sudden swings in market prices, inadequate site management, and problems in supply chain and procurement are the top three causes of conflict due to technical problems. The research methodology involves extensive literature review, preliminary mapping, interviews and a questionnaire survey. The data were analysed through SPSS. In total, 46 causes of conflicts due to technical and contractual problems are determined and ranked in later stages.

K E Y W O R D S:

Conflict, Construction Industry, Contractual Problems, Technical Problems

1. Introduction

The construction industry has a complicated and competitive environment in which participants with varying perspectives, skills, and knowledge of the construction process collaborate. Conflicts can emerge between such individuals [1]. Conflict is described as a serious disagreement between two or more parties on different issues. Despite considerable scientific research and improved management practices, building projects are still unable to tackle a wide range of challenges, including conflicts, productivity loss, poor performance, and many more [2]. Due to the potentially large number of people involved in the construction process and their diverse organizational goals, external factors, changing conditions and different expectations, the risk of misinterpretation and misunderstandings increases which ultimately leads to conflicts [3].

Conflicts are among the most common cause that jeopardizes the success of building projects. In order to determine the appropriate mitigation approach for their prevention and control, it is important to identify the most likely reasons for conflicts that may develop during the project [4]. A conflict may be detrimental to an organization, particularly if it diverts workers' attention away from constructive endeavours. It can sabotage group dynamics and fuel interpersonal hatred to the point that group members may be unable to cooperate to accomplish organizational objectives. Construction conflict really impacts the delivery of projects. So, it is necessary to identify the root causes of construction conflict in order to establish an effective mitigation strategy. Moreover, according to previous research, the root causes of conflicts vary from nation to nation and area to area. Hence it is necessary to identify the causes of conflict, particularly in a specific region. This paper aims to investigate the existing literature and analyse and rank the causes of conflict resulting due technical and contractual problems in the construction industry of Sindh Pakistan.

2. Literature Review

The construction industry is renowned for its potentially contentious environment. Thus, the formation of conflicts between concerned parties is common in such a complicated environment [1]. The construction sector has seen several evolutionary changes in recent decades as a result of technological advancements. Despite considerable scientific research and improved management practices, building projects are still unable to tackle a wide range of challenges, including conflicts [2]. Due to the potentially large number of people involved in the construction process and their diverse organizational goals, external factors, changing conditions, and different expectations, the risk of misinterpretation and misunderstandings increases which ultimately leads to conflicts [3]. From various international research studies, it is evident that the root causes of conflicts vary from nation to nation and area to area. Delays in payments were determined to be the primary source of conflict in both the Libyan and Serbian construction sectors by [4] while excessive contract modifications were ranked second in Libya while differences in the evaluation were second in Serbia. Similarly, [5] reveal that bad governance and contract arrangement are the leading causes of disputes in Ghana, whereas poor risk management and communication are the leading causes of conflicts in China. The same result was seen after comparing multiple papers as according to research by [6] the top main reasons for conflicts include payment delays and contractual claims. While [7] study of conflicts in the Nigerian construction sector, shows poor client financial projections, and lack of funds are major causes of conflicts. Due to such results, it is very important to know the causes of conflicts, particularly in specific regions. According [8] [9] [10] [11] the root cause of conflict can be categorized into three types which are conflicts due human behaviour, contractual and technical problem. This study only considers causes of conflicts only due to contractual and technical problems because accessing human behaviour is very difficult.

The most frequent challenges in project operations are the technical conflicts caused by ambiguity. The quantity of information needed to complete a job and the proportion of information the organization has previously processed is what is referred to as uncertainty. The complexities of the project and the number of additional factors that must be addressed, such as money and schedule limitations, influence how much information is required. Uncertainty can result in overdesign, a poor site or soil research report, inaccuracies and incomplete technical requirements, among other things, all of which can cause conflict [8].

According to Ismail N [10], late instructions from the architect or engineer, unrealistic client expectations, and inadequate technical specifications are causes of conflicts due to technical problems. According to Salooma and Laila (2016) [11] particular technical problems that result in conflicts include failing to schedule and update requirements, comprehend and accurately price the works, and plan and execute changes to the original scope of work. Moreover another study finds that late supply of materials, failure to calculate the complete budget cost, lack of information, and inadequate planning for development procedures are causes of technical conflicts. While many studies have identified contractual conflicts as a major cause of construction delays, their underlying causes have been rarely explored. By identifying the underlying causes of contractual conflicts, we can implement preventative measures that are usually overlooked in risk management and dispute resolution processes [12].

According to Willow (2020) [13] contract clauses dealing with the variation that are ambiguous, one-sided or unbalanced contracts that leave one party vulnerable to accusations and unprotected, contract administrator's failure to meet relevant contract obligations and non-serviceable contract information are the primary causes of conflict resulting from contractual problems. Moreover lack of clarity in documents, confusing phrases in contract documents, and unclear contract terms or wording that might produce a double meaning in contract documents are causes of contractual conflict [14].

Contractual issues are the root of the majority of conflicts. A large number of these disagreements may be avoided or handled by raising awareness, clarifying, and identifying the causes of conflict due to contractual problems. Lack of clarity regarding expectations is one of the causes of contractual disagreement. A conflict will emerge when contractual parties have differing expectations for the outcome. When contracting parties neglect to read the contract or make assumptions without fully understanding its terms, disputes are inevitable. Furthermore, clauses in contracts are frequently ignored, which results in conflicts. This often happens when the parties' rights and obligations aren't clear to one another [15].

3. Research Methodology

An extensive literature was conducted to identify causes of conflict due to technical and contractual problems. In order to check relevancy of identified causes with Sindh's construction industry as well as with their specific categorize semi-structured interviews were conducted. The identified factors were processed through a short pilot study. Experts' opinions during the pilot study are amended in the final set of questionnaires which was sent to numerous practitioners working in the construction industry via hard Mail, Emails, and WhatsApp.

3.1 Data Collection

Data was collected from construction industry professional of Sindh, Pakistan. Ten semi-structured interviews were conducted. The aim of interviews was to gather deep knowledge about the subject before the questionnaire survey and also to check the relevancy of conflict relative to their specific category and also with Sindh's construction industry. For questionnaire survey sample size following equation was used. However 157 responses were received.

$$\mathbf{SS} = \frac{\boldsymbol{Z}^{2}\times\boldsymbol{P}(\mathbf{1}-\boldsymbol{P})}{\boldsymbol{C}^{2}} \qquad \mathbf{SS} = \frac{\mathbf{1.96^2}\times\mathbf{0.5}(\mathbf{1}-\mathbf{0.5})}{\mathbf{0.08}^{2}} = \mathbf{150.06} \approx \mathbf{150} \quad \text{(eq. 1)}$$

SS = Sample Size, Z = (1.96 for 95% confidence level), P = Percentage picking a choice, (0.5 used for sample size needed), C = Margin of error (8%)

3.1 Data Analysis

Data was analysed through SPSS. Causes of conflicts were ranked according to their mean. Cronbach's alpha coefficient was calculated to gauge the internal consistency of survey items. Each component's standard deviation and mean score was analysed through SPSS. Also data was collected on the basis of Likert scale and ranked accordingly, see Table 1.

Table 1: Pimentel (2019), Five point Likert scale

Likert Scale	Interval		Remarks
1	1.00-1.79	0.79	Not at all important
2	1.80-2.59	0.79	Slightly Important
3	2.60-3.39	0.79	Moderately Important
4	3.40-4.19	0.79	Very Important
5	4.20-5.00	0.80	Extremely important

4. Results and Discussion

The following results were obtained after conducting research which shows causes of conflict due to contractual and technical problems ranked according to their importance.

4.1 Respondents Personal Information

Participants were professionals with expertise in the construction industry. The results of research shows that 77% of participants were bachelor's degree holders while 14% were Master's degree holders, and only 9% were diploma holders. Moreover majority of participants belongs to Hyderabad and Karachi South, 22% and 16% respectively, see Figure 1-2.

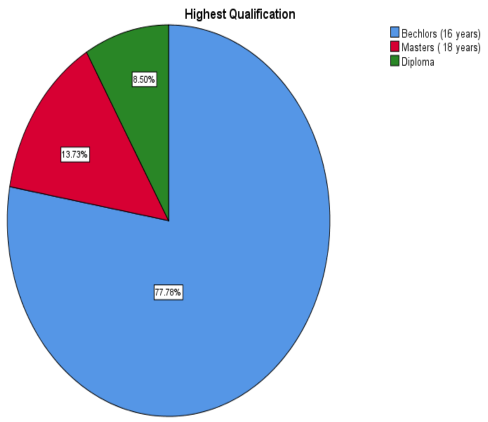

Fig. 1. Highest qualification of Respondents

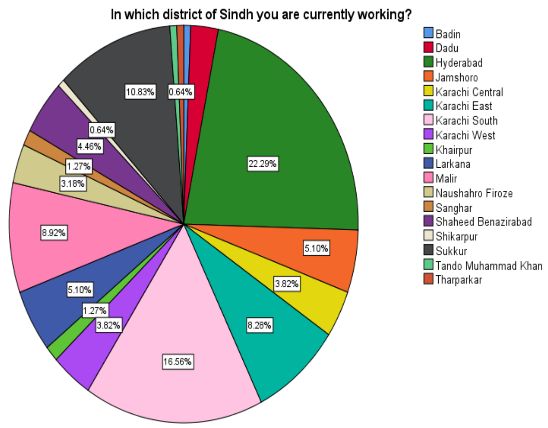

Fig. 2. District in which participants are currently working

4.2 Causes of Conflicts Due to Contractual Problems

Table 3 illustrated the causes of conflicts due to contractual problems. Following causes are first identified through literature review and then these causes are ranked by conducting qualitative and quantitative surveys. In following table each causes is ranked according to mean which is calculated with the help of SPSS. Also standard deviation is shown which checks average amount of variability. At the end of table Cronbach's alpha is shown which is coefficient measures the internal consistency. The results show that seven causes of conflicts are extremely important, while ten causes of conflict due to contractual problems are moderately important according mean interval given by Table 1. The top most important cause of conflict due to contractual problem is inadequate definition and specification of the precise scope of contract. A contract scope of work is a written description of the work that will be carried out in accordance with a contract or subcontract when the scope work is not defined properly it may result in contractual conflict. The client's inability to pay according to the contract, it come under breach of contract and it is second most important cause of contractual conflict. Third most important cause of conflict is changes in the initial cost commitment under the contract. Results (Table 2) show that all causes of conflict due to contractual problems are important and not a single cause of conflict come under mean scale of not important at all. It is important to note the least important cause of conflict due to contractual problem is application of extension of time and improper project schedules.

Table 2: Ranking of causes of conflicts due to contractual problems

Causes	Rank	Mean	S.D
1. Inadequate definition and/or specification of the precise scope of contract works	1st	4.70	.729
2. Client's inability to pay according to the contract/Delay interim payment from the client	2nd	4.67	.769
3. Changes in the initial cost commitment under the contract.	3rd	4.64	.891
4. Poor documentation	4th	4.63	.906
5. Vague contract clauses that deal with changes in work requirements	5th	4.63	.921
6. Occurrence of various construction contract issues due to the failure of the parties in anticipating the project design problems	6th	4.46	1.009
7. Ambiguity in roles and responsibilities	7th	4.27	1.303
8. Non-serviceable contract information or lack of information	8th	3.71	.741
9. Ambiguous provisions/more than one interpretation	9th	3.26	.721
10. Unrealistic contract duration and requirements of the parties	10th	3.03	.683
11. Excessive contract variations	11th	3.01	.622
12. Employer's/contract administrator's failure and/or negligence to meet the relevant contract obligations	12th	3.00	.595
13. Unilateral early termination of the contract	13th	2.96	.587
14. Acceptance of unclear/imprecise tender offers without proper clarifications, negotiations, and recording of the changes	14th	2.93	.551
15. Poor coordination by the client; for example, a contract where a client is	15th	2.85	.812

Causes	Rank	Mean	S.D
responsible for obtaining licenses and permits required and they fail to properly communicate these to the project stakeholders			
16. One-sided or unbalanced contracts which leave one party unprotected and open to accusations	16th	2.847	.769
17. Application of extension of time and improper project schedules	17th	2.833	.777
Cronbach's Alpha	**.920**		

4.3 Causes of Conflicts Due to Technical Problems

Table 3 illustrated the causes of conflicts due to technical problems. Following causes are first identified through literature review and then these causes are ranked by conducting qualitative and quantitative surveys. In following table each causes is ranked according to mean which is calculated with the help of SPSS. Also standard deviation is shown which checks average amount of variability. Results shows that eleven causes of conflicts due to technical problems are extremely important. While fourteen causes are moderately important and only four causes are slightly important according mean interval given by table 1. According to result sudden swings in market prices is top most important cause of technical conflict. Due to inflation and sudden changes in materials prices is key cause of technical conflict. The inadequate site management is second most important cause of conflict. The problems in supply chain and procurement can have direct and indirect effect on project which ultimately results into conflict; the result shows it is third most important cause of conflict due to technical problems. Results show that all causes of conflict due to technical problems are important and not a single cause of conflict come under mean scale of not important at all.

Table 3: Ranking of Causes of Conflicts Due to Technical Problems

Causes	Rank	Mean	S.D
1. Sudden swings in economic and market conditions	1st	4.726	.739
2. Inadequate site management	2nd	4.709	.729
3. Problems in supply chain and procurement	3rd	4.705	.763
4. Deficiency in the bill of quantity	4th	4.681	.734
5. Incomplete drawings and design specifications/Drawing flaws and negligence in design/Incomplete technical specifications	5th	4.675	.841
6. Delay in payments	6th	4.668	.762
7. Lack of clarity regarding requirements and budget cost	7th	4.666	.837
8. Poor communication	8th	4.634	.843
9. Opening for inspection	9th	4.617	.858
10. Limited resources	10th	4.611	.852
11. Over-designing or under-designing	11th	4.586	.862
12. Late delivery of materials	12th	3.044	.633
13. Late or ambiguous instructions or information from the architect, engineer, or client	13th	3.031	.603
14. Dissatisfaction of architects/engineers with the work of the main contractor	14th	3.019	.593
15. Failure to plan and carry out work changes	15th	2.949	.552
16. The difference in common goal among the project team members	16th	2.898	.611
17. Inadequate contractor’s experience or unqualified contractor	17th	2.891	.764
18. Delay caused by any organization or person (utility service/environmental protection agencies/government organizations)	18th	2.884	.652
19. Failure to understand and accurately quote or price the task	19th	2.879	.762
20. Failure of the contractor in meeting the client's requirements	20th	2.872	.704
21. Non-compliance of the contractor with the design	21st	2.872	.757
22. Rework due to error	22nd	2.859	.771
23. Accidents during construction	23rd	2.834	.774
24. Complex design and construction requiring detailed and lengthy reviews	24th	2.802	.720

Causes	Rank	Mean	S.D
25. Insufficient site or soil investigation.	25th	2.339	.807
26. Functional problems of building	26th	2.184	.791
27. Failure to perform the task on time	27th	2.172	.817
28. Shortage of skilled labor	28th	2.159	.76
29. The owner's arbitrary changes in the design and technical norms/Changes in owner's requirements arising during the post-tender	29th	2.133	.760
Cronbach's Alpha	**.942**		

5. Conclusion

Despite considerable scientific research and improved management practices, building projects are still unable to tackle a wide range of challenges, including conflicts. This paper aims to identify and rank the causes of conflict in the building construction industry of Sindh, Pakistan. To rank causes of conflict due to contractual and technical problems, an extensive literature review, preliminary mapping, interviews, and a questionnaire survey were conducted. The data were analysed through SPSS. In this research in total, 46 causes of conflicts due to technical and contractual problems are determined and ranked accordingly. The study concludes that results inadequate definition of the precise scope of the contract, the client's inability to pay according to the contract, and changes in the initial cost commitment under the contract are the top three causes of conflicts due to the contractual problem, while least important is the application of extension of time and improper project schedules. It is suggested to construction industry stakeholders to mitigate conflict due to contractual problems according to priority given by the Table 1. According to the findings, the most significant factor contributing to technical dispute is abrupt changes in market pricing due to inflation and abrupt changes in material pricing. The second most significant source of conflict is poor site management. Supply chain and procurement issues may have a direct or indirect impact on a project, which eventually leads to conflict and it is third most important cause of conflict due technical problems. While the owner's arbitrary changes in the design and shortage of skilled labour are the least important causes of conflict to technical problems. It is suggested to construction industry stakeholders to mitigate conflict due to contractual problems according to priority given by the Table 2. The study through the results suggests that conflicts due to contractual and technical problems are most important causes of conflicts. In this regard construction industry stakeholders should mitigate conflict according to priority given by this study. This research study will help stakeholders of construction in conflict management. Construction industry professionals should review this study in order have clear knowledge on conflict prone areas.

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ID 123: Tasks and Practices Involved in Conceptual Phase to Improve Construction Productivity

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A B S T R A C T

The growth of the construction industry is primarily determined by the quality and productivity of construction projects. Project productivity is one of the most important factors to consider during the conceptual phase of the project. Proper productivity planning during the conceptual phase of a project leads to project completion on time and with high quality. This study aims to evaluate the impact of significant tasks in the conceptual phase on project productivity, as well as related best practices related to the conceptual phase of a project that enables required site productivity and overcome conceptual phase issues. An extensive literature review of articles obtained from various research databases was conducted to identify conceptual phase tasks and practices associated with construction industry tasks. A questionnaire survey completed by professionals in the construction industry was used to collect data for the study. The data were analysed with SPSS, and found that Consents and Permits; Financial Planning Techniques; Project Planning; Contract Management; Project Management Team; Construction Philosophy; A Procurement Plan; and Design of Structures are major tasks in the conceptual phase of construction projects. The study also reported fifty best practices related to the task in the conceptual phase. Implementation of these practices will be helpful to increase site productivity.

K E Y W O R D S:

Conceptual Phase, Productivity, Essential Tasks, Construction Projects.

1. Introduction

Construction is thought to be one of the most important sectors of the economy. It touches almost every aspect of human life. As a result, researchers have faced a significant challenge in overcoming construction-related issues [1]. The construction industry is critical to any country's development or improvement. The development of the construction industry is primarily determined by the quality and productivity of construction projects [2]. A proper evaluation of the construction project is required before making a firm selection or decision to continue with the construction project. The way a project is structured determines how successful it will be. We know from previous research that we give very little time to projects at the beginning, so we fail to properly evaluate the number of issues that can later cause problems [3]. One of the most important factors to consider during the conceptual phase of project planning is project productivity. Proper productivity planning during the conceptual phase of a project leads to project completion on time and with high quality [4]. Construction projects include comprehensive phases of initialization, planning, execution, and closure. The project quality is directly related to proper or convenient management in all of the above-mentioned phases. Productivity is the most important factor for any project's construction manager [5]. However, in the above-mentioned phases where strategic or important decisions are made, the initialization or conceptual phase is critical. It is designed to define a client's aspect or requirement [6]. Despite the fact that this phase provides a tremendous opportunity for improving the construction project and the final cost estimation. The degree of future uncertainty is maintained or encountered during this conceptual phase [7, 8].

2. Literature Review

Pakistan's construction industry is vital to the country's social and economic well-being. The Pakistani government is currently planning to expand the country's infrastructure. A research conducted by [5] determined that there is a need to improve project management techniques in order to increase the productivity and performance of Pakistan's industry. The authors concluded that the main factor affecting the performance of Pakistan's construction industry is improper resource utilization in construction projects. From this research. It was concluded that the Pakistan construction industry can overcome the issues with good leadership, a realistic plan, and upfront planning. Projects in the social sector face serious challenges due to a lack of labor and management support. As a result, it is critical to pay close attention to these details in order to increase productivity. In developing countries, no proper research is conducted to determine the success or failure of any project. These issues must be resolved in order for projects to be completed successfully [4].

Today's major concerns in civil engineering and construction engineering are how to increase construction project productivity and make projects more cost effective. These issues have prompted experts to gather tasks, best practices, and new methodologies that will result in more successful projects. Constructability assessment, which takes into account construction expertise and experience from the start of a project in the early stages of projects, is one of the tried-and-true techniques for fusing the design and construction phases [9]. The conceptual phase has the greatest impact on the upcoming phases of construction projects, Execution, Detailed Engineering, and start up phase. Decisions taken during the conceptual phase have an important effect on the success of the subsequent phases. The tasks related to conceptual phase tasks were identified using a wide range of literature reviews and previous experiences. Permissions, design of structures, financial plan, construction philosophy, project planning, and contract management are the identified tasks. In depth study of conceptual phase shows that these tasks are inextricably linked. As a result, it is critical for construction industry to learn about conceptual phase tasks and their relationship to construction project productivity. Most of the literature has discussed other phases of the construction project and lacks on study regarding the conceptual phase. Abdul-Kadir and Price [3] reported the knowledge and relationships of tasks and their definitions related with the conceptual phase based on a broad literature review and expert interviews. A questionnaire, interviews with various organizations, and case studies were conducted for this study. Based on the results of the questionnaire and case studies, the authors concluded that in order to improve productivity in construction projects, it is essential to focus more on the conceptual phase. The authors recommended ten tasks and associated best practices related to the identified tasks, which will lead to an increase in construction project production. Poor management during the conceptual phase increases project costs and decreases productivity. Due to a lack of planning during the conceptual phase of construction projects, productivity suffers, resulting in time and cost overruns. As a result, it is necessary to identify and assess the tasks related with the conceptual phase's impact on construction productivity. As a result, this research is being carried out in order to identify various tasks and associated practices involved in the conceptual phase of a construction project that affect productivity in construction projects. The conceptual phase was evaluated using a literature review [3, 9 -14] by categorizing it into 8 tasks that are completed using the 50 different practices listed in Table 01 below.

Table 01. Identified tasks and practices

S. No.	**01. Consents and Permits Practices**
01	The entire consent and permit process must undergo a cost-benefit analysis.
02	It is necessary to evaluate how long the consent and permit processes take.
03	Before moving forward with consents and permits, information and data must be established.
04	Long-term projects must consider the political stability.
05	Risk management needs to be done.
	02. Financial Planning Techniques
06	It's important to secure funding sources.
07	A payment method needs to be decided.
08	Accurate estimates and mechanisms for cost control must be established.
09	Connect improvement in performance to inherent financial motivation.
	03. **Project Planning**
10	Planning must be driven by construction.
11	Define project objectives clearly.
12	Project objectives should be documented in writing.
13	Project goals should be acceptable to all stakeholders.
14	Set up a straightforward and efficient communication system.
	04. **Contract Management**
15	Client goals should be taken into account when choosing a specific contract type.
16	Contract type should be chosen at right time.
17	There should be a process in place for resolving disputes
18	Client, contractor, and consultant teams must scrutinize specifications to facilitate the construction process on site.
19	Eliminate all superfluous information from the contract document
20	The contract document must include quality assurance
21	The client and contractor should share the risk fairly
	05. Project Management Team
22	The client project management team must be under the direction of a strong leader.
23	Team members must meet certain requirements

24	Teambuilding exercises must be implemented to promote cooperation and strategy.
25	The client team must be independent of the parent organization.
26	The project team must remain intact for the duration of the project.
27	There must be unambiguous senior management support for each client and contractor team.
28	Teams from clients and contractors must foster a culture of trust and cooperation.
29	When the situation calls for it, learn about other cultures
	06. Construction Philosophy
30	Elements must standardize to make design and construction easier
31	The site's design must take site efficiency into account
32	The constructability idea must be incorporated from the very beginning of design
33	Design must encourage easy access to labour, supplies, and machinery
34	Set up an organized system for tracking and handling materials
35	Before entering the site, all materials and equipment must be fully certified
36	Make use of nearby resources
37	Positive labour relations must be upheld during the construction phase
38	It is necessary to identify the raw material sources
	07. A Procurement Plan
39	Ensure that the resources are accessible
40	For a project, only invest in and set up a tried-and-true system
41	Ensure that materials are delivered on time and are of the appropriate quality and quantity
42	Make suppliers accept exact delivery schedules
43	Look for manufacturing and shipping issues that cause delivery deadlines to be missed
	08. Design of Structures
44	The goal of the detailed design must be a simplified design
45	The methods used in design must be standardized
46	The design must encourage effectiveness during construction and upkeep
47	When designing, a 3-D system must be used
48	For a specific project, continuity within the design team must be preserved
49	Construction-related factors must drive the design schedule
50	Priority must be given to the detail engineering of the main item with a lengthy delivery period

3. Research Methodology

The primary goal of this study is to assess the effect of significant tasks in the conceptual phase, which affect the productivity of any project, and related best practices that are connected to the conceptual phase of significant projects that enable required site productivity and to overcome the issue related to the conceptual phase. At the start, an extensive literature review was conducted to identify the tasks and practices related to the conceptual phase. The identified tasks and practices were then shaped into a questionnaire format to determine the level of adoption and importance of tasks and related practices. To collect data from field civil engineers, a questionnaire survey was designed and distributed. They were asked to rank the adoption level of identified tasks and related practices on a five-point Likert scale from never adopted to always adopted. They were also asked to rank the importance level of identified tasks and related practices on a five-point Likert scale, from unimportant to highly important. The data analysis was performed using SPSS 26 to obtain the most significant tasks and practices. A total of 105 valid questionnaires were collected after the questionnaire was distributed to over 160 individuals. Assessment of the level of adoption and importance was done using the RII (Relative Important Index) method, calculated based on frequency calculated with the help of the statistical software SPSS. RII is a tool for prioritizing questionnaire results and assessing the adoption and significance of parameters [15]. The formula for RII is given below:

$$RII = \frac{\sum W}{A \times N} = \frac{5n5 + 4n4 + 3n3 + 2n2 + 1n1}{5N}$$

The questionnaire, which has three sections, was then designed based on the aforementioned factors. The first section contains the respondent's demography knowledge; the second section contains the adoption level of tasks and related practices; and the third section contains the importance level of tasks and related practices. For calculating the adoption level in the second section of the questionnaire, responders were asked to rank on a Likert scale from 1–5.

1. Never adopted.
2. Rarely adopted
3. Sometimes adopted
4. Often adopted
5. Always adopted

Then for calculating the importance level in 3rd section of the questionnaire responders were asked to rank on a Likert scale from 1-5,

1. Unimportant
2. Slightly important
3. Important
4. Very important
5. Highly important

4. Results and Discussion

The overall survey response rate was 35% responses from contractors, 33% responses from consultants, 20% responses from clients, and 12% from others. After the collection of responses, the data was run in SPSS to get the frequencies of responses. Then the relative importance index analysis was done using the above-mentioned formula. The RII value for the adoption of tasks for consents and permits, financial planning techniques, project planning, contract management, project management teams, construction philosophy, a procurement plan, and the design of structures is 0.7 and 0.8, respectively. The outcomes of the adoption and importance levels of practices Critical practices were determined by ranking the practices based on significance values obtained by multiplying the RII value of adoption and the RII value of importance level as adopted from Noman et al. [16], who prioritized the communication modes based on RII values obtained by multiplying the RII value of occurrence with the RII value of effectiveness of the respective mode of communication. Table 2 displays the results of the practice prioritization.

Table 02. Relative importance index of identified practices

Practices		RII for Adoption	RII for Importance	RII for Adoption x RII for Importance
P1	The entire consent and permit process must undergo a cost-benefit analysis.	0.7	0.7	0.49
P2	It is necessary to evaluate how long the consent and permit processes take.	0.6	0.7	0.42
P3	Before moving forward with consents and permits, information and data must be established.	0.7	0.7	0.49
P4	Long-term projects must consider the political stability.	0.6	0.7	0.42
P5	Risk management needs to be done.	0.6	0.7	0.42
P6	It's important to secure funding sources.	0.7	0.7	0.49
P7	A payment method needs to be decided.	0.7	0.7	0.49

Practices		RII for Adoption	RII for Importance	RII for Adoption x RII for Importance
P8	Accurate estimates and mechanisms for cost control must be established.	0.7	0.7	0.49
P9	Connect improvement in performance to inherent financial motivation.	0.7	0.7	0.49
P10	Planning must be driven by construction.	0.7	0.7	0.49
P11	Define project objectives clearly.	0.7	0.7	0.49
P12	Project objectives must be in written form.	0.7	0.7	0.49
P13	Project goals must be acceptable to all parties.	0.7	0.7	0.49
P14	Set up a straightforward and efficient communication system.	0.7	0.7	0.49
P15	Client goals should be taken into account when choosing a specific contract type.	0.6	0.7	0.42
P16	Ensure timely selection of contract type.	0.7	0.7	0.49
P17	There should be a process in place for resolving conflicts.	0.7	0.7	0.49
P18	The specification must be carefully reviewed by the owner's, designers', and contractor's staff in order to streamline the field construction process.	0.7	0.7	0.49
P19	Eliminate all superfluous information from the contract document.	0.7	0.7	0.49
P20	The contract document must include quality assurance.	0.7	0.7	0.49
P21	The client and contractor should share the risk fairly.	0.7	0.7	0.49
P22	The client project management team must be under the direction of a strong leader.	0.7	0.7	0.49
P23	Team members must meet certain requirements.	0.7	0.7	0.49
P24	Teambuilding exercises must be implemented to promote cooperation and strategy.	0.7	0.7	0.49
P25	The client team must be independent of the parent organization.	0.7	0.7	0.49
P26	The project team must remain intact for the duration of the project.	0.7	0.7	0.49
P27	There must be unambiguous senior management support for each client and contractor team.	0.7	0.8	0.56
P28	Teams from clients and contractors must foster a culture of trust and cooperation.	0.7	0.7	0.49
P29	When the situation calls for it, learn about other cultures.	0.7	0.7	0.49
P30	Elements must standardize to make design and construction easier.	0.7	0.7	0.49

	Practices	**RII for Adoption**	**RII for Importance**	**RII for Adoption x RII for Importance**
P31	The site's design must take site efficiency into account.	0.7	0.8	0.56
P32	The constructability idea must be incorporated from the very beginning of design.	0.7	0.8	0.56
P33	Design must encourage easy access to labor, supplies, and machinery.	0.7	0.8	0.56
P34	Set up an organized system for tracking and handling materials.	0.7	0.7	0.49
P35	Before entering the site, all materials and equipment must be fully certified.	0.7	0.7	0.49
P36	Make use of nearby resources.	0.7	0.8	0.56
P37	Positive labor relations must be upheld during the construction phase.	0.7	0.7	0.49
P38	It is necessary to identify the raw material sources.	0.7	0.7	0.49
P39	Ensure that the resources are accessible.	0.8	0.7	0.56
P40	For a project, only invest in and set up a tried-and-true system.	0.7	0.7	0.49
P41	Ensure that materials are delivered on time and are of the appropriate quality and quantity.	0.7	0.8	0.56
P42	Make suppliers accept exact delivery schedules.	0.7	0.7	0.49
P43	Look for manufacturing and shipping issues that cause delivery deadlines to be missed.	0.7	0.7	0.49
P44	The goal of the detailed design must be a simplified design.	0.7	0.7	0.49
P45	The methods used in design must be standardized.	0.7	0.8	0.56
P46	The design must encourage effectiveness during construction and upkeep.	0.7	0.7	0.49
P47	When designing, a 3-D system must be used.	0.6	0.7	0.42
P48	For a specific project, continuity within the design team must be preserved.	0.7	0.7	0.49
P49	Construction-related factors must drive the design schedule.	0.7	0.7	0.49
P50	Priority must be given to the detail engineering of the main item with a lengthy delivery period.	0.7	0.7	0.49

From Table 01, it is identified that there are eight practices whose value is 0.56 and others are in between (0.42 to 0.56). The practices whose value is 0.56 is considered as most significant practices in conceptual phase which affect the productivity in the construction industry of Pakistan, separately shown in Table 02.

Table 02. Significant tasks and practices

Sr. No.	Tasks	Practices	Values
01	Project Management Team	There must be unambiguous senior management support for each client and contractor team.	0.56
02	Construction Philosophy	The site's design must take site efficiency into account.	0.56
03		The constructability idea must be incorporated from the very beginning of design.	0.56
04		Design must encourage easy access to labor, supplies, and machinery.	0.56
05		Make use of nearby resources.	0.56
06	A Procurement Plan	Ensure that the resources are accessible.	0.56
07		Ensure that materials are delivered on time and are of the appropriate quality and quantity.	0.56
08	Design of Permanent Structures	The methods used in design must be standardized.	0.56

From the above table 2 it is perceived that the task “Construction Philosophy” with four related practices is a most important task in conceptual phase followed by the task A Procurement Plan with related two practices. Project Management Team with one related practice and Design of Structures with one practice each are also important tasks and practices in the conceptual phase. Above-mentioned four tasks and eight practices have an importance index value same 0.56 which shows that all these tasks and practices have equal importance in the conceptual phase.

5. Conclusion

For the successful completion of the project, it is very important to give proper attention to every phase of the construction project. However, there is a lack of proper attention in the conceptual phase [3]. Thus, it is necessary to identify the tasks associated with the conceptual phase and evaluate their effects on construction productivity. To improve the productivity of construction sites, it is very important to give proper concentration to tasks and related best practices during the conceptual phase [9]. This research established that there are eight tasks and 50 related practices in the conceptual phase of construction projects. In the conceptual phase, the adoption and importance level of tasks and related practices that affect productivity were measured. The four tasks and eight practices mentioned above are extremely important in the conceptual phase, as they can help us improve construction productivity.

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Sustainable Material and Innovative Structures

ID 19: Effect of Industrial Waste on Mechanical and Durability Performance of Concrete

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A B S T R A C T

Production of concrete for the construction of structures like, buildings, highways and bridges requires huge amount of cement and aggregates. Consumption of large amount of cement not only affects the natural environment but also strength of concrete. On the other hand, due to heavy concrete production for construction industry causes depletion of natural resources like fine and coarse aggregate in future which motivates this study to be undertaken in order to utilize waste materials in concrete instead of aggregate and cement. This study investigates the properties of concrete by partially substituting fine aggregate with coal bottom ash (CBA) and cement with fly ash (FA). To achieve this objective, concrete was produced with OPC type-I cement, fine aggregate passing #16 sieve, coarse aggregate of size 10mm, CBA and FA locally available were used. An optimum dosage level of fly ash (15%) was selected from preliminary testing and used together with CBA at various dosage level ranging from 0-35% as fine aggregate replacement. Cubes and cylinders were cast and tested against compressive, tensile, carbonation and sulphate attack test at the end of required curing age. Findings of this study suggest that mechanical performance in terms of compressive and split tensile strength were significantly improved at 25% CBA level which is 52.32 MPa and 3.23 MPa respectively, but not higher than that of conventional concrete mix, it is because the CBA has porous nature and need extra amount of moisture for complete hydration which can be achieved with longer curing durations. Furthermore, the durability of concrete was also found to be improved in terms of carbonation and sulphate attack.

K E Y W O R D S:

Coal Bottom Ash (CBA), Fly Ash (FA), Mechanical properties, Durability Properties

1. Introduction

Because of ease in construction, better performance and high service life concrete is mostly preferred construction material now a days, it is also known as manmade rock due to its flexible nature in extreme weather conditions. On the other hand, high demand for concrete causes a scarcity of natural resources. It has also been observed from the literature that using a large amount of industrial waste and, environmental pollutions are the key issues that result in achieving a better solution of other are some of the factors that are responsible for obtaining new solutions for a sustainable development. The only way a sustainable development can be accomplished is if reserve capacity improves. The decrease in energy and material utilization makes it feasible to increase resource efficiency. The use of solid industrial wastes such fly ash, bottom ash, waste foundry sand, slag, silica fume, and waste glass in the production of concrete is the suggested solution. These concrete technologies' low costs, great durability capabilities, and environmental friendliness help to mitigate the negative consequences of the concrete industry's economic and environmental issues.

Many studies were conducted to determine the influence of CBA on the performance of concrete few of which are briefly discussed. As reported by Topcu et al. [1] that it is possible to produce durable geopolymer concrete by adding CBA as a replacement of sand without adding cement in concrete, they investigated various parameters to depict the performance of concrete at different curing ages. Another study conducted by Ghafoori and Bucholc [2], more sustainable and durable concrete can be obtained by using high-calcium coal bottom ash. It was observed that workability was increased when they added the coal bottom ash in place of sand in concrete for fixed slump. Furthermore, split tensile strength was found to be higher or equivalent when 50% of sand and 50% of CBA were used in the mix, they also suggested that it is observed that compressive strength was also found the be in the range of normal concrete mix and can be compared. In a study conducted by Aggarwal et al. [3] showed that that the obtained compressive strength of concrete when CBA was added was not higher than that of normal concrete but the observe smaller amount of decrease at higher curing ages mainly at 28 days of curing. Kim and Lee [4] found that while the modulus of elasticity of high strength concrete built with coal bottom ash as fine aggregate decreased dramatically, the strength parameters did not change appreciably. Additionally, the reduction in modulus of elasticity caused by the addition of coal bottom ash to concrete was validated by Andrade et al. (2009) [5]. Use of coal bottom ash as fine aggregate in concrete results in a reduction in abrasion resistance, according to published research by (Aramraks, 2006; Singh and Siddique, 2015) [6], [7]. Concrete's compressive strength increased when fly ash was utilized as the fine aggregate, but its abrasion resistance decreased (Siddique, 2003a,b) [8], [9]. According to Ghafoori and Bucholc (1997) [2], the use of water-reducing admixtures has a significant impact on the compressive strength and splitting tensile strength of concrete built using coal bottom ash as a partial replacement for sand.

Coal ash is a huge byproduct of thermal power facilities. This ash content is made up primarily of fly ash, with bottom ash making up around one-fifth. Because of its granular nature, bottom ash is occasionally used in place of sand in concrete. However, over the past few years, fly ash has become a popular cement substitute in concrete. Replacing cement with fly ash reduces the initial strength development since fly ash has a low calcium content. Therefore, up to 30% of cement is typically replaced in order to prevent such a negative effect. Fly ash is used much less frequently in the concrete industry overall because cement accounts for roughly 20% of the volume of concrete used in building and other construction projects. Fine aggregate, on the other hand, makes up 50-100% more of the concrete mix than cement and serves as an inert filler. As a result, if the goal is to maximize the utilization of waste materials such as coal ash, complete replacement of fine aggregate may be a better option.

It has been noted that while the replacement level of fly ash has increased, concrete consistency has also increased. In addition to strength development, fly ash is a pozzolanic material that contributes to the structures strength (Siddique 2003a) [8] and long-term corrosion resistance (Maslehuddine et al. 1989) [10] have also increased. Nevertheless, concrete with high replacement rate loses its workability and abrasion resistance (Siddique 2003b) [9]. Thus, it was concluded to set the highest level of replacement of fly ash up to 50% of the volume of fine aggregate. However, according to Bilir et al. (2015) [11], prior to modification of any property of sand mortar it can be suggested that fly ash can be substituted up to 60%–70% with sand in mortar preparation.

There have been a limited number of studies that have investigated the performance of concrete with CBA and FA, but very few have used both CBA and FA as replacements for sand and cement, respectively [12]. The experimental mix with 75% bottom ash and 20% fly ash improves compressive, flexural, and split tensile strength qualities, as well as drying shrinkage of concrete as stated by Rafieizonooz (2016) [13], exhibits improvements in compressive, flexural, and split tensile strength qualities as well as drying shrinkage of concrete. Furthermore, the resistance to sulphate and sulphuric acid increased when compared to the control concrete (Rafieizonooz 2017) [14]. This study was undertaken to use both CBA and FA in concrete to experimentally determine the mechanical and durability performance of concrete, which many researchers have not yet considered. Therefore, the objective of this study is dual fold. First objective was to investigate the mechanical performance of concrete using CBA (0-35) as a replacement of sand, combined with fly ash of optimum level of 15% as substitute of cement for mechanical performance density, compressive strength and split tensile strength test were conducted at the end of 7 and 28 days of water curing. Second one is to determine the durability properties of concrete with coal bottom ash and optimum level of fly ash as a partial replacement of sand and cement respectively by carbonation and sulphate attack test.

3. Research Methodology

3.1 Materials

Cement: Throughout this study, OPC (Ordinary Portland Cement) of Type-I complying with ASTM C150-05 (2005) and BS 12 (1991) was used. It was bought from the Nawabshah local market under the brand name "Lucky cement," which was made by "Lucky cement factories."

Sand: To achieve fine material that is accessible locally, a 4.75mm sieve was employed. Prior to being mixed with concrete, sand was also cleaned and dried to SSD.

Aggregate: In this study, concrete mass for experimental work was made with coarse aggregate that ranged in size from 10-15. For the purpose of sieving coarse aggregate, several standards mesh were also employed. The sieved aggregates were cleaned to remove any tackiness and then allowed to dry up for SSD (Saturated Surface Dry).

3.2 Dosage of coal bottom ash (CBA) and fly ash (FA)

The sand was replaced with CBA and cement was replaced by FA partially in percentage by weight of the total weight of cement/ binder. CBA samples were taken from the Lakhra coal power plant in the district of Jamshoro. Sieve No.4 was used to sieve coal bottom ash and, FA was bought from supplier located in Karachi, Pakistan. In all eight batches of the concrete are cast with different percentages of the CBA and FA dosage. The Table 1 present the details of the materials mix proportion along with dosage details of CBA and an optimum dosage of FA which is 15% as per DOE method of mix design.

Table 1: Mix details used in this study

Batch	Type	Cement (%)	FA (%)	CA (%)	CBA (%)	W/B
C	Control	100	100	100	---	**0.5**
FA-CB5	Fly Ash-Bottom Ash	100	95	100	5	**0.5**
FA-CB10	Fly Ash-Bottom Ash	100	90	100	10	**0.5**
FA-CB15	Fly Ash-Bottom Ash	100	85	100	15	**0.5**
FA-CB20	Fly Ash-Bottom Ash	100	80	100	20	**0.5**
FA-CB25	Fly Ash-Bottom Ash	100	75	100	25	**0.5**
FA-CB30	Fly Ash-Bottom Ash	100	70	100	30	**0.5**
FA-CB35	**Fly Ash-Bottom Ash**	**100**	**65**	**100**	**35**	**0.5**

3.3 Specimen Preparation

For determination of mechanical and durability performance cube cubes of $100mm \times 100mm \times 100mm$, for compressive strength of concrete and cylinders of $100mm \times 200mm$ for tensile strength of concrete were cast and tested. Prior to the ingredients being mixed, all the components, including water, cement, and sand, were weighed. The blending was done by hand. To guarantee consistent FA dispersion in the mix, the sand and binder (OPC and Fly ash) were first vigorously combined for around 3 to 5 minutes [15]. After that, water was gradually incorporated into the dry mixture, and mixing the concrete continued for about three minutes to produce a homogenous mixture. The precise specimens were cast in regular sizes. All the samples were taken out of the mould after 24 hours of casting. One day before testing, the specimens were taken out of the particular curing regime and thoroughly cleaned with dry cloths to remove any foreign particles that may have been present [15]. The specimens were examined for any type of deformation, including cracked and broken edges. The experiments were carried out in the structure's laboratory of QUEST's Nawabshah campus's Civil Engineering department.

3.4 Test Methods

Density: Following one day of casting and just before the stage of demolding, the densities of all the cylindrical specimens were also measured. It is computed by dividing the specimen's area by its weight as described in as per [16].

Compressive strength: One of the essential tests for evaluating the mechanical/physical behavior of concrete specimens is the compression strength test adopted as per [17] and the values were obtained using equation 1. After

28 days of water curing, the compressive strength of each specimen containing and bacteria FA and CBA was tested using the following equation, where f_{cu} is the compressive strength, P represent the highest load which the concrete specimen can carry during the test, and A is the area of the specimen.

$$\boldsymbol{f_{cu}} = \frac{\boldsymbol{P}}{\boldsymbol{A}} \quad (1)$$

Split tensile strength: After 28 days of water curing, the following equation was used to conduct tensile strength tests on all specimens, both with and without FA and CBA, using a universal testing machine (UTM) and a constant loading rate as per [18].

$$\boldsymbol{f_t} = \frac{\mathbf{2P}}{\boldsymbol{\pi}\mathbf{LD}} \quad (2)$$

Corrosion analysis: For the corrosion analysis test, cylindrical specimens measuring 100 200 mm were created. Each specimen had a 12 mm diameter, 300 mm long bar inserted in the center. The samples were immersed in water for 28 days after demolding. Following a 28-day curing period, the specimens were immersed for 14 days in a water tank containing a 3% NaCl solution. After 14 days, the samples were removed from the water tank and allowed to air dry. When this 90-day cycle of wet and air-dry curing was completed. ASTM C-876 was used to calculate the corrosion potential [19]. The corrosion potential of a specimen was calculated using the average of three specimens.

Sulphate attack: Concrete's sulphate resistance were determined by varying the lengths of prism specimens measuring 25 mm 25 mm 285 mm. These samples were created in accordance with ASTM C1012 [20]. The prisms were taken out of the mould prior to insert in water for curing up to 28 days in a sodium sulphate solution. The samples' lengths were measured once more. The length change was measured with a digital meter.

4. Results and Discussion

4.1 Density of Concrete

The Density is an important factor to be considered for strength and permeability. Density increase values due to use of different CBA dosage level is depicted in Figure 1 based on test results obtained in laboratory. From **Figure 1**, it may be noted that density of concrete goes on decreasing with the addition of CBA with optimum dosage of FA up to the dosage of 25% of total sand replacement level. The average density values were achieved as at 0.50 w/c ratio and without CBA content is found to be 2345 kg/m^3. It was observed that the density of normal mix is higher than that of the mixes containing the CBA. Maximum decrease was seen at 25% replacement of CBA with sand which is found to be 5 % when compared with normal mix concrete. Because CBA fine aggregate has a higher porosity than natural fine aggregate, the unit weight of the CBA concrete was reduced.

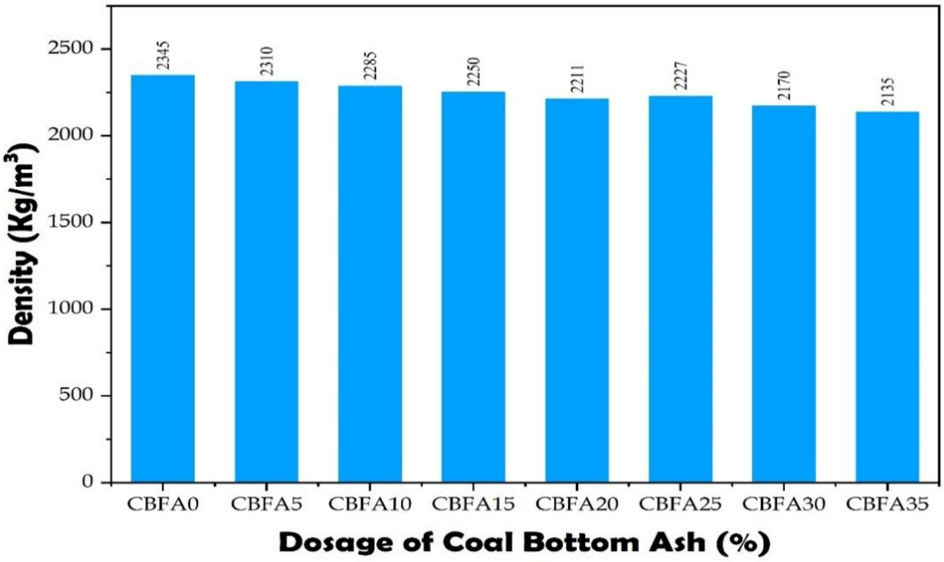

Fig. 1: Density of concrete mix with and without CBA+FA

4.2 Compressive Strength

Figure 2 shows the results of the CBA concrete's compressive strength test under the two different curing durations. Overall, the CBA component had a minor impact on the compressive strength of the CBA concrete. As the CBA content grew from 0% to 35%, the compressive strengths of all the specimens under water curing was slightly decreased. Normal mix concrete shows compressive strength of 55.44 MPa and 38.33 MPa at 28 and 7 days respectively which is slightly higher than that of mix containing the CBA and FA. Rafieizonooz et al. [13] also showed a modest decline in compressive strength.

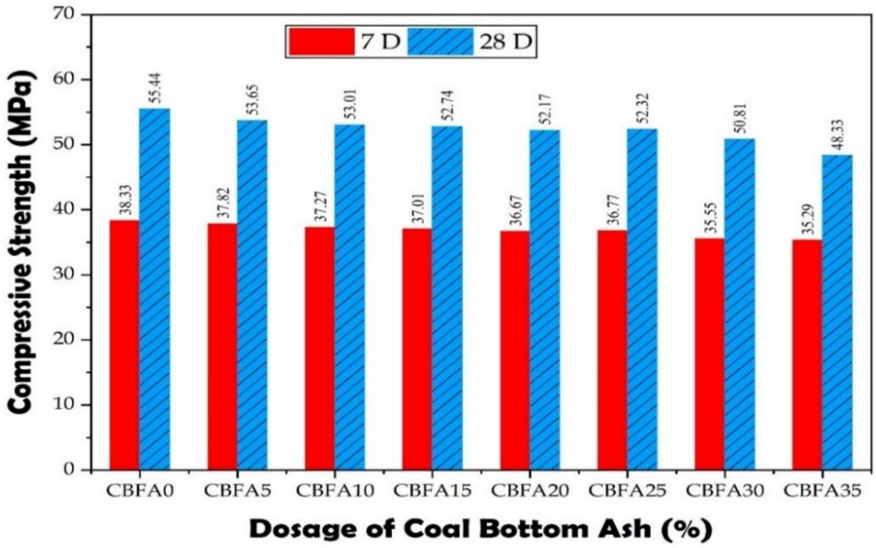

Fig. 2: Compressive strength of concrete mix with and without CBA+FA

Furthermore, Cheriaf et al study [21] demonstrated that CBA's pozzolanic reaction accelerated noticeably at a curing age of more than 28 days and that the pozzolanic reaction's increase in compressive strength would partially offset the compression strength decline in concrete containing CBA as a replacement for fine aggregate. The compressive strengths of the FA-CB25% specifically dropped by 5.6% at the end of 28 days water curing.

The specimen's drying circumstances had a considerable impact on the compressive strength. The compressive strength of the concrete specimens at various CBA contents was decreased. Maximum decrease was found to be 5.6. According to Hager's study [22], hydrated calcium silicate (C-S-H gel) dehydrates at 105°C, which inflicts some structural damage on cement paste. The compressive strength of the CBA concrete could be affected by this phenomena. In addition, when the temperature rose, water evaporated from the concrete, increasing its porosity. Additionally, the compressive strength of the CBA concrete was reduced as a result.

4.3 Split Tensile Strength

Figure 3 depicts the splitting tensile strength of CBA concrete at 7 and 28 days after curing for both SSD and oven-dried conditions. The results of the tests revealed that as the CBA concentration increased, the splitting tensile strengths of the CBA concrete decreased significantly. When comparing CBFA20 and CBFA25 specimens to normal mix concrete, the splitting tensile strengths decrease by 3.1 and 2.7%, respectively, as the CBA level increases from 0% to 35%.

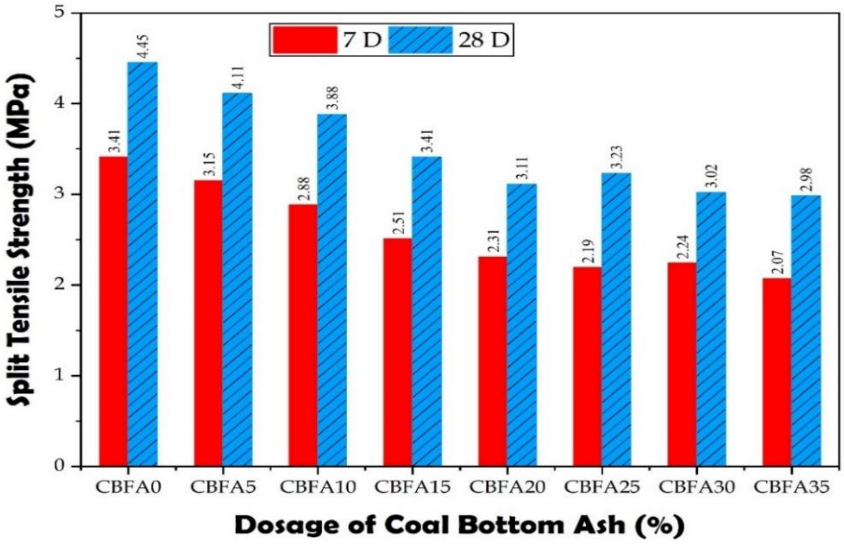

Fig. 3: Split tensile strength of concrete mix with and without CBA+FA

However, in Singh and Siddique's investigation [7], the combination with a 25% CBA content demonstrated the highest splitting tensile strength; however, at a curing age of 28 days, a steady decline in splitting tensile strength was observed. Because CBA particles are less dense and have a more porous structure than natural fine aggregate particles, the CBA density is lower. Furthermore, due to the porous structure of the CBA particles, internal fissures form quickly when load is applied to CBA concrete.

4.4 Corrosion Analysis

It is a proven fact that the chloride inclusion in concrete causes steel corrosion, which has a significant impact on RCC constructions. According to the findings of this investigation and other related studies [23–27], the addition of FA and CBA resists chloride penetration inside the concrete matrix and increases internal resistance in concrete. Figure 4 shows that as the CBA percentage increased, so did the resistance to chloride ions. Mixing CM with 15% FA and 0 CBA yields -290 mV, while mixing M7 with 15% FA and 35% CBA yields -197 mV.

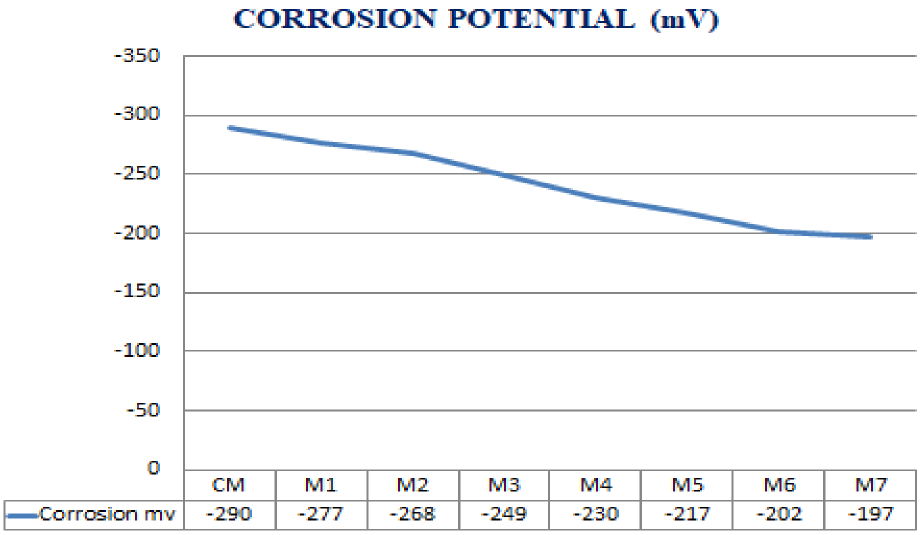

Fig. 4: Corrosion Potential mV

The findings made it very evident that concrete corrosion resistance can be greatly improved by the use of fly ash and coal bottom ash. Singh and Siddique [27] Bottom ash is more resistant to chloride-ion penetration as. Halit Yazici [28] investigated whether using fly ash and silica fume in self-compacted concrete increased resistance to chloride-ion penetration. Kou and Poon [29] discovered that using CBA in concrete increases resistance to chloride ion penetration. Furthermore, Detwiler et al. [30] investigated the effect of various supplementary cementitious materials on the chloride resistance of cured concrete. These studies back up the findings of the current study. All of these by-products outperform the standard concrete mix in terms of performance and improve the concrete's durability.

4.5 Sulphate Attack

The use of fly ash and coal bottom ash in the concrete matrix provides excellent resistance to sulphate attack. According to **Table 2**, as the percentage of CBA in the mix increases, so does the resistance to sulphate attack. Samples were immersed in a Na_2SO_4 solution for the sulphate resistance test. The length change of each sample was measured with a digital meter. It can be seen that after Na_2SO_4 exposure, CM with 15% F. A 0% CBA yields a 0.56% increase, while combining M7 with 15% FA and 35% CBA yields a 0.18% increase. The majority of the researchers have described the same pattern. Using CBA in concrete, according to Sajjad et al. [31], reduces the negative effects of sulphate and chloride in concrete.

Table 2: Sulphate Attack of 28-Days in sodium sulphate solution (Na2So4).

Mix	%	Initial Length (mm)	Final Length (mm)	% Increment
CM	CM0%	285.3 ± 0.04	286.9± 0.03	0.56
M1	FA-CB5	285.0 ± 0.01	286.2± 0.03	0.42
M2	FA-CB10	285.3 ± 0.02	286.3± 0.03	0.35
M3	FA-CB15	285.2 ± 0.02	286.1± 0.03	0.32
M4	FA-CB20	285.4 ± 0.03	286.2 ± 0.03	0.28
M5	FA-CB25	285.5 ± 0.04	286.2 ± 0.03	0.25
M6	FA-CB30	285.3 ± 0.03	286.9 ± 0.03	0.21
M7	FA-CB35	285.5 ± 0.04	286 ± 0.03	0.18

Mangat and Khatib [32] conducted research showing the influence of silica fume on durability properties of concrete and suggested that an optimum dosage of 5-15% of silica fume as a cement substitute improved concrete sulphate resistance. Ghafoori and Cai [33], [34] also depicted the same effect of bottom ash in concrete. Based on their findings, bottom ash provides good resistance to sulphate attack.

5. Conclusion

The following conclusions can be drawn from the current study:

1. From preliminary testing, an ideal dosage level of fly ash (15%) was considered and employed in combination with CBA at several dosage levels ranging from 0 to 35% as a replacement for fine aggregate.
2. According to the current study, mechanical performance (compressive strength and tensile) goes on decreasing i.e., a maximum decrease of 12. 8% in case of compressive strength & 33% decrease in case of split tensile strength were observed at 28 days of curing, further, it was noticed that both compressive and tensile strength values are almost equivalent to normal mix concrete. That might be due to the porous nature of the CBA particles which causes internal cracks to form quickly when load is applied to CBA concrete. But because of highly porous nature, concrete needs much amount of water for hydration process which generates the crystalline products and tends to increase the strength.
3. The study also found that if a longer curing duration is used, the strength increment can be significant and higher than that of normal mix concrete. This is because CBA has a porous nature, and a longer curing duration reduces internal cracking by allowing enough gel to form inside the concrete mass, making the concrete surface compact and strong, allowing for higher compressive and tensile strengths.
4. Additionally, it was discovered that concrete was more resistant to sulphate and carbonation attack.

5. Acknowledgment

Authors are thankful to our whole team for making this work possible. The authors are thankful to Almighty Allah, who is ever graceful on us.

6. Reference

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ID 21: Effect of Magnetically Treated Water on Workability and Compressive Strength of Concrete.

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A B S T R A C T

Concrete is one of the major constituents in the construction industry throughout the world. Different methods and materials have been used to enhance its properties like workability and compressive strength. In order to enhance the properties of concrete, magnetized water in concrete is used in this research to improve the workability and compressive strength of concrete. Also, this magnetically treated water reduces the need of cement content required for the specified compressive strength value. When water is exposed to the magnet of different intensities showing improvement in workability and compressive strength compared to conventional concrete. Five different concrete mixtures were made in total, four of which used magnetized water and one of which used ordinary tap water. The 0.8, 1.4, 2.0, and 2.4 tesla strengths of the permanent magnets utilized to create the magnetic water were tested. The results of tests on the slump, compressive strength, density, and water absorption for all five mixes showed that the production of concrete with magnetically treated water resulted in enhanced compressive strength and improved workability. Furthermore, concrete was found to be denser and less water absorbent when above mentioned magnetic intensity levels were used.

K E Y W O R D S:

Magnetically Treated Water, Compressive Strength, workability.

1. Introduction

The most significant and widely utilized building material is concrete. The majority of researchers are working to increase the workability and compressive strength of concrete using a variety of techniques, including the use of a variety of chemical and mineral additives, both of which are expensive. One of the most efficient and cutting-edge solutions for improving the compressive strength and workability of concrete [1-3] is the use of magnetized water rather than tap water. Hydrogen bonds between polar water molecules that are attracted to one another cause clusters or groups of molecules to form [4]. Due to the magnetic treatment of water, large clusters of water molecules are broken up and reorganized into smaller groups, which makes it easier for water molecules to penetrate cement grains (Fig. 1) and increase workability, compressive strength, and concrete durability [5-7].

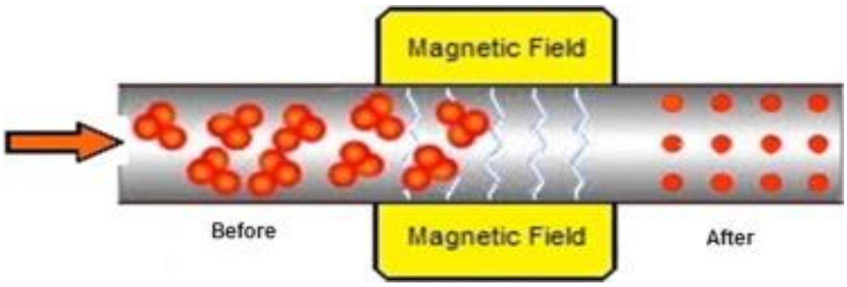

Figure 1: Mechanism of water molecules before and after the magnetization of water

There hasn't been much research done on how magnetized water affects the mechanical and physical properties of concrete. Soto Bernal et al. [9] examined the effect of magnetic fields on the physicochemical, microstructural, and mechanical properties of concrete after the cement paste had been mixed and three distinct magnetic additive forces had been matched to the environmental variables. In this test, the hydration rate, setting time, and greater heat of hydration were all sped up in comparison to the non-magnetic water samples since the moist samples were cured in wet conditions by producing a magnetic field in a tube while the concrete was being pumped on the spot, Myoung S. Choi et, al. [10] observed the effect of electromagnetic field intrusion on the establishment of the lubricating layer in concrete pumping. According to the tests on the pumping networks with initial dimensions of 12.5 cm in diameter and 1,000 m in length, the approach enhanced concrete pumping performance by improving the qualities of the lubricant layer between the pipe wall and the concrete interface. The thickness of the coating was measured using an ultrasonic velocity profiler [10]. H. Afshin et, al. [11] used magnetic water in concrete mixtures to improve the performance of high-mechanical concrete in their test inquiry. When consistently flowing water was transported through a magnetic field, the surface tension decreased and the number of water groups decreased from 13 to 5 or 6. The results were much improved when magnetised water and around 450 kg of cement were applied for 15 minutes at a rate of 2,261 litres per minute at room temperature. Concrete's workability and compressive strength can be improved using magnetised water, and the amount of cement required to achieve the desired compressive strength value can be decreased [11]. Using magnetic water, Adnan Flayeh Hassan [13] evaluated how cement mortar cubes affected the initial and final setting times, consistency, and compressive strength after 1 and 7 days, respectively. It has been proven that using magnetic water to make cement mortars can decrease the initial and final setting times while improving the compressive strength of the concrete. The best water-to-cement ratio, based on the results of this research study is 0.45, which requires less water to complete the hydration process than is often used on construction sites [13]. Sadam M. Ahmed [14] investigated the effects of magnetically treated water on the compressive strength and workability of concrete using a 1.2 T magnetic intensity and a 0.71 m/sec water velocity. He discovered that fresh concrete had 15-20% greater workability and compressive strength than usual concrete created with ordinary tap water [14].

3. Research Methodology

3.1 Materials

Cement, water (Tap v/s magnetized water), fine sand and coarse aggregates were obtained from Bolhari plant in area of Jamshoro Sindh Pakistan.

3.1.1. Cement

In this study, Type I Portland cement that complied with ASTM Type 1 standards and was provided by the Lucky Cement Factory in Karachi, Sindh, was utilized.

3.1.2. Aggregates

In this research study, sand from bholari crush plant was utilized having size smaller than 4.75mm having specific gravity 2.68 and coarse aggregates had been utilized were from the same plant with a maximum size of 20 mm having specific gravity 2.98.

3.1.4. Water Used in Concrete Mixes

Tap water and magnetized water were the two types of water used in this investigation. Tap water was passed through permanent magnets with strengths of 0.8, 1.4, 2.0, and 2.6 tesla to create magnetized water at a steady rate of 28 ml/sec.

3.2. Concrete Mix Design

The fresh and hardened characteristics of concrete were examined in this research investigation using five different mixtures. For this, a control mix with a target strength of 25 MPa was developed. Portland Cement (ASTM TYPE 1) was used in each batch. The maximum particle size of coarse aggregate is 20 mm, its specific gravity is 2.66, and its unit weight is 1395 kg/m3. For each mix, a constant water to cement ratio of 0.49 was utilised. Tap water was subjected to magnetic fields of strengths of (0.8, 1.4, 2.0, and 2.6) tesla, produced by permanent magnets, at a constant flow rate of 28 ml/second, to produce magnetized water. The constituents of concrete mixes are shown in Table.1, along with the magnetic field strengths applied for concrete made from magnetized water.

Table 1 Magnetic intensity used in water

S.NO.	Mix	Constituents in (kg/m^3)				Magnetic intensities used in water	W/C Ratio
		Cement	F.A	C.A	Water		
1	CM	370	664	1085	182	0	0.49
2	MI(0.8)	370	664	1085	182	0.8	0.49
3	MI(1.4)	370	664	1085	182	1.4	0.49
4	MI(2.0)	370	664	1085	182	2.0	0.49
5	MI(2.4)	370	664	1085	182	2.6	0.49

3.2.1 Sample Preparation and Testing Procedures

To ensure accuracy, all materials required for the experimental study were prepared, weighted, and checked. In order to meet the parameters, the fineness of fine and coarse aggregates was evaluated. To ensure that all aggregate types are functional, the basic weights were checked and a sieve analysis was performed to ensure that they met both fine and coarse aggregate requirements. For mixing and curing, drinking water was used. At a rate of 28 ml/sec, permanent magnets were used to magnetize the water. The slump test was performed and evaluated immediately after mixing in accordance with BS EN 12350-2 [17]. Compressive strength testing was performed on five mixtures in accordance with BS EN 1390-3 [18] and results were recorded after 3, 7, and 28 days.

3.3 Magnetic Intensities

Magnetized water produce was used in the concrete mixes. In order to enhance the intensity for various mixes, hollow-shaped magnets were utilized in this investigation. These magnets were joined as one unit by opposite poles and positioned outside the pipe's diameter. Magnets were used in order of 2, 4, 6 and 8 for MI1, 2, 3 and 4 respectively. After mixing the concrete in the concrete mixer, a slump test according to BS EN 12350-2 [17] was performed on the concrete mixture. A total of 45 cubes were cast, and compressive strength tests were performed after 3, 7, and 28 days.

3.3.1 Sample Testing Procedures.

To ensure quality, all materials needed for the experiment were prepared, checked, and weighted. The unit weight and absorption were determined to meet the fine and coarse aggregate criteria, and a sieve analysis test was performed to ensure that all aggregate forms were properly graded. According to WHO guidelines, the water used for mixing and curing was drinkable. Water was magnetized and connected to the pipe connecting the water tank using permanent magnets with a hollow circular shape of the same diameter. The slump test was performed on all five mixtures in accordance with BS EN 12350-2 [17] and was assessed immediately after mixing. Compressive strength tests were performed on 3 days, 7 days, and 28 days.

4. Results and Discussion

4.1. Effect on Workability of concrete

The fresh property of concrete (i.e. workability) was tested using both magnetized and normal drinking water. Magnetized slump levels for MI(0.8) and MI(1.4) produced with magnetized water of intensities 0.8 and 1.4 tesla were higher than non-magnetized concrete (CM). But a noticeable difference can be observed in the MI(2.0) and MI(2.4) mixes whose slumps has decreased drastically due to the reason that up-to certain limit (i.e. 1.4 tesla intensity of magnet) the properties of water are improvised as the angle between the hydrogen molecules in water decrease causing the water clusters to break into smaller, but after a certain limit of magnetic intensity the chemical properties of water completely change and it becomes acidic somehow and hence when it reacts with cement causes it to be less workable compared to the other mixes same as any other admixture or additive in concrete enhances its properties when used up-to a certain limit. The effect of magnetized water in different mixes of concrete can be seen in Table 2 as well as the Fig. 4 and Fig. 5

Table 2. Slump test Results

S. NO.	CONCRETE MIX	SLUMP(mm)
1	CM	45mm
2	MI(0.8)	60mm
3	MI(1.4)	70mm
4	MI(2.0)	55mm
5	MI(2.4)	25mm

Figure 2: Slump test

Combined permanent magnets with opposite poles in counts 2, 4, 6, and 8 to influence water molecules moving through their magnetic field have been used in this research paper. The size of the water molecules within a cluster are reduced by a magnetic field, which has a significant impact on water molecular clusters (see Figure 6.2 below). This decrease in molecules occurs as the magnetic field strength increases, causing additional involvement of water molecules in the cement hydration reaction [18, 19]. When water and cement combine, clusters of water molecules form around the cement particles. The water layer around the cement base is thinner in the case of magnetized water compared to the normal drinking water whose clusters are larger in size.

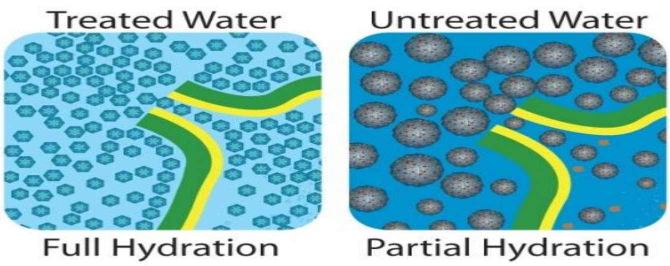

Figure 3: Effect of Magnetization on water molecules

The slump values of control mix were compared with the concrete mixes made with magnetically treated water. The increase in slump was observed when magnetized water was used with the same w/c ratio. This might be the result of the combination of magnets with opposing poles, which and affected water molecules passing through the magnetic field of the magnets. The size of the water molecules within a cluster are reduced by a magnetic field, which has a substantial impact on water molecular clusters (Figure 5). As the magnetic field intensity increases, the number of molecules decreases, which causes more water molecules to be involved in the cement hydration reaction [15, 16].

4.2. Effect on Compressive Strength of concrete.

The compressive strength values at 3, 7 and 28 days respectively and the magnetic concrete strength variance percentage as opposed to non- magnetic concrete are shown in Figure 6 and Table 3.

Table 3: Compressive strength Results on various ages

Mix ID	Compressive Strength at various days (MPa)		
	3 days	7 days	28 days
CM	30.75	32.1	41.63
MI(0.8)	33.35	36.93	43.57
MI(1.4)	35.72	38.78	46.54
MI(2.0)	23.42	25.43	34.22
MI(2.4)	22.29	23.89	28.18

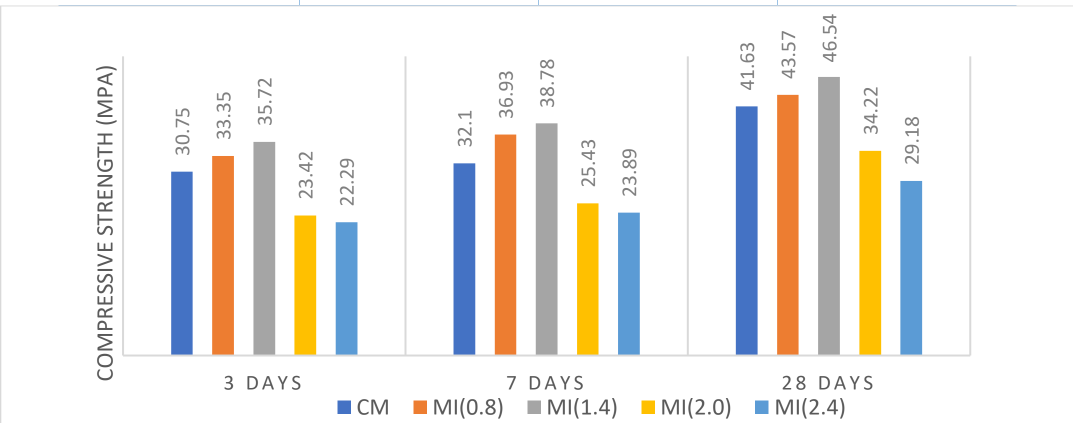

Figure 4: Compressive strength results on various ages

Results for compressive strength indicate that, when compared to concrete mixes created with regular tap water, those made with magnetised water had greater compressive strengths. When compared to conventional concrete, it was shown that magnets with intensities of 0.8 and 1.4 tesla produced better outcomes. However, the results only improved up to the optimal level of magnetic strength; mixtures with greater magnetization intensities (i.e. 2 and 2.6 tesla) did not do so. This is due to the fact that water molecules are polar and are drawn to one another by molecular groups or clusters that have formed hydrogen bonds [4]. As shown in Fig. 1, magnetic water treatment breaks down and reorganizes water molecule clusters into smaller groups, which facilitates water penetration into cement grains and results in efficient hydration that increases concrete's workability, compressive strength, tensile strength, bending strength, and durability [7].

4.3. Density of Concrete

Figure 5 illustrates the effect of magnetic water on concrete density. When magnetized water was used with the same w/c ratio, concrete density improved. The results show that using magnetized water in the concrete improves the density to some extent. According to results the density of MI(0.8) and MI(1.4) has improved when compared to conventional concrete, but the density of MI(2.0) and MI(2.6) has decreased because highly magnetized water loses its properties and reacts negatively with the cement, causing a decrease in density.

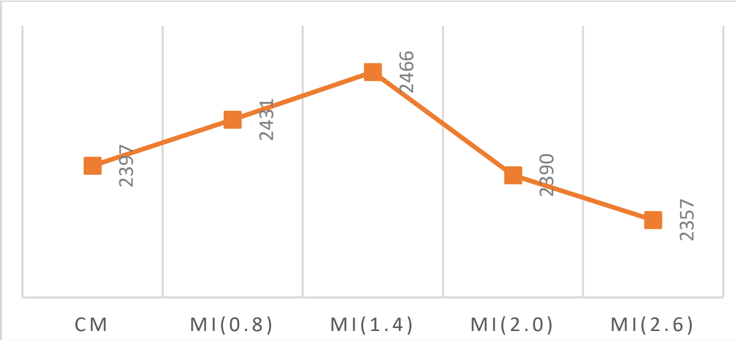

Figure 5: Variation in density of concrete due to magnetization of water

4.4. Water Absorption of Concrete.

The impact of magnetized water on the rate of water absorption of concrete is illustrated in Figure 8. When using magnetised water instead of regular tap water, reduced rate of water absorption was observed for the same w/c ratio. The results show that, using magnetised water in concrete improves its ability to absorb water to some extent. Fig. 8 clearly shows that, in comparison to conventional concrete, the rate of water absorption in MI(0.8) and MI(1.4) has decreased [11]. This is because the larger molecular clusters break down into smaller ones that can more easily penetrate within cement particles, leaving very few air voids, reducing the amount of water that may enter the structure during the curing process and making it less porous. MT(1.4), which cost 11.8% less than traditional concrete, produced the best results.

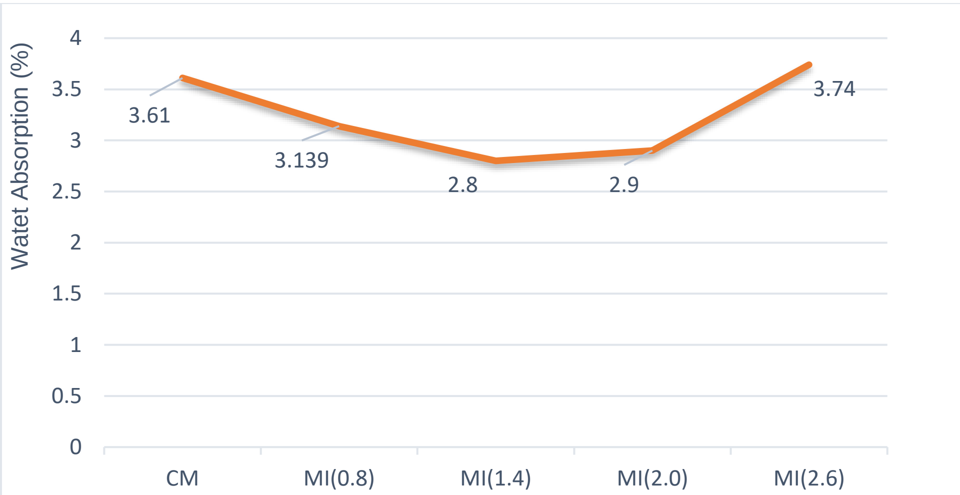

Figure 6: Rate of water absorption

5. Conclusion

Based on the experimental results, the following conclusions were reached:

By using magnetized water, workability was increased for MI(0.8) and MI(1.4) by 4.66 percent and 11.79 percent respectively, and slump was decreased for MI(2.0) by 17.8 percent and 32.26 percent. Slump values show that the use of magnetized water with intensities of 0.8 and 1.4 tesla improved concrete workability due to the complete hydration process of cement and lower surface tension due to broken water clusters after magnetization of water.

The compressive strength data demonstrates that the concrete mix produced using magnetised water has enhanced compressive strength when compared to the concrete mix produced with regular tap water. The MI(1.4) made with magnetized water generated by 1.4 Tesla magnetic intensity of magnets offered the highest results, 11.8 percent better than that of ordinary concrete during a 28-day period.

1. By using magnetized water, water absorption rate of concrete decreased for MI(0.8) and MI(1.4) by 13.04 percent and 22.43 percent respectively, but with more higher intensity of magnetization to water increased the water absorption rate of concrete. The best results were obtained from MI(1.4) prepared with magnetized water produced by 1.4 Tesla magnetic intensity, which was 22.43 percent greater than that of conventional concrete.
2. By using magnetized water, density of concrete increased for MI(0.8) and MI(1.4) by 1.42 percent and 2.88 percent respectively, but with more higher intensity of magnetization to water decreased the density of concrete gradually. The best results were obtained from MI(1.4) prepared with magnetized water produced by 1.4 Tesla magnetic intensity, which was 2.88 percent greater than that of conventional concrete.

5. Acknowledgment

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ID 37: Properties of Concrete Incorporating Recycled Aggregates: A Sustainable Approach

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A B S T R A C T

Sustainable construction goal is to protect the environment and is being widely adapted. This study investigated the performance of concrete cubes prepared with recycled concrete aggregate that are obtained from the concrete research institutions. The samples are prepared with normal aggregates concrete (NAC) and recycled aggregates concrete (RAC) at multiple water-cement ratios of 0.5, 0.6 and 0.7. The RAC cubes were made using 100% of recycled aggregates. The maximum compressive strength achieved for NAC cubes was 24MPa for a mix proportion of 1:2:4 at 0.5 w/c ratio, whereas for RAC cubes it was 13.2MPa for the same mix proportion but at a higher w/c ratio. Based on the comparison of compressive strengths of NAC and RAC, it was concluded that recycle aggregates have the potential to replace the normal aggregates if prepared at higher water cement ratios.

K E Y W O R D S:

Recycled Aggregate, Tested Aggregate, Compressive Strength.

1. Introduction

Globally, the demand of aggregates has increased up to 26.8 billion tons per year [1]. The rapid use of natural aggregates is a universal matter of concern; thus intense pressure is coming on the construction industry to propose a sustainable solution without compromising the performance of concrete. A large quantity of construction waste is generated by demolishing the structures or the damage caused to material while manufacturing. This waste mostly ends up being discarded in landfills. The use of waste concrete as recycled aggregates in new concrete is beneficial from the view point of sustainability and resources reservation. In this regard, the study for the utilization of various recycled building materials is promoted.

The main difference between conventional concrete and recycled concrete is the presence of adhered mortar to the recycled aggregates. In this manner, the recycled concrete has two interfaces. One is the interface between adhered mortar and the original aggregate and the new interface between the new mortar and the recycled aggregate.

2. Literature Review

A large number of experimental studies have been carried out in recent times to explore the procedures, uses and properties of recycling of construction waste and recycled material. In past many researchers have investigated the effect of recycled coarse aggregate on concrete compressive strength.

Sobuz et. al. (2022) carried out a study for the size and concentration effect of RCA on the production of high strength concrete. In this study, eight concrete mixes were produced with varying RCA concentration at an interval of 15%. They concluded that all the mixes have satisfactory slump, which led to high workability of concrete. It was also noted that high workability and density of the mixes reduced with an increasing concentration of RCA replacement level. Furthermore, it was noted that the decrease in split-tensile strength of the RAC with the increase of the RCA concentration was relatively smaller than compressive strength. The sustainability assessment shows that RAC is a low cost and environment friendly for concrete production with better strength [2].

Wang et. al. (2011) carried out an experimental study to investigate the effect of recycled coarse aggregate on concrete compressive strength. The experiment was carried out with 30 concrete mix proportions to achieve the compressive strength in the range of 20 to 60 MPa. The cubes were casted from natural coarse aggregate concrete as well as recycled coarse aggregate concrete. The 28-days results show that the concrete strength is affected by the strength of different types of recycled aggregates used. The effect of type of aggregate was more obvious for high strength concrete as compared to normal weight concrete [3]. Another experimental study undertaken by Khan et. al. (2018) used a concrete mix of 1:2:4 using water-cement ratio of 0.4 and 0.5 and varying percentages of recycled coarse aggregate [4]. A study carried out by Thomas J. et. al. (2018) claims that the replacement ratio of aggregates had significant effect on the strength of concrete. Replacement of up to 25% of natural aggregates with coarse aggregates does not result in any impact on strength. However, replacement of aggregate beyond 25% affects the strength properties of concrete [7].

Azzawi (2016) tested recycle aggregate concrete made from crushed tile and concluded that the tensile strength, compressive strength and elastic modulus are affected with the use of recycled aggregate replacing more than 25% of natural coarse aggregate [5]. Xiao J. et. al. (2022) evaluated the structural engineering applications of recycled aggregate concrete in terms of its seismic performance. The study concluded that the seismic performance of a properly design RAC structure is similar to that of NAC. So, the use of recycled aggregate concrete is theoretically and practically adaptable due to its acceptable seismic performance. The use of RAC will also benefit to reduce the overall cost of the project and provide environmental advantages as well [6].

An experimental study carried out by Arezoumandi et. al. (2015) for finding out the effect of 100% replacement of natural aggregate with recycled aggregate on the flexural strength of reinforced concrete beams. It was found that recycled concrete aggregate beams have comparable ultimate flexural strength and approximately 13% higher deflection corresponding to the ultimate flexural strength of the natural aggregate beams [8]. Yang et. al. (2020) studied the behaviour of recycled aggregate concrete on the flexural behaviour of concrete beams. In their study they have replaced the natural aggregate with 30%, 50% and 100% recycled aggregate. The study concluded that the crack pattern of RCA beams was similar to that of NCA beams, however, the RCA beams showed smaller crack spacing. The flexural strength was slightly affected by the recycled aggregate content [9].

The effects of recycled aggregate on concrete mix were studied by Nakhi et. al. (2019). In this study, concrete was made using different percentages of concrete (0 – 100%, with increments of 10%). The samples were also exposed to sea water with 3% chloride concentration and tested after 2 and 4 weeks of exposure. The results showed that the density and air content of new concrete decreased with an increase in recycled aggregate content, up to 40% of recycled aggregate concrete showed the best strength [10].

3. Research Methodology

3.1 Preliminary Tests for Aggregates

This study targets the comparison of compressive strength of concrete made with natural coarse aggregate and recycled coarse aggregate with varying water-cement ratio of 0.50, 0.60 and 0.70 at different mix proportions i.e. 1:2:4 and 1:4:8. To examine the behaviour of recycle aggregate concrete (RAC), following tests were conducted to observe the characteristics of aggregates, both natural and recycled, before using it in concrete:

(a) Water-absorption test

(b) Apparent specific gravity

(c) SSD specific gravity

(d) Bulk specific gravity

The detailed results of preliminary tests are shown below in Fig. 1. ASTM 127-93 prescribes the procedure to measure and calculate the water absorption, apparent specific gravity and bulk density. As summarized in the standard, the procedure is followed as a sample of aggregate is washed, drained and placed in a wire basket and immersed in water for 24 hours. The sample is weighed while submerged in water. The aggregate is then removed from water after 24 hours and transferred to an absorbent cloth to surface dry. This surface dried sample is then weighed. After that, the sample is placed in oven to dry and then weighed after 24 hours. With the relationships of mass and weight the specific gravity and absorption are calculated [6].

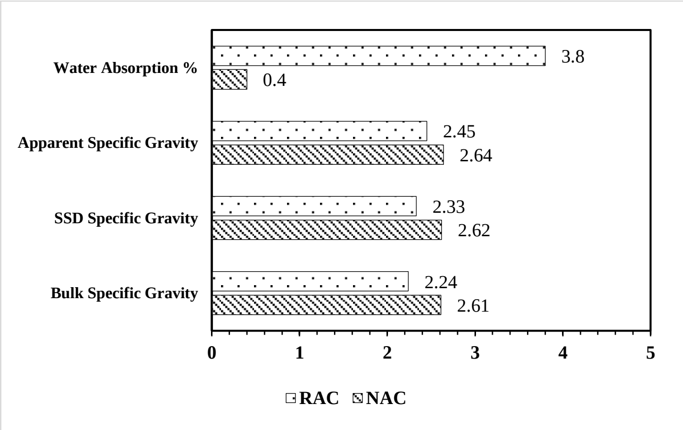

Fig. 1: Different test results for NCA and RCA

The specific gravity for natural aggregates ranges from 2.5 to 3.0 and for recycled aggregates it ranges from 2.3 to 2.6. The water absorption capacity for natural aggregates is 0.1% to 2.0% and for recycled aggregates it is 3% to 12%. It was noted that recycled aggregate showed higher water absorption capacity as compared to natural aggregate but it lies within the range specified for recycled aggregate. The apparent specific gravity, SSD specific gravity and bulk specific gravity tend to decrease for the recycled aggregate as compared to the natural aggregate.

3.2 Concrete Mix

The concrete mix design is the critical parameter in the success of the recycle aggregate concrete. The calculation of the mix design consists of ordinary Portland cement, coarse aggregate, fine aggregate and water. The Ordinary Portland cement (Type I) used in this study conforms to BS-EN 197-1:2000 and its chemical composition and physical properties are shown below in Table 1. In order to look for the suitable application of recycled aggregate concrete, the mixes were selected which can be used for structural elements and non-structural elements. Therefore, pre-defined mix design ratios were used in this study. Two kinds of concrete mixes were used i.e. 1:2:4 at water-cement ratio 50%, 60% and 70% whereas the concrete mix of ratio 1:4:8 with the water-cement ratio 70% was used. Trial concrete mixes were carried out at 50% and 60% at 1:4:8 concrete ratio but were not suitable as concrete started to crumble and adequate mixing was not possible.

Table 1: Chemical composition and physical properties of OPC used (Manufacturer's specifications, only MgO and SO_3 specification available)

Chemical Composition of OPC		**Physical Properties**	
MgO	1.50	Fineness (cm^2/gm)	2800
SO_3	2.50	Initial setting time(min)	120
Insoluble residue I.R.	0.30	Final setting time (hrs)	3.25
Loss on ignition L.O.I.	1.65	Soundness (mm)	0.50
Lime Saturation Factor L.S.F.	0.91	Compressive strength 28-d (N/mm^2)	45.0

The ratio of concrete mix remained same for both natural coarse aggregate (NCA) and recycled coarse aggregate (RCA). The casting of RAC cubes is carried out by 100% replacement of natural aggregate. The fine aggregate passed through #4 sieve and the fineness modulus of 2.8 was calculated. Whereas, natural coarse aggregate was used with maximum size of 10 mm. The recycled aggregates were fetched from the debris located at the reinforced concrete lab at Sir Syed University of Engineering and Technology, Karachi. The left-over aggregates are around one to two years old. Before using the recycled aggregate, the aggregates were crushed into approximate 10 mm size and were allowed to sieve through 19 mm and retained at 9.5 mm. The detail of the concrete mixes is shown in Table 2 and Table 3.

Table 2: Mix proportion at 1:2:4

Type of aggregate (concrete ratio)	Mix Proportions (kg)			Water/ cement ratio
	Cement	Fine aggregate	Coarse aggregate	
NAC (1:2:4)	1.34	2.68	5.36	0.50
	1.34	2.68	5.36	0.60
	1.34	2.68	5.36	0.70
RAC (1:2:4)	1.34	2.68	5.36	0.50
	1.34	2.68	5.36	0.60
	1.34	2.68	5.36	0.70

Table 3: Mix proportion at 1:4:8

Type of aggregate (concrete ratio)	Mix Proportions (kg)			Water/ cement ratio
	Cement	Fine aggregate	Coarse aggregate	
NAC (1:4:8)	0.725	2.90	5.80	0.70
RAC (1:4:8)	0.725	2.90	5.80	0.70

3.3 Workability Test

The workability of the freshly made concrete of all the mixes was also tested according to ASTM C143-90a. The slump test was used in order to test the consistency and adequacy of w/c ratio of the concrete mixes. The results indicated low workability for all the concrete mixes which was suitable for road construction. The test results are shown below in Figure 2. There was no slump observed at w/c ratio of 0.50 for 1:2:4 concrete mix, both using natural coarse aggregate and recycled coarse aggregate.

3.4 Experimental Setup

With the calculated mix, 32 cubes of size 150 mm x 150 mm x 150 mm were casted according to BS 1881: PART 108: 1983. The concrete cubes were casted in total in which 24 cubes were prepared at mix design ratio (1:2:4 at w/c of 0.50, 0.60 and 0.70) and 8 cubes were prepared at mix design ratio (1:4:8 at 0.70 w/c). Similarly, total 32 samples of reinforced concrete beams of size 500 mm x 100 mm x 100 mm were casted, out of which 24 beams of concrete ratio 1:2:4 at w/c of 0.50, 0.60 and 0.70 and 8 beams were of concrete ratio 1:4:8 at w/c of 0.70. The beams were provided with four rebar of #4 size (12.7mm nominal diameter). The specimens were un-moulded after 24 hours and kept for curing under standard conditions as prescribed by ASTM C192-90a, for 28 days. The cubes were tested under compression on 28 days using Compression Testing Machine (CTM) as per the procedure described in ASTM C36-86.

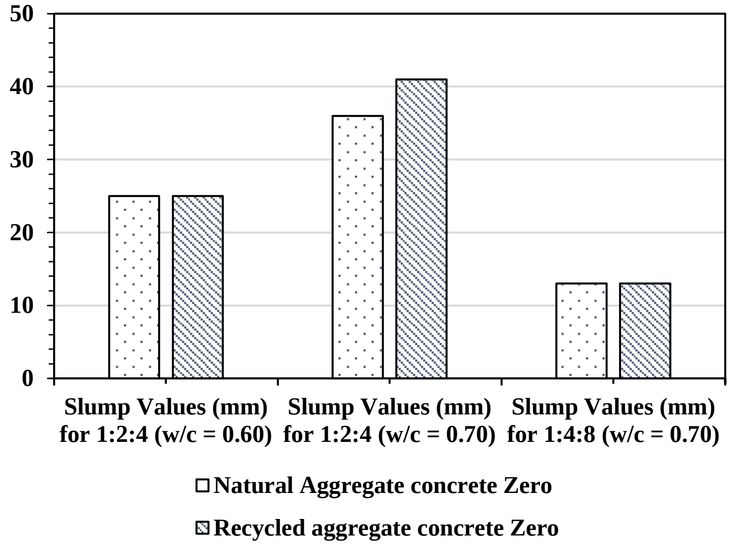

Fig. 2: Slump test results for concrete mixes (1:2:4 and 1:4:8) for varying w/c ratios

There are two loading methods used for testing the flexural strength of a specimen, which are third-point loading and centre point loading. In this study the beams were tested under centre-point loading as shown in Figure 3. The specimen was tested on Universal Testing Machine (UTM) and loaded continuously with a constant load rate until failure.

Fig. 3: Flexural testing of RAC beams on UTM

4. Results and Discussion

Due to limited testing facilities, this study is only examined for the compressive strength of concrete cubes and flexural strength of reinforced concrete beams.

4.1 Compressive Strength of Concrete Cubes

Table 4 shows the results for the cube specimens tested under compression. The results indicate that the test cube achieved substantial strength at w/c ratio of 0.70 when used with the concrete mix proportion of 1:2:4 and it tends to increase for the mix proportion of 1:4:8. The lower w/c ratio makes proper mixing harder. Also, the recycled aggregate was not wet enough and it absorbed more water than required thus leaving less water for the hydration process to be completed and gain strength. The compressive strength of recycled aggregate concrete cubes decreases by 35% at w/c ratio of 0.6 for M15 concrete and it increases by 27% for M7.5 concrete.

Table 4: Average compressive strength of control cubes (NAC) and test cubes (RAC) at 28 days

Concrete Mix	W/C Ratio	Average Compressive Strength MPa (Ksi)	
		Control Cubes (NAC)	Test Cube (RAC)
1:2:4	0.50	24 (3.47)	2.34 (0.34)
1:2:4	0.60	19.30 (2.80)	12.82 (1.86)
1:2:4	0.70	14.50 (2.10)	13.20 (1.91)
1:4:8	0.70	0.41 (0.06)	0.55 (0.08)

4.2 Flexural Strength of Reinforced Concrete Beams

Table 5 shows the results for the beam specimens' flexural strength. The results show that at higher w/c ratio the flexural strength of beams casted with NCA and RCA shows good agreement and very less difference can be seen, however, at lower w/c ratios the flexural strength of NCA beam specimen was at least 50% higher as compared to RCA beam specimens.

Table 5: Flexural strength of control beams (NAC) and test beams (RAC) at 28 days

Concrete Mix	W/C Ratio	Flexural Strength MPa (Ksi)	
		Control Beams (NAC)	Test Beams (RAC)
1:2:4	0.50	26.33 (3.82)	10.06 (1.46)
1:2:4	0.60	29.78 (4.32)	19.37 (2.81)
1:2:4	0.70	25.78 (3.74)	23.16 (3.36)
1:4:8	0.70	8.75 (1.27)	8.06 (1.17)

5. Conclusion

The experiments carried out in this study conclude that for recycled aggregate concrete, 28-days compressive strength can be obtained close to that of natural aggregate concrete at water-cement ratio of 0.7 (both 1:2:4 and 1:4:8), whereas the strength was noted to decrease than the control concrete for the same mix proportions at water-cement ratios of 0.50 and 0.60. In light of the obtained results, it is suggested that the recycled aggregates must be used in wet condition to yield better result for compressive strength. The cracking of the recycled concrete beams was comparable to the typical concrete beams, with a linear elastic behaviour before the first flexure cracks occurred, and then the main steel yielded, and eventually the concrete crushed. The beams without shear reinforcement fails at a much lower value of cracking load. This happened due to the fact that the weakest link in recycled concrete is the mortar adhered to the recycled aggregate and it fails more rapidly as compared to natural aggregate concrete. Aggregate interlock and bond between concrete and the reinforcement are mechanisms that seem to work correctly in reinforced concrete beams made with recycled coarse aggregate. Further experiments are advised to understand more about the behaviour of concrete prepared with recycle aggregates.

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ID 39: Effect of Coir Fiber on Flexural Strength of Concrete Maintaining Uniform Workability

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A B S T R A C T

Concrete has significant compressive strength, and while it lacks tensile strength and flexural strength, the most commonly used flexural reinforcement in concrete is steel, due to a recent hike in the price of construction materials like steel, the research is going on to use other cheap materials to reduce the amount of steel as a flexural reinforcement in the concrete. Coir fiber has proved to be beneficial for enhancing the flexural strength but reduces the workability of fresh concrete significantly. That’s why, by using a super plasticizer with coir fiber, workability can be maintained to enhance the properties of fresh concrete. The research aims to determine the effect of coir fiber on the flexural strength of concrete while maintaining constant workability at every proportion of fiber by use of super plasticizer and to obtain the optimum fiber content. The constant workability of 40±5mm was achieved by using a super plasticizer with the help of a hit and trail method fixing the amount of plasticizer for every proportion of fiber used. Beams for each proportion of coir fiber, 0%, 0.4%, 0.8%, and 1% (by weight of cement) were casted and cured for 28-days, then flexural strength was determined. The Flexural strength increased by 21%, 25%, and 15.24% with a fiber proportion of 0.4%, 0.8% and 1% respectively, in comparison with plain concrete. The Optimum results were found at 0.8%. It was concluded that a significant increase in flexural strength was observed with the inclusion of coir fiber. The results show coir fiber can be used to enhance the flexural strength of plain concrete.

K E Y W O R D S:

Flexural Strength, Coir Fiber, Super plasticizer, Constant workability, Concrete, Coir reinforced fiber concrete

1. Introduction

Concrete is one of the most used construction materials all over the world. It has replaced all other materials due to some salient features like strength, mechanical properties and behaviour against weathering, durability, and aesthetic requirement. Day by day research is going on improving the mechanical and durability characteristics of concrete. Engineers have a great focus on stability of structure so the structure should be safe, economical and eco-friendly for sustainable construction [1]. Use of fiber in concrete has evolved nowadays, for the past few years use of fiber in concrete has increased because they enhance the mechanical properties e.g. Flexural and Tensile strength of concrete from 15% to 30%. Commonly steel has been used as a flexural and tensile reinforcement for concrete but right after COVID-19 situation has prevailed the world has seen an unexpected hike in prices of construction materials. The cement and steel has touched their all-time high rates. Economic situation of country as well as all the other sector including Construction sector is effected by this market inflation. Economical Construction has become so difficult on the other side pollution and waste management issue are getting worse day by day. Both issues are adversely affecting the goals of sustainable construction. . So research is going on to use waste and cheap material which can enhance the flexural strength of plain concrete so the amount of steel used as flexural reinforcement in concrete can be reduced on the other side with reuse of these waste materials like Natural Fiber (Figure 1) in construction industry, the goals of waste management can also be achieved. Use of Natural fiber in concrete has improved seismic behavior of building as well as flexural strength, tensile strength, toughness, and ductility of concrete [2]. Fibers are classified based on their origin. There are some natural fibers that are extracted from plant animals or minerals [3, 4]. On the other hand, artificial fiber is industry-produced fiber [5].Coir fiber, also known as coconut coir, is mostly used natural fiber in concrete due to its positive impact on concrete mechanical strengths. From previous research coconut fiber, proved to be very fruitful to increase flexural strength of concrete [6]. Coir fiber has been practically used in many ways in construction sector previously. Coir fiber used in plaster combinations

[7]. Coir fiber has been used as low-cost roofing material. Coir fiber has been used in roofing tiles[8]. Coir fiber has been used in wall panelling [9]. Coir fiber has been used to reduce the thickness of rigid pavement[10]. Besides all these positive impacts it has one negative impact that is loss of workability in concrete due to use of fiber in concrete which adversely affect the compaction, placing and mixing of green concrete and this is the gap where improvement is needed because workability is one of the most important properties of Fresh concrete, so by maintaining a workable concrete, engineers can get benefit of flexural enhancement of plain concrete by coir fiber while overcoming the issue of loss of workability by coir fiber. Waste management goals can also be achieved, the aim of the research is to determine the effect of coir fiber on the flexural strength of concrete while maintaining constant workability by use of super plasticizer.

Figure 1: Processed Coir fiber

Literature Review

Nasir, Syed Ayoub has done the experimental analysis of the coir & jute reinforced concrete with plain concrete aspect ratio of both fibers were use as 75 volume-based addition procedure was used two sizes of aggregate 9.5mm (about 0.37 in) and 12mm (about 0.47 in) were used the mix design of 1:2:4 was used the fiber were as volume based addition by 0.5,1,1.5 (%).the flexural strength was found to be increase constantly with increment of fiber % even up to 1.5% optimum results were obtained. The impact of fiber on the flexural resistance capacity was more than that on compressive strength [11]. Khan & Rehman in 2020 determined the efficient content of silica fume for plain &coconut fiber added to concrete the fiber content for that research was optimized up to 2 % the quantity of silica was used in different proportions of 5%, 10%, 15%, 20% by mass of the cement. This research opened the new topic of the utilization of fiber reinforced concrete in concrete road pavement as it reduces the thickness up to 12 mm so it will be economical as well. The plain concrete gives better performance when 10% silica is used while coconut fiber reinforced performance was better with 15% silica content as they reduce depth of concrete road by 4% and 8% respectively [10].

Nadgouda, 2014 compared conventional concrete with fiber reinforced concrete in which the fiber was used in different the test was done by adding the fiber percentage 3, 5, 7 by weight of cement. M_20 grade mix was formed by the mix design ratio of 1:1.5:3 It was seen the 28 days (about 4 weeks) the flexural performance at the 3% was greater than conventional concrete increased up to 12% [12]. Sarangi and Sinha, 2016 determined the suitability of coir fiber plus PP (propylene) fiber in concrete. The synthetic and natural fibers are used at the same time and performance is analyzed. Three different samples 0.75% of pp and 0.25% of CC fiber secondly 0.5% of both and thirdly 0.75% of CC and remaining of PP. the flexural behavior was also improved up to high extent the most fruitful results were obtained when 0.75% propylene fiber and 0.25% of coconut fiber was used [13]. Chandel et al., 2016 compared the mechanical behavior of plain & reinforced coir concrete the size of core fiber was reduced up to 0.2cm (about 0.08 in) different proportions 1% 3% 5% by weight of cement were used to check the impact of coir fiber on concrete. Best results were found at the 1% of fiber the compressive strength was increased by 13% the flexural strength was increased15% the prominent increase on the other side is m split tensile strength as it is increased by 40% [14]. C, Achudhan & CO used larger size random coir fiber with a larger length fiber in order increase the workability of concrete mix as number of fibers per kg of cement will be reduced to enhance workability, coir was added as 1%, 2%, 3% was added as volume fraction of concrete the conventional mix of 1:1.5 was used . bending behavior was improved by the use of coir fiber in concrete the optimum results in all cases were found at 3% [15].

Sekar and Kandasamy, 2018 in this research they found the optimum value of coir fiber to be added in coconut shell concrete which is a type of light weight concrete and fraction of coir fiber by volume was from 1% to 5% it was added in both coconut shell concrete as well as plain concrete prominent increase in both plain & fiber concrete for flexural strength was found the increase was observed 30.63% & 50.63% respectively while best result were found in the fraction of 3% [16]. Bindhu. K.R and CO, 2018 studied The strength of coconut fibre reinforced concrete (CFRC) with varying amounts of coconut fibre (0.5%, 1%, 1.5%, and 2% by weight of cement) and coconut shell aggregate concrete with varying amounts of coconut shell (15%, 30%, and 45%) in place of coarse aggregate were compared to that of conventional concrete. For maximal flexural and tensile strength, 1% (by weight of cement) of coconut fibre in CFRC was found to be the ideal percentage. The compressive strength of concrete was not significantly reduced when 15% of coconut shell was used in place of traditional aggregate, which was determined to be the ideal percentage[17]. Hartwell in 2011 determined flexural strength of the coconut fibre reinforced concrete determined at different percentages (4%, 5%, and 6% by the weight of cement) of fibre it is seem that when fibre content is increased there is an increase in flexural strength with a maximum at 5% of fibre [18].

From the literature we have seen coir fiber has been used in concrete from 0.5% to 6% by volume of concrete or by weight of cement. In different researches the optimum coir fiber content has been founded between 0.1%-2 percent by weight of cement. So in this research we have used coir fiber by weight of cement from 0% to 1% in several proportion.

2. Materials & Methodology

2.1 Materials

Concrete strength depends upon the quality and strength of the different constituents of concrete. Every constituent has its own role in the performance of concrete.

2.1.1 Fine aggregate

Fine aggregate is an important part of concrete mix. Different types of tests were performed whose results are tabulated below in Table 1. Fine aggregate size ≤ 4.75mm having Fineness modulus =3.13 (coarse sand was used), also see Fig. 2.

Table 1: Results of testing on fine aggregate

Tests on Fine Aggregate	
Gradation of coarse aggregate	F.M=3.13(coarse sand)
Water absorption	1.41%
Specific gravity	2.631
Loose unit weight	$1480\frac{kg}{m^3}$
Compacted unit weight	$1601\frac{kg}{m^3}$

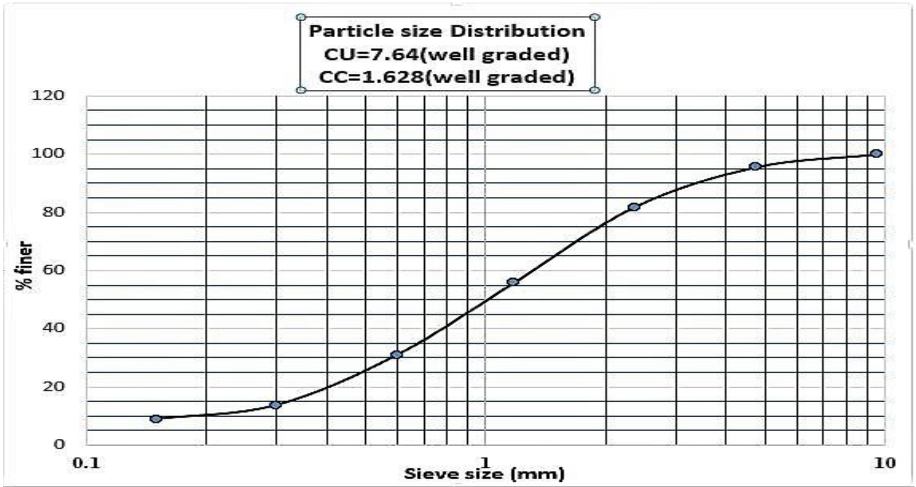

Fig 2: Sieve analysis curve for fine aggregate

2.1.2 Coarse aggregate

Coarse aggregate is one of the most important constituents about 65% or 70% of volume of concrete. Maximum coarse aggregate size=20mm (as per standard), see Table 2 and Fig. 3.

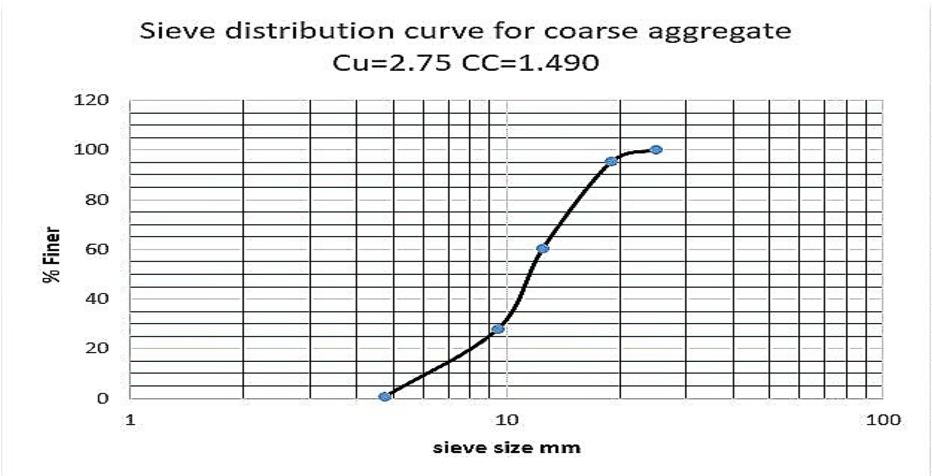

Fig 3: sieve analysis curve for coarse aggregate

Table 2: Results of testing on coarse aggregate

Testing results on Coarse Aggregate	
Gradation of coarse aggregate	Less than 20mm
Water absorption	1.2%
Specific gravity	2.58
Loose unit weight	$1276\frac{kg}{m^3}$
Compacted unit weight	$1410\ \frac{kg}{m^3}$

2.1.3 Cement

Cement is the most important constituent of concrete and of prime importance its act like a binder for concrete Following are some important results of test which are performed on cement, see Table 3.

Table 3: Results of cement testing

Testing Results on cement		
1	Fineness of cement	95%
2	Normal consistency of cement	0.33
3	Initial setting time	28 mints
4	Final setting time	8 hour 54 mints

2.1.4 Water

It is also a constituent of concrete, different test were performed to check the suitability of water for concreting, see Table 4.

Table 4: Results of water testing

Testing results on water	
Hardness of Water	258mg/L
Chloride content in water	172mg/L
Total Dissolved Solid	770mg/L
PH of water	7.77
Acidity of water	0mg/L
Alkalinity of water	0 mg/L

2.1.5 Coir fiber

Coconut fiber is one of most important natural fiber that has been used due to its strong tensile nature which help its to improvise the mechanical strength and durability of plain concrete Some properties like specific gravity length and density was taken as per literature [19].

Table 5: Properties of coir fiber

Length	diameter	Specific gravity	Density	Water Absorption	Aspect ratio
50mm	0.4mm-0.8mm	1.18	1.4-1.5g/cc	80%	125 to 62.5

2.1.6 Expanplast SP511 (complies with ASTM C-494)[20, 21]

It is a water reducing super plasticizer will lower the water required for a mix, increase workability of concrete and reduce the slump loss without reducing ultimate strength.

2.2 Methodology

I. All the material was collected including cement, fine aggregate, coarse aggregate, water, super plasticizer & Processed coconut fiber of uniform size of 50mm.

II. The Mix design of 3000 psi for plain concrete was done. Mix proportion of **1:2.05:3.07** with water cement ratio of **0.50** was obtained by standard mix design method.

III. The fiber proportions of 0%, 0.4%, 0.8%, and 1% by weight of cement in mix proportion were selected.

IV. To get a constant workability of concrete mix with in slump range of 40±5mm, trails mixes were done at each proportion of fiber, plasticizer was introduced in several proportion in ml/kg of cement. The trail for constant workability was done until we get the workability by slump test within range of 40±5 at particular fiber content. Process was repeated at all selected fiber proportion results of successful trails at each proportion is given in **Table 6**.

V. The beams with dimension 500mm×100mm×100mm for flexural strength were cast according to code (ASTM C293-08)[22] the total number of beams casted were 12. Before casting of beam at each proportion the slump test was performed to verify the results obtained during trails of constant workability.

VI. Beams were cured for 28 days in clear water and afterwards the 28 days- flexural strength was obtained by performing center point loading test on cured beams in UTM and results were obtained.

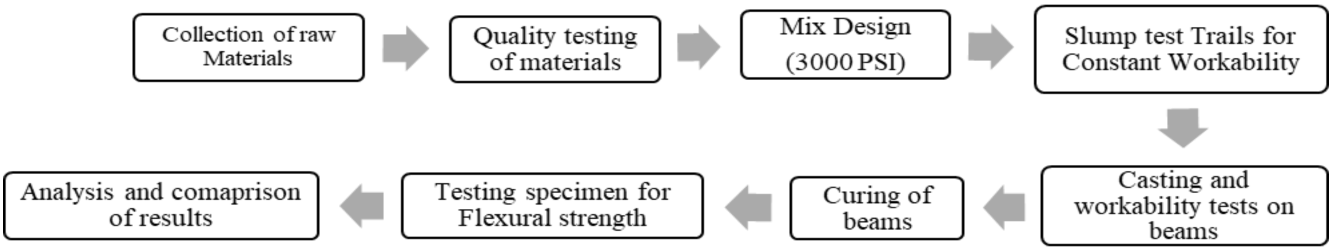

Figure 4: Flow chart of methodology

Table 6: Mix proportion

Mix no	Water (kg/m^3)	Cement (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	Fiber proportions (kg/m^3)	Plasticizer to obtain constant workability(±45mm) (ml/kg of cement)
FM0%	186	372	767	1142	0	0
FM0.4%	186	372	767	1142	1.488	5.22
FM0.8%	186	372	767	1142	2.976	7.22
FM1%	186	372	767	1142	3.72	8.83

FM=fiber Reinforced Concrete mix

Figure 5: Constant workability trails

3. Result and Discussion

The flexural strength testing was done on beam in UTM and failure cracks appeared as shown in **Figure 6.**

Figure 6 Failure Cracks in coir fiber reinforced beam

3.1.2 Results and analysis

Flexural strength was determined for all three sample for each proportion of fiber. Testing was done by center point loading testing in accordance with ASTM C293. The results are given below in tabulated form in **Table 8.**

Table 8: Flexural strength Results of samples at respective fiber proportion

S. No	Fiber content (%)	Sample	Failure load (N)	Flexural strength (MPA)	Average strength	Increase in strength (%)
1	FM0	1	5935	4.451	4.367	-
		2	5320	3.99		
		3	6218	4.663		
2	FM0.4	1	6930	5.1975	5.285	21
		2	7530	5.6475		
		3	6680	5.01		
3	FM0.8	1	7830	5.872	5.458	25
		2	7170	5.377		
		3	6833	5.125		
4	FM1	1	6795	5.0962	5.022	14
		2	6300	4.7275		
		3	6989	5.2425		

FM= Coir Reinforced Fiber concrete

Graphical representation of results are given below in **Figure 7.**

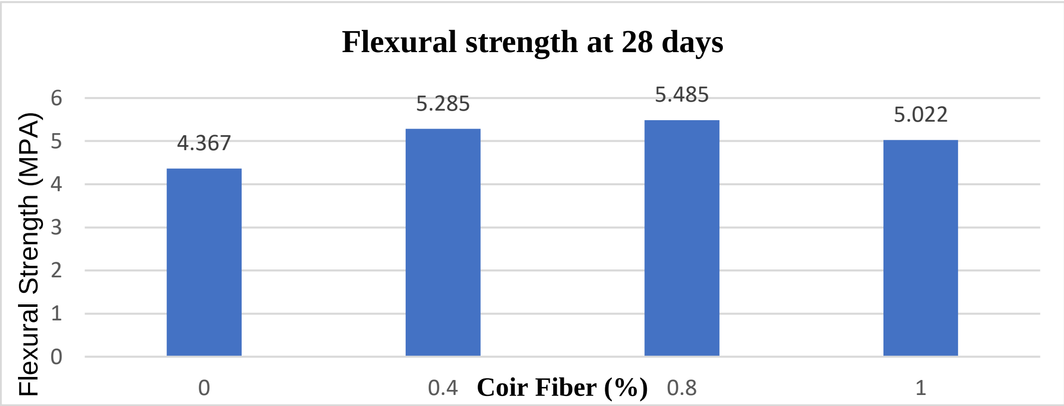

Figure 7: Coir fiber vs flexural strength graph

The result showed that flexural strength increase with increase of fiber content the optimum results were found at 0.8% fiber. The coir fibers has improved the flexural strength of concrete a seen previously from the the recent research work done on coir fiber reinforced concrete [11]. The main cause of this increase is due to ductility of concrete is increased by addition of coir fiber its improve the resistance of coir fiber against flexural stress develop in concrete.coir reinforced beam has alsown a good bonding characteristics as on the only cracks are appeared instead of collapse at the failure load which was in accordance with past few researches [23]. Coir fiber it self has 5 to 6 times more strains development than other natural fiber so its give the same improvement to concrete by enhancing ductility [24].

5. Conclusions & Recommendations

I. The flexural strength of concrete increase with the increase of fiber content. The flexural strength was increased by 21% at fiber proportion 0.4%, 25% at the fiber proportion of 0.8% and 14% at the 1%, hereby optimum results was found at 0.8%

II. The coir fiber reinforced can be preferred in light weight plain concrete structure as it can be enhance its tensile and flexural capacity

III. Construction industry would have great benefits of that use of coir fiber will proved to economical as well as environmental friendly construction.

IV. The use of workable concrete as per achieved by super plasticizer was found to be useful during placement, mixing, casting overall fresh concrete properties were enhanced by increasing workability

V. It will have a huge impact on the construction industry as the cost of construction will be reduced by use of coir fiber as the amount of steel will be reduced because coir fiber will enhance the flexural capacity of concrete that will ensure less requirement of steel as a flexural reinforcement for concrete that is already been reinforced with coir fiber

VI. The use of coir fiber reinforced concrete also proved to be environmental friendly as it will help in waste management as we reuse the waste material (coir fiber) for beneficial purpose

VII. For future consideration the optimum fiber content obtained from the research can be used in which we can use optimum fiber content with different proportion of steel (by % of designed area of steel e.g. 10% of area of steel with optimum fiber content) in concrete to find how much steel requirement reduced by using coir fiber in concrete

6. Acknowledgement

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ID 47: Determination of Pozzolanic Activity of Buffalo Dung Ash to Utilize as Cement Replacement Material in Concrete

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A B S T R A C T

Cement is now more expensive and used second only to water due to the rising amount of construction activity throughout the world, which has increased the demand for it to 4.4 gigatons per year. In the meantime, a tonne of clinker generates a tonne of CO2 while consuming a significant amount of energy and raw materials (10–11 EJ/year), which is why a cost-effective and environmentally friendly cement alternative is required now. More than 30 million buffalos live in Pakistan. There are 450 million kg of dung generated in Pakistan alone, with each animal capable of producing up to 15 kg every day. This study intends to evaluate the pozzolanic activity of buffalo dung ash and identify the ideal development conditions and dosage for the ash as a cement substitute in ordinary concrete. Five samples of buffalo dung ash were made for this purpose by calcining the dung in a muffle furnace for an hour at 400, 500, 600, 700 and 800 degrees Celsius, then cooling and filtering through a No. 100 sieve. According to ASTM C311, the Strength Activity Index was calculated. According to the findings, produced ash at 600 ^oC has a maximum Strength Activity Index of 94.2%, which satisfies the requirements of ASTM C618 for pozzolanic material. X-ray Fluorescence test further supported these findings. Additionally, when 5%, 10%, 15%, and 20% of this ash were used in place of cement in concrete, the compressive strength rose by 11.2% on a percentage basis when compared to the control mix on a 10% replacement. Based on parameters examined, the Buffalo Dung ash calcinated at 600^{o}C for 1 hour have potential to replace 10% of cement in concrete to get optimum results.

K E Y W O R D S:

Buffalo Dung ash, Pozzolanic activity, XRF, Cement Replacement Material

1. Introduction

As we all know, due to its many benefits, concrete has become most widely used man-made construction material. Portland cement, which serves as a binding agent, is the principal component of concrete. Cement is now more expensive and used second only to water due to the growth in construction activity throughout the world, which has increased demand for it to 4.4 gigatons annually [1]. In the meantime, a tonne of clinker creates a tonne of CO_2. [2]. During the process of making cement, the cement industry is considered to be responsible for around 10% of all CO2 gas emissions, which contribute to global warming [3]. Additionally, the need for energy to produce cement at high temperatures of around 1400°C to 1500°C has climbed to 10-11 EJ annually, or about 2-3% of the world's main energy consumption [4]. Due to the building sector's ongoing dependence on cement as the primary element in binders, another disadvantage of cement is that it depletes natural resources like clay and limestone at an alarming rate [5]. Therefore, in order to reduce cement usage, researchers from all over the world are working to identify the potential of several readily available and ecologically friendly cement alternatives that might replace Portland cement in concrete partially or entirely.

By primarily generating milk, buffalos are contributing significantly to Pakistan's national economy. Buffalo contributes around 68% of the nation's total milk production [6]. More than 30 million buffalo heads are in Pakistan's only for milking purposes one may generate up to 15 kg of dung per day, totalling 450 million kg in Pakistan alone [7]. Buffalo dung is not widely used in Pakistan. Massive amounts of air-polluting gases including ammonia, nitrous oxide, hydrogen sulphide, and most crucially, carbon dioxide and methane, are produced when fresh buffalo excrement and oxygen in the air mix. Studies have shown that people who live close to factory farms have a greater chance of developing chronic asthma, lung inflammation, immunological suppression, and even mental problems. Inhaling these toxic vapours in large enough doses can be lethal. Another issue to be worried about is the issue of global warming brought on by these gases. 14.5 percent of the world's GHG emissions come from the cattle industry [9].

Therefore, an effort is made to investigate the Pozzolanic activity of B.D.A and determine the best conditions for developing the ash, along with the best dosage as cement replacing material in Normal concrete, in order to determine the potential usage of B.D.A in concrete, clean the environment due to the generation of the large quantity of B.D.A, to improve the properties of concrete economically, and to somewhat reduce CO_2 content.

2. Literature Review

A variety of studies have been done in the past on the use of various types of ashes in concrete, but none have looked into the cementitious qualities of B.D.A. or the ideal development circumstances for it. Here, certain studies mostly on cow dung ash and cattle manure are addressed and utilized as reference. Narayana *et al.* (2020) examined CDA's pozzolanic activity and determined the qualities that give cow dung ash concrete its strength. When cement replacement was made at 5%, 10%, 15%, and 20% by weight, concrete behaved well against sulphate and acid attacks compared to control mix, increasing its compressive strength by 16.33% and tensile strength by 17%, respectively, at 15% replacement. As a result, it was suggested to use 15% CDA in place of cement in concrete [10].

Kumar *et al.* (2015) has determined that pozzolanic activity of CDA utilizing the strength activity index by employing CDA, and since the SAI at 7 days of curing was greater than the required minimum of 75% in his findings, it was concluded that CDA had pozzolanic activity [11]. Vasu.K (2019) tried to figure out how to use cow dung ash in concrete. The CDA burnt at temperatures between 450°C and 500°C. The ash was sieved through a 300-micron sieve (#50) and added to concrete in amounts of 5%, 10%, 15%, and 20% by weight of cement. Concrete's cubical strength shown a 12% increase on 10% replacement. These findings led to the recommendation that 10% of the cement be replaced with CDA [12].

Inderveer Singh Gurjar *et al.* (2015) evaluated the behaviour of concrete when dried Rise husk ash burnt at 450°C to 500°C and cow dung ash burned at 450°C to 600°C are used in equal amounts to replace some of the cement. Both ashes were sieved through a 150-micron (#100) sieve before being employed as a partial substitute for cement in concrete at a proportion of 5% to 25%. It was found that at 5% substitution, the compressive strength was increased by 30%. As a result, it was discovered that 5% of #100 sieved CDA burnt at 400 to 600oC was ideal [13].

Sruthy B *et al.* (2017) conducted an experimental analysis to determine the impact of replacing some of the cement with glass fibres and cow dung ash. In this investigation, cement was substituted with 150-micron (#100) sieved CDA at weight replacement rates of 6%, 8%, 10%, 12%, and 14% while workability was maintained by adding superplasticizer at a rate of 0.5 to 0.7% by weight of cement. Results indicated that at 8% CDA and 0.5% glass fibres, maximum compressive strength improved by 6%, while at 8% CDA and 0.5% glass fibres, split tensile strength increased by 20%. Conclusions were drawn, stating that concrete can benefit economically from using up to 8% CDA as a partial replacement for cement and 0.5% glass fibers [14].

C Venkatasubramanian *et al.* (2017) tried to use coconut firers and cow dung ash in the concrete. Cement was substituted with cow dung ash, and coconut fibers were added to the concrete to increase its strength. The dried cow dung cakes were burned at 450°C to 500°C to produce the cow dung ash, which was then sieved using a 150-micron (#100) sieve. The less than 1 cm in size, finely cut coconut fibers were purchased at the neighborhood market. The 150 mm cubes and 150 mm x 300 mm cylinders were cast and allowed to cure for 7, 14, and 28 days with 2.5%, 3%, and 3.5% CDA replacing the cement by weight of the cement and 1% coconut fibers. When compared to M-25 normal cement concrete, the results of the modified concrete performed better. Compressive strength and indirect tensile strength tests revealed that replacing 3.5% of the CDA increased the amended concrete's compressive strength by about 77.2% and 75.5% and its tensile strength by roughly 46%. Thus, it was determined that concrete's characteristics were improved by 3.5% of CDA and 1% of coconut fibres [15].

3. Research Methodology

The method used in this study to assess the pozzolanic activity of Buffalo dung ash is as in Figure 1.

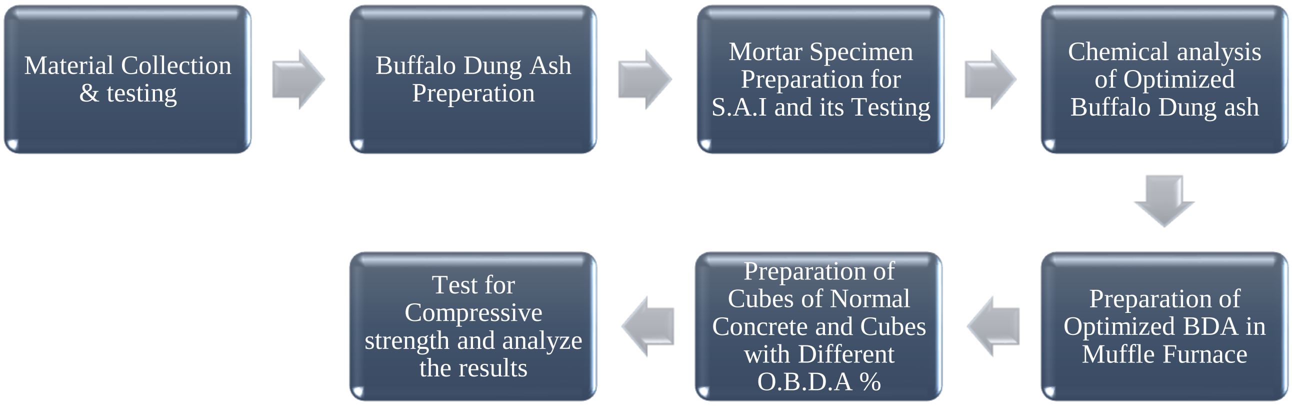

Fig 1: Methodology flow chart of research

3.1 Materials

Lucky Brand Ordinary Portland Cement (OPC), which the business claims to conform to ASTM C150 type I, is employed in this study effort. The coarse materials for concrete came from the Nooriabad crushing facility with a nominal maximum size of 20mm, in accordance with ASTM C33, while the fine aggregates came from Bolari, a location in Thatha Sindh. Table 1 displays the aggregates' physical characteristics. According to ASTM C311, clean natural sand that had passed through sieve number 30 and been retained on sieve number 60 was used in the mortar. The only source of buffalo dung utilised is from a single buffalo, and it comes from a Buffalo farm near Qasimabad, Hyderabad. The results and discussion section's Table 5 displays the chemical make-up of the optimised buffalo dung ash. All experimental work uses regular drinking water.

Table 1: Physical Properties of Ordinary Portland Cement

Properties	**Results**
Fineness	95%
Consistency	0.31
IST	55 minutes
FST	7 hours and 45 minutes
Soundness	4.5 mm
Sp. gravity	3.14

Table 2: Physical Properties of Fine and Coarse Aggregates

Properties	**Fine-Aggregates**	**Coarse-Aggregates**
Fineness Modulus	3.07	-
Sp. gravity	2.66	2.59
Loose Bulk-density (Kg/m^3)	1834	1450
Compacted Bulk-density (Kg/m^3)	1939	1656
Water Absorption (%)	2.01	1.16

3.2. Buffalo Dung Ash Preparation

First, five samples of buffalo dung ash were made by calcining dried and crushed buffalo dung for an hour each at temperatures of 400°C, 500°C, 600°C, 700°C and 800°C in a muffle furnace. After cooling for 24 hours, these five buffalo dung ash samples were sieved through #100 (150 microns) and kept in airtight containers.

Fig. 2: Preparation of B.D.A

3.3. Mortar Specimen Preparation for S.A.I

In accordance with ASTM C 311, 2 in. (50 mm) mortar specimens were made for the control mix and by substituting all Buffalo dung ash for 20% of the cement using the sample that was burnt earlier at five different temperatures, by weight. The sand-to-binding-material and water-to-binding-material ratios used to create the mortar mixes were 2.75:1 and 0.485, respectively. The sand used to create the mortar cubes had passed through Sieve number 30, but had been caught on sieve number 60. Table 3 displays mixture specifics. For mixing, compaction, and molding, the following standards were used: ASTM C305, C10, and C109. In order to determine the compressive strength for each curing age, three specimens were cast.

Table 3: Mix Proportion for Mortar Cubes

Mix IDs	O.P.C	B.D.A	Sand	W/B ratio	Water
C.M	500 g	0 g	1375 g	0.485	242 g
B-400	400 g	100 g	1375 g	0.485	242 g
B-500	400 g	100 g	1375 g	0.485	242 g
B-600	400 g	100 g	1375 g	0.485	242 g
B-700	400 g	100 g	1375 g	0.485	242 g
B-800	400 g	100 g	1375 g	0.485	242 g

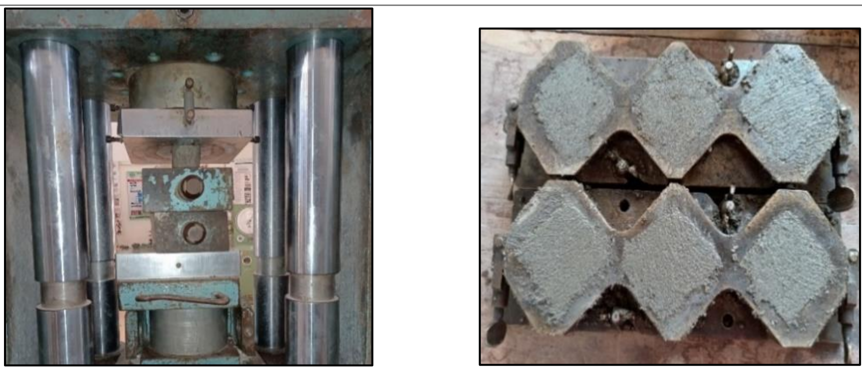

Fig. 3: Preparation and testing of Mortar Specimen for different tests

3.4. Strength Activity index (SAI)

The strength activity index is the percentage ratio of the strength of mortar cubes made with a 20% weight-for-weight B.D.A substitution of the cement to that of control-mix. Using ASTM C311/C311M - 18 as a guide, the S.A.I test was conducted.

$$S.A.I = \frac{M}{C.M} \times 100$$

M stands for modified mix. Compressive strength and C.M, or Control Mix, are measured at 7 or 28 days of curing, respectively.

The strength activity index test is used to examine whether or not the cement replacing the material is pozzolanic and whether or not the usage of pozzolana in concrete will result in an acceptable level of strength growth.

3.5. Concrete Cubes Preparation

A mix design ratio is decided upon using the D.O.E approach and trials, as indicated in Table 4.

Table 4: Mix Design of Normal Cement Concrete

Materials	Quantity	Slump
Cement	365 Kg/m^3	55 mm
Fine Aggregates	735.5 Kg/m^3	
Coarse Aggregates	1100.8 Kg/m^3	
Water	196.7 Kg/m^3	
1 : 2.01 : 3.01 @ W/C = 0.54		

The 100mm x 100mm x 100mm cubes were cast and dried using the aforementioned mix design ratio of conventional concrete and optimal B.D.A at various weight percentages of 5, 10, 15, and 20.

4. Results and Discussion

4.1 Compressive Strength of Mortar Cubes

To assess the reactivity of BDA, compressive strength tests were conducted on mortar cubes. According to ASTM C109, testing was carried out on the samples at ages of 7 and 28 days after wet curing. The outcomes are displayed in Figure 4. The results show that the higher percentage of B.D.A replacement decreased the compressive strength of all mortar cubes compared to the control mix, but that strength increased at burning temperatures up to 600ºC due to the pozzolanic reaction brought on by the reactive silica in amorphous in B.D.A. The results also show that the reactive pozzolanic reaction increases with temperature, but there is a sudden decline in strength on the further increasing temperature of burning, which can be attributed to the presence of crystalline silica on burning temperatures of 700ºC and 800ºC, which reduces the pozzolanic reaction [16]. The compressive strength of mortar cubes was tested, and it is evident from the findings that BDA calcinated at 600ºC for 1 hour had the highest compressive strength compared to other BDA-containing samples.

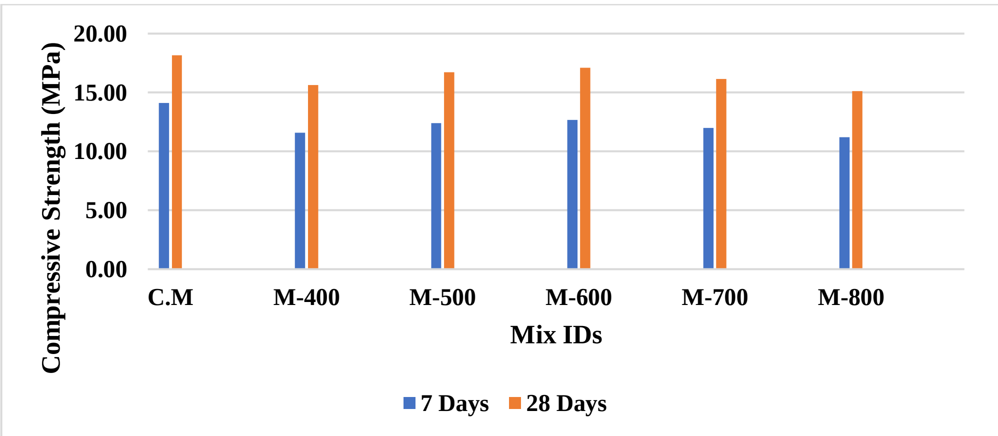

Fig. 4: Compressive Strength of Mortar Cubes at 7 and 28 Days

4.2 Strength Activity Index (SAI)

According to the SAI data shown in figure 5, the SAI of BDA is growing up to 600°C as a result of pozzolanic interaction with reactive amorphous silica contained in the B.D.A, which is increasing with burning temperature. Due to the presence of crystalline silica, which slows down the pozzolanic process, the SAI then decreases with continued temperature rise [16]. According to ASTM C 618, the S.A.I presented in figure 5 clearly demonstrates that all mortar mixes have S.A.I values greater than 75%, which is the minimum amount that can be used as pozzolanic material in concrete. However, for the M-600 mix, which is made by substituting B.D.A for cement (600 ^{0}C @ 1hr), the S.A.I values are 89.7% and 94.2%, which is significantly higher than 75% Thus, it is established that optimized buffalo dung ash, or B.D.A created by burning B.D.A at 600 ^{0}C for 1 hour, has more pozzolanic activity than other samples.

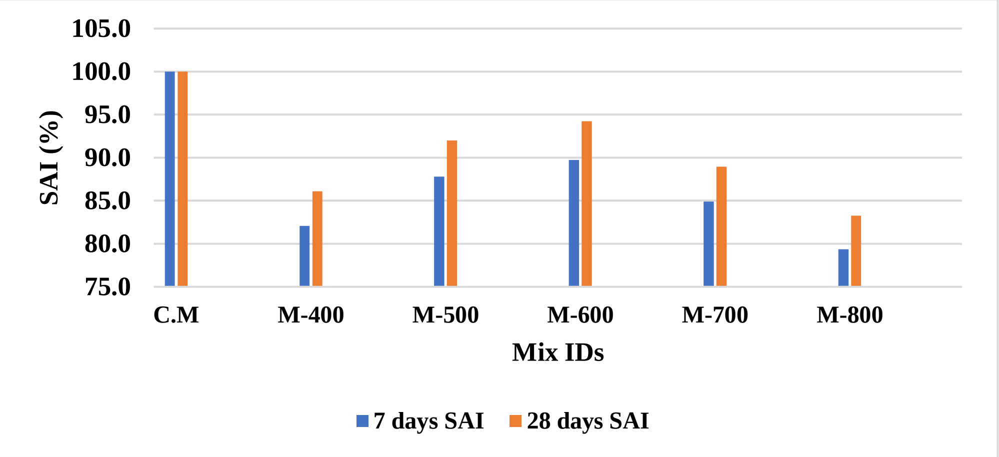

Fig. 5: SAI of Specimen at 7 and 28 Days of curing

4.3 Chemical Analysis of Optimized Buffalo Dung Ash

To prove its pozzolanic capabilities, the chemical analysis of buffalo dung ash calcined at 600°C for 1 hour is also carried out, as indicated in Table 5 below.

Table 5: Chemical Analysis of Optimized Buffalo Dung ash using XRF test

Constituents	% Wt. Chemical Composition
SiO_2	57.72
CaO	7.43
Fe_2O_3	3.42
MgO	5.04
Al_2O_3	9.58
Na_2O	0.68
K_2O	1.20
P_2O_5	6.49
TiO_2	0.29

A pozzolanic material must include at least 70% SiO_2, Al_2O_3, and Fe_2O_3 in accordance with ASTM C 618. According to Table 3, the XRF analysis of buffalo dung ash generated at 600 oC revealed that it contains 71.61% $SiO_2 + Al_2O_3 + Fe_2O_3$. Therefore, BDA's chemical makeup justifies its use in concrete in accordance with ASTM C-618 since it satisfies the criteria for pozzolanic material.

4.4. Compressive Strength of Concrete Cubes

According to the findings of an investigation into the compressive strength of cubed concrete at 7 and 28 days after curing, shown in Figure 6, the optimised buffalo dung ash is also helpful in boosting concrete's compressive strength by a maximum of 11.2% at 10% replacement. The increasing trend up to 10% replacement is caused by an increase in secondary CSH gel content due to a pozzolanic reaction caused by B.D.A, but a decline in strength on a further increase of B.D.A in concrete is caused by a decrease in CSH get produced from the hydration of cement which pozzolanic reaction of B.D.A could not compensate for.

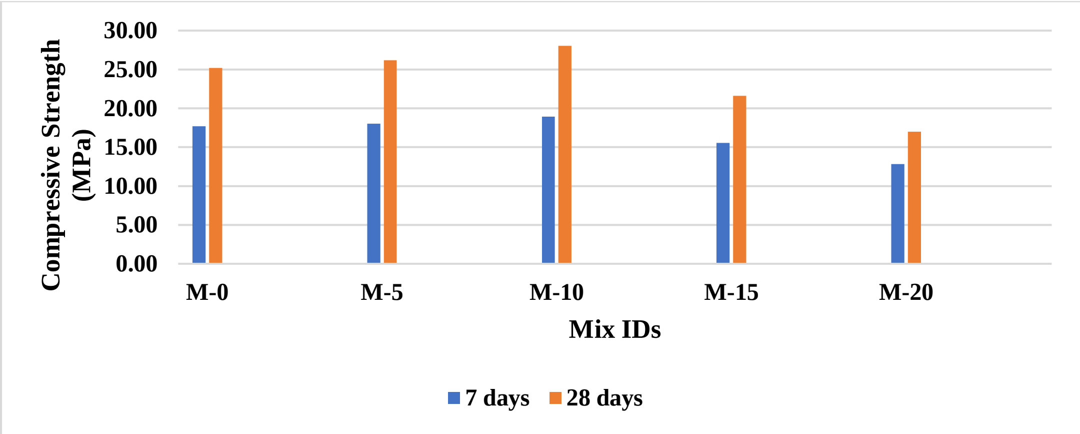

Fig. 6: Compressive Strength of Concrete Cubes at 7 and 28 Days

5. Conclusion

The following conclusions can be drawn from experimental results:

- The S.A.I test revealed that all samples of buffalo dung calcinated at temperatures ranging from 400°C to 800°C, at intervals of 100°C, had S.A.I values greater than 75%, indicating that they could be used as a pozzolana in concrete in accordance with ASTM C618.
- The buffalo dung ash has a maximum Strength activity index after being calcined at 600ºC for an hour, making burning circumstances of 600 ºC for an hour ideal for producing highly pozzolanic (Optimized) BDA.
- According to ASTM C618, the chemical analysis of optimised buffalo dung ash also points to it being a pozzolanic substance.
- Concrete with optimised buffalo dung ash used as a 10% replacement for cement has an 11.2% increase in compressive strength.
- Finally, it is advised to use Buffalo dung ash generated at 600oC with a heating time of 1 hour to replace the 10% cement in regular concrete.

6. Acknowledgment

First and foremost, we are grateful to ALMIGHTY ALLAH for the numerous favours He has bestowed upon me, which have allowed us to work on and complete this thesis on schedule. Additionally, we appreciate Prof. Dr. Rizwan Ali Memon, Head of the Civil Engineering Department, for always providing us with a state-of-the-art laboratory to perform the experimentation in. My sincere thanks goes out to my boss, Engineer Fahad Ali Shaikh. I appreciate his patient guidance, inspiration, and especially his dedication to research, information sharing, and important time that made this effort possible.

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ID 49: Effect of Various Cement Brands on the Properties of Concrete

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A B S T R A C T

Pakistan as a developing country cannot sustain more economic losses, thus different comparative studies are needed to point out the flaws in the available cement brands for the constructions to be durable for long service life which will eventually reduce the demand for cement in the future. This research work seeks to examine the differences different cement brands make for the compressive strength and workability of the resulting concrete. The four most used cement brands in the surroundings were taken into account for this research project i.e., DG, Falcon, PakLand, and Lucky. Firstly, all these brands' Physical Properties i.e., Fineness, Normal Consistency, and Setting time were assessed according to the ASTM standards i.e., C184, C187, and C191, and keeping differences aside all of them had results within the ASTM standards. An interesting pattern between the Fineness and Setting time of different cement brands was noticed; the finer the cement was the less time it took for its final setting time. Secondly, and most importantly all brands of cement were evaluated for their Compressive strength and Workability according to the ASTM standards i.e., C39, and C143. Concrete cylinders 100mm*200mm in dimensions were cast with three replications for 3, 7, 14, and 28 days of curing respectively with the same water-cement ratios. Compressive strength of 15N/mm^2 was targeted for these cylinders. The slump obtained from these brands of cement was also within the already specified range i.e., 1-3 inches.

K E Y W O R D S:

Pakistan, Cement, Concrete, ASTM, Compressive strength, Workability

1. Introduction

At this stage of the nation's development, it is important to draw attention to the shortcomings in the cement types currently on the market so that the structures that will be built will be sturdy for long service life and will ultimately reduce the demand for cement in the future. Cement production has never been an issue for the various factories spread throughout the country because limestone and clay, the two raw materials needed to make cement, have always been abundant in Pakistan [2]. Instead, the issue has always been the quality of this material's availability on the market. As a result, various factories are currently vying for the right to produce the cement that Construction Companies use. Pakistan's concrete construction projects are expanding quickly as a result of the need to build numerous infrastructures across the nation. In Pakistan, cement production has fluctuated from an average of 2600 thousand tonnes per month over the past 20 years to a low of 3300 thousand tonnes in 2021, which is roughly 1.25 times higher than the average for the previous 20 years [1]. The purpose of this research was to compare and contrast the four most popular cement brands in the region based on their workabilities and compressive strengths. This background informed the choice of the research topic, which was to check what role different types of cement available on the market can play in sustainable construction projects in the region. The cement used should have specific qualities to play an elective role in various infrastructures. The whole project cycle proceeds without any hindrances if the properties of cement consist of a set of standard values that fall within a certain specified range. Additionally, comparing the various commercially available cement brands is reasonable if it is based on these ranges. Therefore, several tests will be carried out in the laboratory to differentiate between the region's most used brands. The price of cement bags tends to increase frequency, and I can attest to that since we when started our research got our cement bags at prices less than half of the price that cement is being retailed at now, which can even be a quarter of that by the time this paper gets published. Cement accounts for an average of 16.5-17% of the overall material costs, and if this material is not properly looked at can be a pain in the heads of the contractors these days due to the economic instability in the country [9]. Workability is a property of fresh concrete which has a significant influence on the properties of hardened concrete. It determines how effortless the concrete will be to mix, pour, and shape into a cylindrical or cubical shape. The most significant factor affecting concrete's workability is the water/cement ratio obtained for a particular mix, apart from the water/cement ratio, the properties of cement solely tend to affect the workability of concrete; the finer the cement, the more water it requires to achieve standard consistency which will eventually increase the workability of concrete [3]. The two most important properties of concrete, i.e., Workability and Compressive Strength have an inverse relation among themselves, the more the workability of concrete, less its compressive strength is. Keeping aside the concrete workability, the quality and quantity of cement used also have a direct impact on the compressive strength of concrete, although to a smaller degree than the water/cement ratio. The cement content and concrete compressive strength possess a linear relationship which has certain limitations on the amount of cement used to enhance concrete's compressive strength beyond a point where it does not appear to be appreciably increased. Various researchers have concluded that the finer the cement is, the greater its compressive strength tends to be, particularly its early age strength; there also exists a definite optimum limit of fineness beyond which the compressive strength decreases. Improvement in fineness boosts compressive strength by 50-100 percent after one day, 30-60 percent after three days, and 15-40 percent after seven days. While the fineness difference results in a significantly lesser difference in compressive strength after the concrete has aged 1 year [4].

2. Materials and Methodology

The materials used in this research include cement, fine aggregate, coarse aggregate, and water. Each material has its impact on the durability of the resulting concrete. The local market was thoroughly investigated and the most used four Ordinary Portland types of Cement were purchased, that are; DG, Falcon, PakLand, and Lucky; it was avoided buying the cement samples past 3 days from their opening. Fine Aggregates passing from a 4.75mm sieve were taken from Bholari, District Kotri. The crushing plant in Nooriabad was contacted for the coarse aggregates that are to be used during this research. All of the mixtures, however, were made with water with a pH of 7.5 obtained from the Material Laboratory at the Mehran University of Engineering and Technology (MUET) Jamshoro's Department of Civil Engineering.

48 specimens of various concrete combinations based on the four types of cement indicated above were cast in total. During this research project, a cement concrete mix with a 1:2:4 ratio (with a water-to-cement ratio of 0.50) was employed. Concrete was mixed using a mechanical mixer. 12 cylinders with a diameter of 100mm and height of 200mm were made for each combination and three each for the four curing times (3, 7, 14, and 28 days), which were then cast to test the compressive strength [5].

3. Results and Discussions

3.1 Workability of Fresh Concrete

Each cement brand employed in this research project had its workability evaluated in line with ASTM standard C-192 [6]. All generated concrete mixes were assessed using a slump cone, and the results of the tests for all the various brands of concrete are shown in Table 1. All the utilized cement brands are workable, with no notable differences. The minor differences between each of the tested brands are shown in Fig.1 It can be noted that there doesn't exist much distinction among their workability.

Table 1. Workability Test Results

S.NO	CEMENT BRAND	W/C RATIO	MIX DESIGN RATIO	SLUMP (in.)
1.	FALCON	0.5	1:2:4	**1.5**
2.	DG	0.5	1:2:4	**1.6**

3.	LUCKY	0.5	1:2:4	**1.25**
4.	PAKLAND	0.5	1:2:4	**1.0**

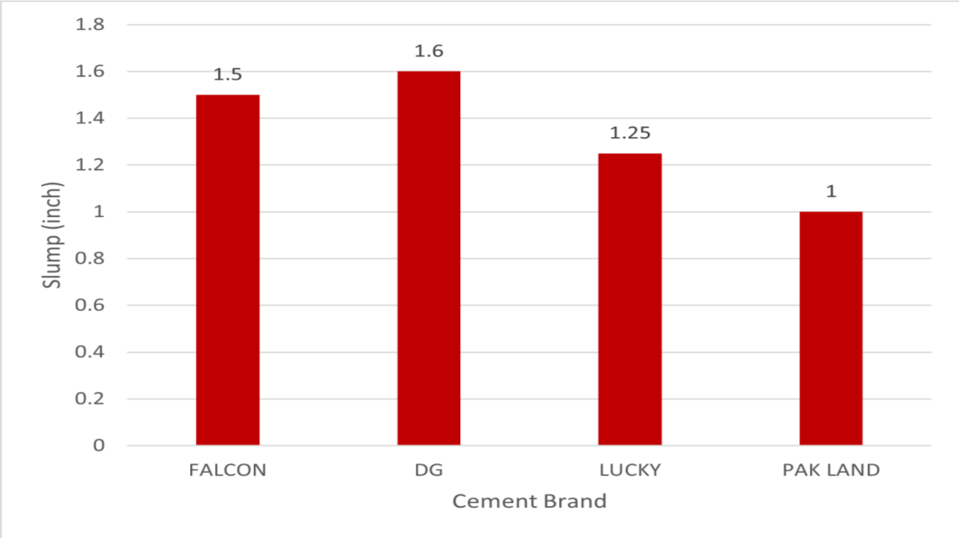

Fig. 1: Variation in Workability Test Results

3.2 Compressive Strength of Concrete

By using a Universal Testing Machine (UTM), several compression strength tests were conducted by ASTM C39/C39M- 18 [7]. Table 2 and Figure 2 shows the outcomes of compression tests performed on cubes using four distinct brands of cement (Falcon, PakLand, Lucky, and DG cement) subjected to 3, 7, 14, and 28 days of curing.

Table 2: Compressive Strength Test Results

CEMENT BRAND	W/C RATIO	MIX DESIGN RATIO	CURING PERIOD (DAYS)	AVERAGE COMPRESSIVE STRENGTH (MPa)	AVERAGE COMPRESSIVE STRENGTH (PSI)
LUCKY	0.5	1:2:4	3	7.81	1132.74
	0.5	1:2:4	7	9.99	1448.93
	0.5	1:2:4	14	13.67	1982.67
	0.5	1:2:4	28	19.05	2762.97
DG	0.5	1:2:4	3	8.15	1182.05
	0.5	1:2:4	7	9.89	1434.42
	0.5	1:2:4	14	17.72	2570.07
	0.5	1:2:4	28	19.53	2832.59
	0.5	1:2:4	3	7.59	1100.83
	0.5	1:2:4	7	8.62	1250.22

PAKLAND	0.5	1:2:4	14	10.20	1479.38
	0.5	1:2:4	28	12.17	1765.10
FALCON	0.5	1:2:4	3	14.23	2063.89
	0.5	1:2:4	7	18.11	2626.63
	0.5	1:2:4	14	18.53	2687.55
	0.5	1:2:4	28	19.77	2867.40

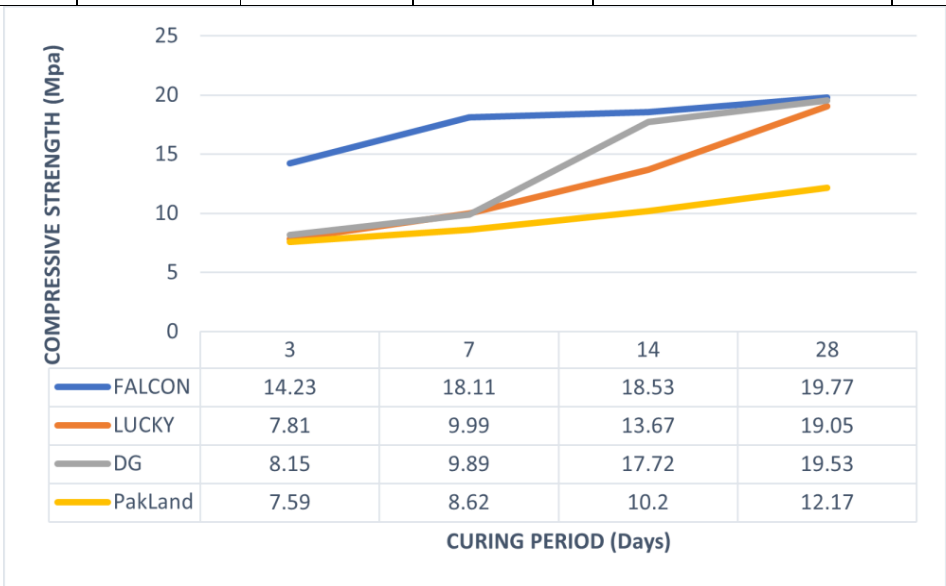

Fig. 2: Variation in Compressive Strength Test Results

Although, every cement brand had almost similar behaviour when being tested for compressive strength and workability but there were some major notable variations to be looked at:

Fig.2 shows the early strength-gaining capabilities of Falcon cement after the curing period of 3 days and 7 days compared to all the other tested cement brands which can be either due to the temperature variations or solely due to the high early strength-gaining capabilities of the Falcon cement, rest all three of the cement brands i.e., PakLand, DG and Lucky behaved similarly after the curing period of 3 days and 7 days. Any chances of the effect of temperature on the compressive strength of concrete or most appropriately early compressive strength gaining capability of concrete were cleared by the 28-day curing period compressive strength results, as despite having the head start in compressive strength for Falcon cement at 3 days and 7 days, it had almost similar results as compared to DG and Lucky cement which had lower 3 days and 7 days strengths. While on the other hand PakLand cement brand despite having a similar 3 days and 7 days curing period compressive strength to Dg and Lucky, didn’t even get to the required strength i.e., 15MPa let away matching the results of other cement brands.

4. Conclusions

The most important findings and conclusions of this research project are mentioned below:

1. After 28 days of curing, Falcon cement provided the highest compressive strength; the peak value attained was around 20MPa, and it could be used in any type of construction project.
2. For the curing duration of 28 days, the compressive strengths obtained from the remaining three brands of cement, namely PakLand, DG, and Lucky, are 12.17 MPa, 19.53 MPa, and 19.05 MPa, respectively.
3. The Falcon cement brand outperformed the other three brands of cement chosen for this research project when all test results were compared, as well as the various curing times of 3, 7, 14, and 28 days. The remaining two cement brands i.e., DG and Lucky, however, showed a bit less strength while still adhering to international requirements.

4. The PakLand cement brand underperformed in this research project when all test results are compared at 14- and 28-Days curing periods.
5. Workability of all the used cement brands was mostly similar, and all of them were in the ranges specified in C 143 [8].

In conclusion, the aforementioned findings proved the validity of the research done, even if further tests needed to be done to establish a statistical distribution of strengths to better forecast the resistance of concrete specimens built by the various cement brands under investigation.

Several iterations were performed to get accurate and average results.

5. Acknowledgment

We will begin by thanking the Glorious and ALMIGHTY ALLAH who provided us with the ability and the energy to complete our Final year project (FYP) to the greatest extent possible. We are extremely grateful to Prof. Dr. Rizwan Memon, Chairman of the Civil Engineering Department, for providing us with well-designed, orderly, and welcoming laboratories. We would also like to express our gratitude to our senior friends and colleagues for their insightful advice on our research work. Last but not the least, we would want to express our gratitude to our supportive and loving families for serving as a continual source of inspiration for us throughout our lives.

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ID 73: Compressive Strength of Concrete with Silica Fume as Partial Replacement of Cement

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A B S T R A C T

The production of cement in factories has a detrimental environmental impact, and to lessen its impact, the use of silica fumes is partially substituted for cement. Silica fume (SF), a byproduct of silicon and ferrosilicon smelting, is useful to develop high-concrete strength. The use of this by-product in concrete contributes to the sustainability of the construction industry. In this research, the compressive strength of concrete is investigated by partially replacing cement with silica fume. The four mixes of 1:2:4 with a water binder ratio of 0.5 were cast at replacement levels of 0%, 7%, 11%, and 15% by weight of cement. Moreover, the compressive strength was measured at 7, 14, and 28 days after curing. As result, it was discovered that the compressive strength of the material was maximum after 28 days of curing when the silica fume was partially replaced by 7%. Additionally, after 7 percent of silica fume, compression strength reduced.

K E Y W O R D S:

Silica Fume, Cement, Concrete, Partial Replacement, Sustainability, Compressive Strength.

1. Introduction

The word concrete derives from the Latin "concretus," which means "compact or concentrated" [1]. When we refer to something as concrete, we mean that it is substantial, solid, and permanent. In the construction industry, concrete is utilized on a very large scale. It consists of a binder, typically cement, coarse and fine aggregates, and water [1]. Cement is regarded as the most effective binding agent used in concrete. Later, with further advancements in concrete, steel bars were incorporated into concrete to make it more resistant to shear failure; this material is known as reinforced concrete.

This advancement in concrete has enabled the construction of extremely tall and stable structures such as dams, skyscrapers, bridges, and tunnels, making the impossible possible. Due to its high strength and durability, concrete has gained enormous importance. In addition, concrete is the second most widely used material in the world, which demonstrates that its properties and behaviour are of utmost importance [1]. Thus, the quality of the concrete used for construction purposes is of the utmost importance. In the past, many efforts were made to improve the properties of concrete in an effective and efficient manner, which means that concrete should provide the required properties economically and without causing environmental hazards.

It has been demonstrated that the production of industrial waste and by-products such as fly ash, copper slag, and silica fume, among others, is one of the leading causes of environmental problems and dangers. Silica Fume is a by-product of silicon and ferrosilicon alloy production. Also known as micro silica due to its extremely fine particle size of less than 1 micron [3]. In order to achieve compressive strength in concrete, Silica Fume has proven to be one of the most effective replacements in concrete technology. And in order to protect the environment from waste (silica fume), silica fume is being utilized as an effective reuse of waste material or by-product.

On the other hand, manufacturing of cement on the large scale is leading to environmental hazards as one problem and reduction (depletion) of natural resources as another simultaneous problem. This problem has led many researchers to use the industrial waste products as partial replacement for the cement in producing concrete. By this, production of cement on large scale can be reduced and adverse effects on the environment will also be reduced [3]. As such, the research aims to find the optimum dosage of silica fume as partial substitution of cement. Furthermore, to find the effect of silica fume replacement on compressive strength of concrete at different curing stages.

2. Literature Review

Israr Ahmed et al. (2020) [6], compressive strength of roller compacting concrete using silica fume as partial replacement of cement was studied. In this piece of a research, SF replacement was taken as 0, 5, 10 and 15% by weight of cement and results were observed at 7 and 28 days of curing. Mix design ration was kept 1:2:4. Results indicated optimum compressive strength of 32.12 MPa at 5%. While compressive strength was decreasing with further increase in SF and it was noted 30.17 MPa at 15% replacement of SF which is the minimum. Udyan Nagendra et al. (2019) [9], compressive strength of concrete on optimum replacement of silica fume by cement was kept under investigation. SF was ranged from 0% to 15% for concrete cubes. Cubes were examined and cured for 7 and 28 days. Upon successful completion of days, compressive strength could be seen increasing up to certain replacement of SF and after that, decline could be seen in compressive strength. Whereas, water binder ratio was kept 0.45. The maximum compressive strength obtained as 11.5% and 10.8% more than compressive strength of conventional concrete on curing period of 7 and 28 days respectively when using 7.5% SF replacement. After that, scenario changed and compressive strength started decreasing after 7.5%.

Vikas Srivastava et al. (2014) [13], Utilized silica fume in varying proportions to see how it affects the concrete workability and compressive strength made with OPC. SF ranged from 5%, 10%, 15% and up to 35% by weight of OPC and these results were compared with 0% replacement level. Researchers found 5% as the optimum content which increased the compressive strength up to 15% and 18% more than conventional concrete strength for the curing period of 7 and 28 days respectively. However, the slump value marginally improved with increasing content of SF and thus workability.

3. Research Methodology

In this study, the compressive strength of each sample was measured using UTM. The samples were made using a variety of replacements, and they were cured for varying amounts of time (Universal Testing Machine). UTM will continue to apply load until the sample is broken, at which point the maximum load that the sample can withstand will be recorded; this maximum load will be the compressive load. After that, the compressive strength of the sample is calculated by dividing the compressive load by the sample's sectional area. For the compressive strength test, nine cubes measuring 100 by 100 by 100 millimetres each were prepared for each mix. Three cubes were cured for 7, 14, and 28 days, respectively. In light of this, a total of 36 cube specimens were prepared for the compressive strength test that was to be performed for this body of work. Concrete has a 1:2:4 design mix ratio, with a water binder ratio of 0.5, see Table 1.

Table1. Mix Proportions

Mix	Binders	
	Silica Fume	Cement
Mix-1	0%	100%
Mix-2	7%	93%
Mix-3	11%	89%
Mix-4	15%	85%

4. Results and Discussion

The compressive strength data for 7, 14, and 28 days after curing are presented graphically in the graphs. The first graph, which displayed compressive strength for seven days, allowed for the conclusion that the maximum strength was achieved when SF was utilized at a concentration of seven percent. The final result was 19.03 MPa, which is approximately 20.91 percent greater than the typical concrete. After then, a pattern of weakening could be noticed in the strength at the 11 percent and 15 percent replacement levels, which are 17.9 MPa and 17.11 MPa, respectively.

The results acquired after 14 days were not the same as those obtained after 7 days, but they did follow a pattern that was very similar in terms of how much they increased and decreased. After conducting the necessary research and analyzing the results, it was determined that the maximum compressive strength was 23.31 MPa at a 7 percent replacement level. It was determined to be a quantity that was 22.65 percent higher than the typical concrete. However, there was a decrease in strength as the SF moved from 11 percent to 15 percent, and it gave strengths of 23.26 MPa and 21.82 MPa correspondingly. This was due to the fact that the strength was directly proportional to the SF, whereas, the graph of 28 days also followed the similar trend but a different set of values was obtained. When the SF was maintained at 7 percent, it revealed that the maximum compressive strength was 30.11 MPa. It is around 22.98 percent greater than the normal concrete. However, 11 and 15 percent of the sample showed a drop in strength, which was measured at 17.9 and 17.11 MPa correspondingly.

The results that were provided in the graph suggested that there was an increase in the compressive strength of concrete from the level of 0 percent replacement up to the level of 7 percent replacement overall. However, when the replacement level was kept at 11 percent or 15 percent, there was a decline in the material's compressive strength. Every one of the instances followed the same pattern of increasing and decreasing severity. However, the greatest strength was measured when 7 percent of the original material had been replaced in each and every instance of curing. The previous research studies that were carried out similarly came to the conclusion that the maximum compressive strength was achieved while using SF in the range of 7-10 percent. According to the findings of this piece of research, the ideal percentage of replacement for compressive strength is 7 percent. When compared to Mix-3 and Mix-4, it replaces cement at a percentage that is lower than the former. Therefore Mix-2 is found to be more economical whereas Mix-3 and Mix-4 found to be less economical.

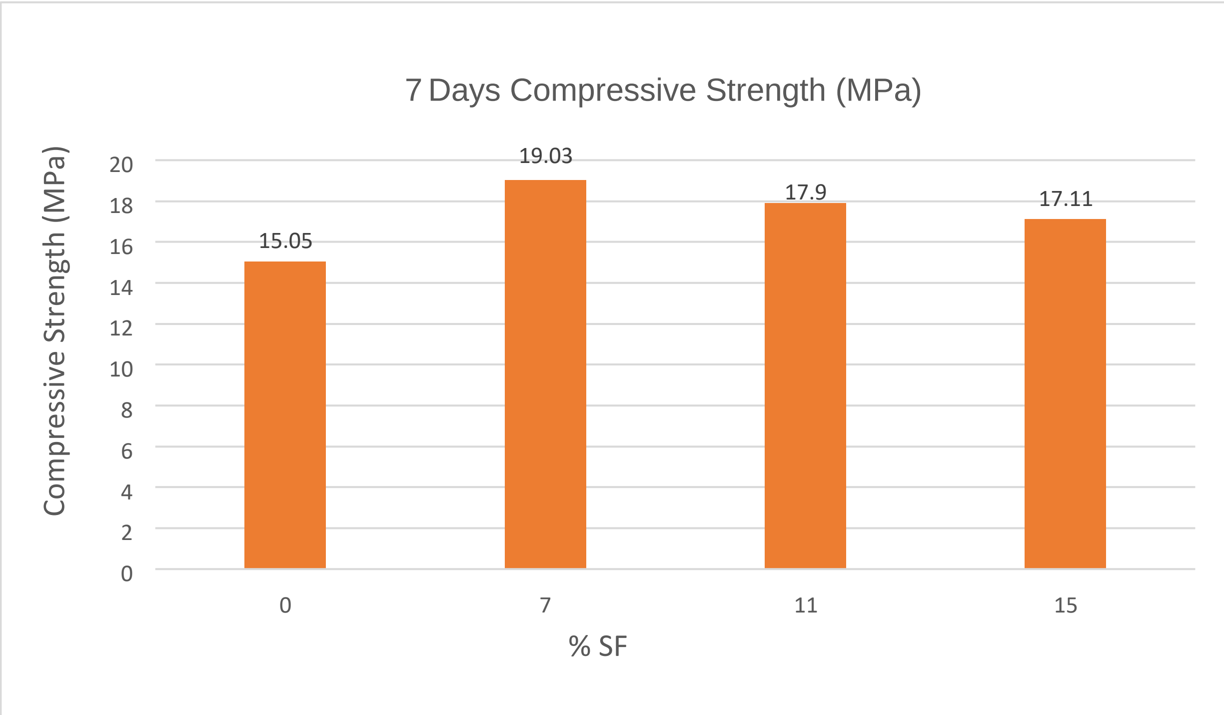

Fig. 1: 7 days curing results

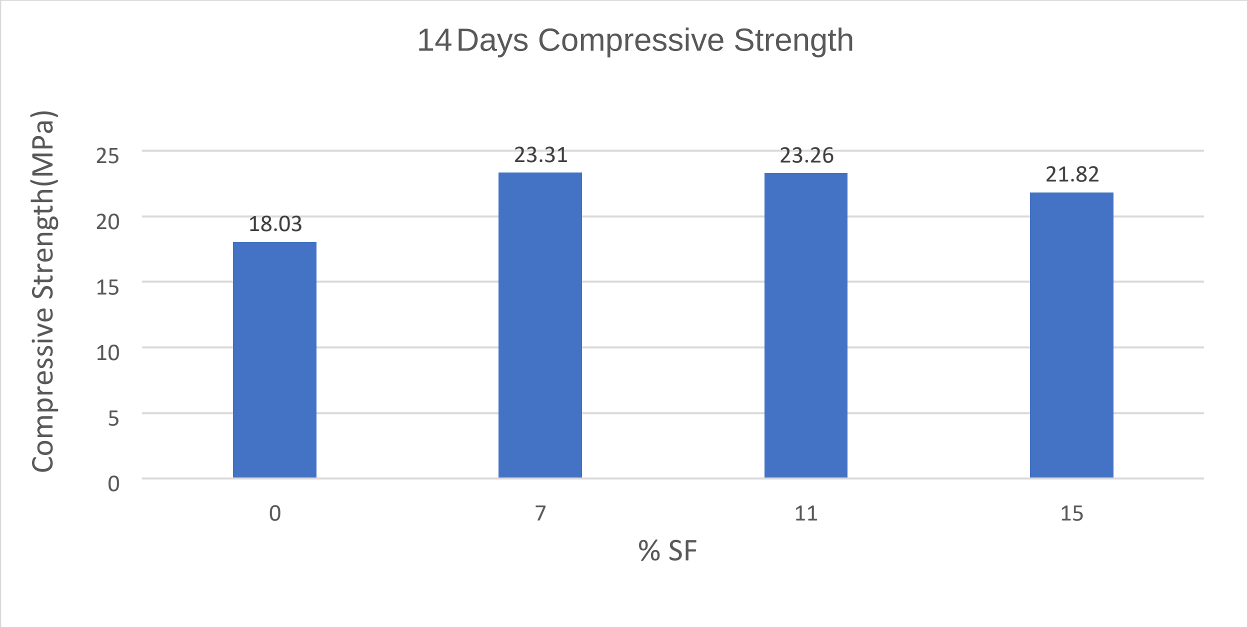

Fig. 2. 14 days curing results.

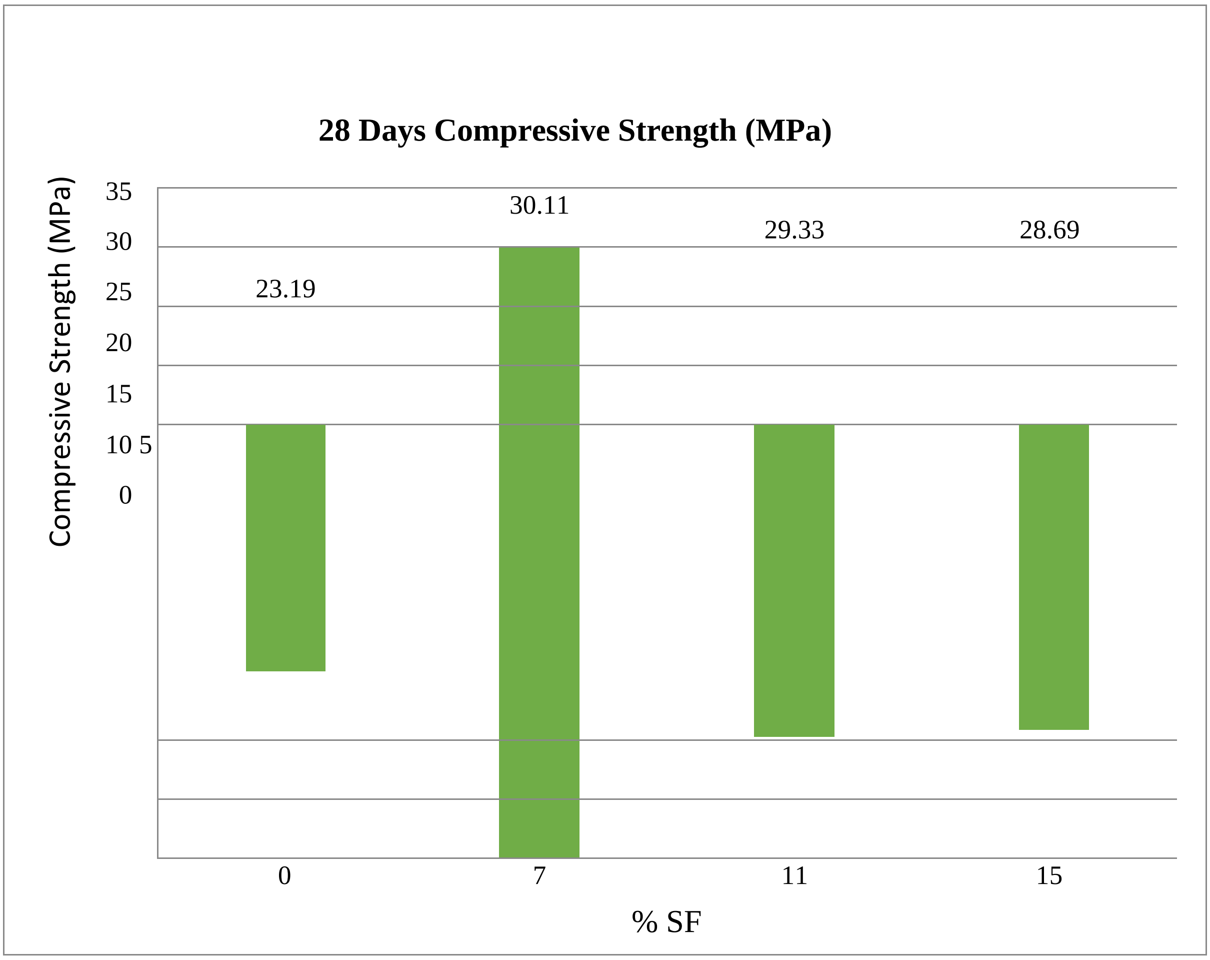

Fig. 3: 28 days curing results

5. Conclusion

The replacement of SF in concrete concluded the increase in compressive strength up to certain limit and then it showed decrease. This scenario is due to the finer size of silica fume particles. Very fine sized particles try to fill up the voids of concrete when it is mixed and compacted. Then it forms a closely packed structure with lesser porosity and which therefore improves the concrete compressive strength. Four different mixes gave results which were similar to the studies carried by research in past. Mix-1 and Mix-2 which used 0% and 7% SF respectively, indicated the increase compressive strength in each case of curing. Whereas Mix-3 and Mix-4 utilizing 11% and 15% respectively, indicated the decrease in strength in each case of curing. The maximum compressive strengths obtained at 7% replacement of SF were 19.03 MPa, 23.31 MPa and 30.11 MPa for 7, 14 and 28 days respectively. Therefore, 7% silica fume content in Mix-2 was found to be the optimum replacement. This replacement showed the maximum compressive strength of 30.11 MPa at 28 days curing period which was about 22.98% higher than the conventional concrete. Conventional concrete (Mix-1) showed the compressive of 23.19 MPa for 28 days curing period.

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ID 74: Exact Solution of Timoshenko Beam Equations Subjected to Varying Loads – a Generalization

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A B S T R A C T

The recent trends in civil engineering and particularly the structural analysis, nowadays, do not only demand use of ancient mathematical tools to better understand the working and stability of structures under different realistic situations, but also concern with the sustainable use of methods to minimize the computational effort and automate the computations to address more complicated structures quickly without compromising on the accuracy. This work emphasizes the utility of mathematical tools for exact profiling and direct analytical expressions for the solution of Timoshenko beam (TB) equations. The usual methods are worked out under different loads on TB equations to finally provide general expressions of rotation and displacement profiles of the beam. The developed exact analytical expressions are not load specific and can be applied directly on any type of load in the realistic sense without having to adopt the usual mathematical methods each time. The exact solutions are obtained for the four most important types of varying loads. MATLAB was used to create a graphical representation of the rotation and displacement parameters of the TB model. The proposed equations are accurate and not approximate and have been validated successfully to produce the expressions which are in line with the existing literature. Thus, a long-term ease-of-approach has been suggested in this study for concrete sustainability in the studies involving the beams.

K E Y W O R D S:

Timoshenko Beam, Exact Solution, Rotation, Displacement, Varying Loads

1. Introduction

The beams are one of the important elements in structures and their careful hybridization in structures, examination and stability play a vital role in safer operations and use of structures and avoiding any collapses. In order to comprehend crucial structural and performance elements of beams subjected to loads, numerous engineers, scientists, and other professionals have developed numerical schemes and tried various methodologies over the course of the history of beam theory [1]. At the beginning of the 20th century, Stephen Timoshenko, a scientist of Ukrainian descent, developed new beam theory [2]. The Timoshenko beam (TB) theory is the name given to this concept in honor of him. Shear deformation and rotational inertia were both taken into consideration by the TB model. Short beams, composite sandwiched beams, and beams that may be pushed at high frequencies are only a few of the different types of beams whose behavior is defined by TB. As a result, the excitation wavelength shortens and reaches to the beam thickness.

Most of the researchers have worked on numerical schemes and modified these schemes to acquire better understanding using approximate solutions of Timoshenko beam model. In [3], authors solved TB problem along with boundary conditions numerically by two non-standard finite difference schemes and locking phenomena was overcome due to uniform meshes. In [4], authors proposed and applied finite difference scheme to obtain numerical solution of Timoshenko beam under constant as well as variable load without facing locking phenomena and discretized system into algebraic sum. In [5], authors proposed an effective computational method to solve Timoshenko beam problem under complex load. This method is modification of inverse finite element method and showed more accurate results when tested on a thin-walled Aluminum beam under four different loads. In [6], authors used the dynamic green function to show the free vibration of an elastically constrained Timoshenko beam on a partly

Winkler basis. For modelling beam structures with diverse boundary conditions, an accurate and direct modelling technique was presented. Due to the Green function results were precise in closed forms. So this technique was more efficient and accurate. Whereas exact analytical solution obtained only by [7], authors developed analytical technique, solved TB problem including boundary conditions, independent of locking phenomena, while two loads were taken, first constant and other one variable. Other researches also worked analytically but for different purposes such as; [8] solve Timoshenko beam theory analytically subjected to normal mode frequency to understand bending vibrations of beam, [9] solved cantilever Timoshenko beam problem analytically taking one end fixed and other end supported by a spring whereas uniform load considered.

The issue with the techniques that have been presented so far in literature is primarily that these were numerical and do not give a precise profile of the problem regarding exact answers. To get a modicum of precision in the findings, the numerical approaches require more accurate values for the perturbation parameter, strictly smaller step sizes, and a significant amount of processing time. For the verification of numerical results we need exact answers. However, in literature only the exact solutions for a fewer loads are available, and there is no direct expression of the solution which is not load specific and which avoids use of the mathematical integrations each time we use it. For this purpose we solve Timoshenko beam model analytically subjected to four most important types of loads along with specified boundary conditions. Earlier, [7] solve TB model analytically subjected to only two loads constant and variable. We extend this concept to other types of loads on the first hand. This is followed by the generalization and validation of the approach.

2. Mathematical Model and Non-dimensionalization

We consider the full resolution Timoshenko beam model described in terms of the differential equations relating the applied load function $p(X)$, shear force $Q(X)$, bending moment $M(x)$, rotation of the cross-section of beam $\theta(X)$ and the deflection of the beam or the traversed displacement of the beam $W(X)$ for a fixed beam of length L, i.e. $X \in (0, L)$ and area of cross-section A. Further the constants $E, I, k, and\ G$ represent Young's modulus of elasticity of beam, moment of inertia, correction factor for shear and modulus of rigidity, respectively, measured in any consistent system of units. However, later on we use the non-dimensionalized model for further simplifications and calculations.

$$-\frac{dQ}{dX} = p \tag{1}$$

$$\frac{dM}{dX} = Q \tag{2}$$

$$\frac{d\theta}{dX} = -\frac{M}{EI} \quad (or)\ -EI\frac{d^2\theta}{dX^2} - Q = 0 \tag{3}$$

$$-\frac{Q}{kGA} + \frac{dW}{dX} - \theta = 0 \tag{4}$$

Since beam is fixed at the end points so boundary conditions can be given as

$$W(0) = W(L) = 0; \qquad \theta(0) = \theta(L) = 0$$

We change the variables to convert the equations (1)-(4) into non-dimensionalized variables using the transformations: $X = xL,\quad Q = \frac{EI\sigma}{L^2}$, $\frac{pL^3}{EI} = f$, $W = wL$. The transformed equations to (1), (3) and (4) are given as (5)-(6), respectively []*:*

$$-\sigma' = f \tag{5}$$

$$-\theta'' - \sigma = 0 \tag{6}$$

$$-\sigma\varepsilon^2 + w' - \theta = 0 \tag{7}$$

Where $\varepsilon^2 = \frac{EI}{kGAL^2}$ is the parameter which is proportional to ratio of the thickness to the length of the beam.

The model (5)-(7) is referred as the non-dimensionalized TB model subject to the boundary conditions

$$w(0) = w(L) = 0; \qquad \theta(0) = \theta(L) = 0$$

3. Main Contributions towards the Exact Analytical Solution of TB Model with Generalization

We first seek the load specific expressions for the rotation and displacement profiles of the fixed TB model as defined in (5)-(7) under following four cases.

$\text{Case} - \text{I: When load is " Triangular" } f = 100x, \dots\dots\dots\ 0 \le x \le 1$

$\text{Case} - \text{II: When load is Trapezoidal } f = 10 + 100x, \dots\dots\dots\ 0 \le x \le 1$

$\text{Case} - \text{III: When load is "Square" } f = 100x^2, \dots\dots\dots\ 0 \le x \le 1$

$\text{Case} - \text{IV: When load is "Circular" } f = 100(4-x)(4+x), \dots\dots\dots\ 0 \le x \le 1$

Using these load cases in (5)-(7) and integrating successively, we can get the exact expressions of the solution for rotation and displacement parameters, which is also the usual practice. For example, in case-III, we have the following process to taylor to such expressions usually.

With $f = 100x^2$ in (5) we have: $\sigma' = -100x^2$, which after integration with respect to x leads to:

$$\sigma(x) = -\frac{100}{3}x^3 + c_1$$

Using expression of $\sigma(x)$ in (6) we have: $\theta''^{(x)} = \frac{100}{3}x^3 - c_1$. Integrating the equation throughout with respect to x twice leads to the following expressions:

$$\theta'(x) = \frac{100}{12}x^4 - c_1 x + c_2$$

$$\theta\,(x) = \frac{100}{60}x^5 - \frac{c_1 x^2}{2} + c_2 x + c_3$$

Imposing the boundary conditions: $\theta(0) = 0$, we have $c_3 = 0$. So,

$$\theta(x) = \frac{100}{60}x^5 - \frac{c_1 x^2}{2} + c_2 x$$

Imposing the boundary condition: $\theta(1) = 0$, leads to the equation (8) for other two constants:

$$-c_1 + 2c_2 = -\frac{10}{3} \qquad (8)$$

Using expressions of $\theta(x)$ and $\sigma(x)$ in (7) we have after integrations:

$$w(x) = \frac{100}{360}x^6 + c_1\left(x\varepsilon^2 - \frac{x^3}{6}\right) + c_2\frac{x^2}{2} - \frac{100\varepsilon^2}{12}x^4 + c_4$$

Imposing the condition: $w(0) = 0$, gives $c_4 = 0$. So,

$$w(x) = \frac{100}{360}x^6 + c_1\left(x\varepsilon^2 - \frac{x^3}{6}\right) + c_2\frac{x^2}{2} - \frac{100\varepsilon^2}{12}x^4$$

Imposing the last condition: $w(1) = 0$, we have the accompanying equation (9) to (8) above in two undetermined coefficients yet, which is:

$$c_1(6\varepsilon^2 - 1) + 3c_2 = 50\varepsilon^2 - \frac{5}{3} \qquad (9)$$

Solving (8) and (9) simultaneously we obtain:

$$c_1 = \frac{20(15\varepsilon^2 + 1)}{3(12\varepsilon^2 + 1)}, \quad c_2 = \frac{5(1 + 18\varepsilon^2)}{3(12\varepsilon^2 + 1)}$$

Thus, for the square load in case – III, we have the following exact solution profiles for the rotation and displacement of the considered fixed TB:

$$\theta(x) = \frac{100}{60}x^5 - \frac{20(15\varepsilon^2 + 1)}{3(12\varepsilon^2 + 1)}\frac{x^2}{2} + \frac{5(1 + 18\varepsilon^2)}{3(12\varepsilon^2 + 1)}x \tag{10}$$

$$w(x) = \frac{5}{18}x^6 - \frac{100\varepsilon^2}{12}x^4 - \frac{10(15\varepsilon^2 + 1)}{9(12\varepsilon^2 + 1)}x^3 + \frac{5(1 + 18\varepsilon^2)}{6(12\varepsilon^2 + 1)}x^2 + \frac{20(15\varepsilon^2 + 1)\varepsilon^2}{3(12\varepsilon^2 + 1)}x \tag{11}$$

In the same way, the results are immediate for the remaining cases, and are all summarized in Table 1.

Table 1. Exact expressions for rotation and displacement of fixed TB with L=1 under various load cases I-IV

Load case	Rotation profile $\theta(x)$	Displacement profile $w(x)$
I	$\frac{25x^4}{6} - \frac{5(40\varepsilon^2 + 3)}{2(1 + 12\varepsilon^2)}x^2 + \frac{10(15\varepsilon^2 + 1)}{3(1 + 12\varepsilon^2)}x$	$\frac{5x^5}{6} - \frac{1}{6}\left(\frac{5(40\varepsilon^2 + 3)}{(1 + 12\varepsilon^2)} + 100\varepsilon^2\right)x^3 + \frac{5(15\varepsilon^2 + 1)}{3(1 + 12\varepsilon^2)}x^2 + \frac{5(40\varepsilon^2 + 3)}{(1 + 12\varepsilon^2)}\varepsilon^2 x$
II	$\frac{25}{6}x^4 + 5\frac{x^3}{3} - \frac{10(1 + 13\varepsilon^2)}{(1 + 12\varepsilon^2)}x^2 + \frac{5(5 + 72\varepsilon^2)}{6(1 + 12\varepsilon^2)}x$	$5\frac{x^4}{12} + \frac{5}{6}x^5 - \left(\frac{10(1 + 13\varepsilon^2)}{3(1 + 12\varepsilon^2)} + \frac{50\varepsilon^2}{3}\right)x^3 + 5\left(\frac{(5 + 72\varepsilon^2)}{12(1 + 12\varepsilon^2)} - \varepsilon^2\right)x^2 + \frac{20(1 + 13\varepsilon^2)\varepsilon^2}{(1 + 12\varepsilon^2)}x$
III	$\frac{100}{60}x^5 - \frac{20(15\varepsilon^2 + 1)}{3(12\varepsilon^2 + 1)}\frac{x^2}{2} + \frac{5(1 + 18\varepsilon^2)}{3(12\varepsilon^2 + 1)}x$	$\frac{5}{18}x^6 - \frac{100\varepsilon^2}{12}x^4 - \frac{10(15\varepsilon^2 + 1)}{9(12\varepsilon^2 + 1)}x^3 + \frac{5(1 + 18\varepsilon^2)}{6(12\varepsilon^2 + 1)}x^2 + \frac{20(15\varepsilon^2 + 1)\varepsilon^2}{3(12\varepsilon^2 + 1)}x$
IV	$800\frac{x^3}{3} - 5\frac{x^5}{3} - \frac{10(1425\varepsilon^2 + 119)}{3(1 + 12\varepsilon^2)}x^2 + \frac{5(942\varepsilon^2 + 79)}{3(1 + 12\varepsilon^2)}x$	$-5\frac{x^6}{18} + (200 + 25\varepsilon^2)\frac{x^4}{3} - \frac{10(1425\varepsilon^2 + 119)}{9(1 + 12\varepsilon^2)}x^3 + \left(\frac{5(942\varepsilon^2 + 79)}{6(1 + 12\varepsilon^2)} - 800\varepsilon^2\right)x^2 + \frac{20(1425\varepsilon^2 + 119)\varepsilon^2}{3(1 + 12\varepsilon^2)}x$

Proposed protocol for generalization

We observe for the most realistic cases the load functions are regular or differentiable and integrable polynomials or even in the non-linear cases the load function can sufficiently be expressed in terms of Taylor's series expansion. This leads us to consider a generalized load function defined in (12) instead of specific load function as in cases I-IV above and Table 1. The generalized load function allows to obtain the expressions of rotation and displacement profiles of the TB model considered here for any load ultimately.

$$f(x) = \sum_{i=0}^{n} a_i x^i \tag{12}$$

In (12) even if the load function is not known explicitly in mathematical form but only known at discrete points across the span of the beam, the series on right side would converge to expected polynomial approximation of $f(x)$

which will converge to the load and also be satisfied at all interpolatory points known initially. Also, in the cases when more than one types of load are subjected to beam throughout the span, the generalized weight function in (12) can be used for the individual ranges and then the full resolution analysis can be successfully reached at through (12).

Assuming a single-piece or one of the many-pieces of a thoroughly or sectionally continuous, differentiable and integrable load function $f(x)$ in the polynomial expansion as defined in (12), we can proceed through integrations in the usual way as demanded in (5)-(7) but on a generalized function instead, we claim to arrive at the generalized exact analytical expressions, (13) and (14) for the rotation and displacement profiles, respectively, of a fixed TB model (5)-(7) of finite length L in the non-dimensionalized form for any load function $f(x)$ in the form (12):

$$\theta(x) = \sum_{i=0}^{n+3} \frac{a_i x^{i+3}}{(i+1)(i+2)(i+3)} - c_1\left(\frac{x^2}{2}\right) + c_2 x \tag{13}$$

$$w(x) = \sum_{i=0}^{n+4} \frac{a_i x^{i+4}}{(i+1)(i+2)(i+3)(i+4)} + c_1\left(x\varepsilon^2 - \frac{x^3}{6}\right) + c_2\frac{x^2}{2} - \sum_{i=0}^{n+2} \frac{a_i x^{i+2}}{(i+1)(i+2)}\varepsilon^2 \tag{14}$$

Where

$$c_1 = 6\sum_{i=0}^{n+3} \frac{a_i (L)^{i+3}}{(i+1)(i+2)(i+3)(L^2+12\varepsilon^2)} + 12\sum_{i=0}^{n+2} \frac{a_i L^{i+1}}{(i+1)(i+2)(L^2+12\varepsilon^2)}\varepsilon^2 - 12\sum_{i=0}^{n+4} \frac{a_i L^{i+3}}{(i+1)(i+2)(i+3)(i+4)(L^2+12\varepsilon^2)} \tag{15}$$

$$c_2 = -\frac{2(6\varepsilon^2 - L^2)}{12\varepsilon^2 + L^2}\sum_{i=0}^{n+3} \frac{a_i (L)^{i+2}}{(i+1)(i+2)(i+3)} + 6\sum_{i=0}^{n+2} \frac{a_i L^{i+2}}{(i+1)(i+2)(12\varepsilon^2+L^2)}\varepsilon^2 - 6\sum_{i=0}^{n+4} \frac{a_i L^{i+4}}{(i+1)(i+2)(i+3)(i+4)(12\varepsilon^2+L^2)} \tag{16}$$

In (13)-(16),

a_i's are coefficients of applied load.

c_1 and c_2 are arbitary constants of solution which can be determined directly using $(15) - (16)$.

L is length of beam.

n is polynomial degree of applied load function.

4. Results, Discussion and Validation

Here, we exhibit the graphical profiles of the rotation and displacement profiles of the fixed TB model with $L = 1$ under the load cases I-IV defined in Table 1. Further the effect of parameter ε for some of its values is also examined. Finally, the generalized expressions as in (13)-(16) are validated in parallel to the well-known equations for elastic beams extensively found in literature.

Using the exact solutions of triangular load (Case-I), we have Fig. (1) and Fig. (2), respectively, for rotation and displacement subject to different values of "ε". As the value of "ε" increases, the rotation of the beam increases and displacement is stable for having small possible values, whereas it becomes unstable for having larger values. For each *value of*, the graph of rotation gives positive and negative values of rotation over the length of the beam. Displacement is positive over the entire length and is maximal between x = 0.5 and x = 0.7.

Fig. (3) and Fig. (4) represent solutions of the Timoshenko beam model under trapezoidal load (case-II) for distinct values of "ε". Here we have positive as well as negative values of rotation. Both values increase when the value of "ε" is increased. Displacement is sensitive to the values of "ε". Between x=0.5 and x=0.7 displacement is approaching to 8×10^4 when "$\varepsilon = 100$ ".

For the square load, we have solutions in their graphical distributions in fig.(5) and fig.(6) for case-III. We can deduce that parameter "ε" have an effect on rotation and displacement. Larger the value of "ε" greater the rotation and displacement of the beam. For $x \in (0,0.5)$, we have positive value of $\theta(x)$ and negative values for $x \in (0.5,1)$. Since load is square so it has larger weight on half end points so the graph of displacement is tilted to the right hand side see fig(6).

When the circular load (case-IV) is applied to the beam, we have solutions presented graphically in fig. (7) and fig.(8), respectively. The rotation of the beam is the same for all distinct values of "ε", since all the graphs are coincident. Displacement at the middle of the length of the beam is maximum. This is a clear representation of a circular load. Figures (1)-(8) clearly demonstrate the sensitivity of the TB modelunder the considered specifications for four types of load.by varying values of "ε".

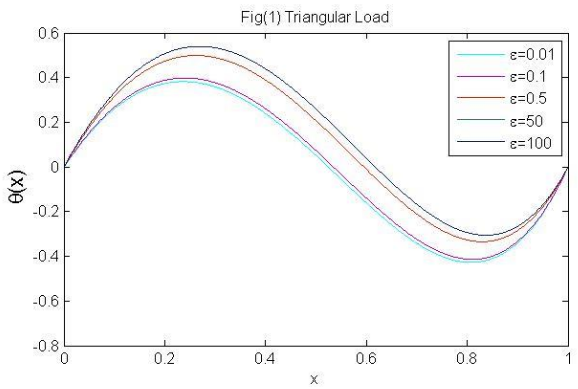

Figure 1. Rotation profile of the considered TB model under Triangular load for different $\boldsymbol{\varepsilon}$

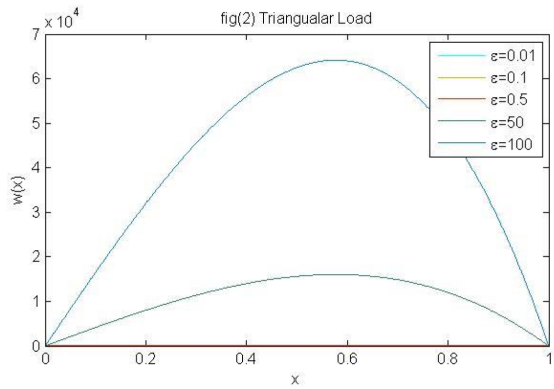

Figure 2. Displacement profile of the considered TB model under Triangular load for different $\boldsymbol{\varepsilon}$

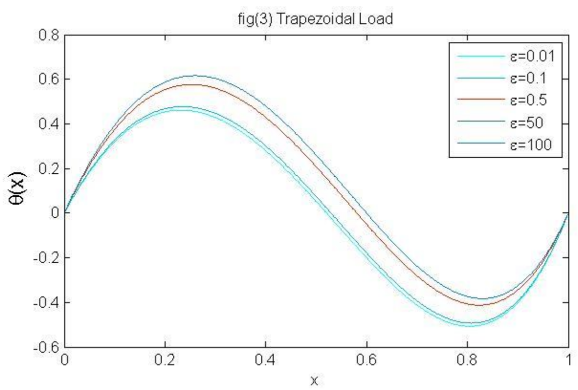

Figure 3. Rotation profile of the considered TB model under Trapezoidal load for different $\boldsymbol{\varepsilon}$

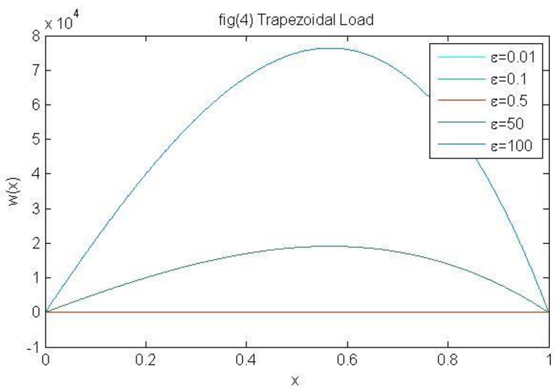

Figure 4. Displacement profile of the considered TB model under Trapezoidal load for different $\boldsymbol{\varepsilon}$

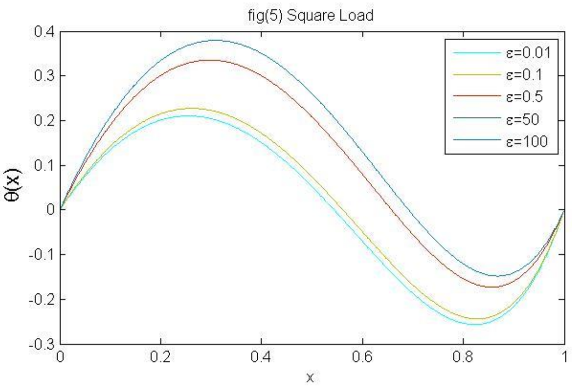

Figure 5. Rotation profile of the considered TB model under square load for different $\boldsymbol{\varepsilon}$

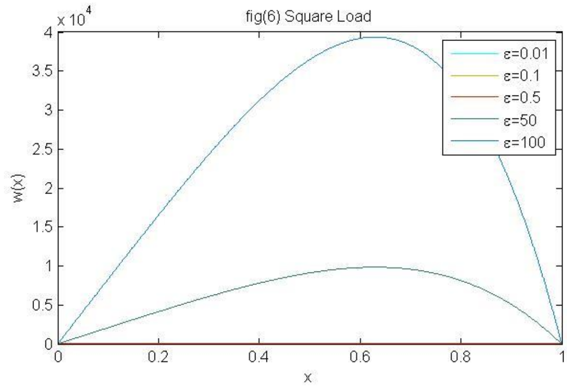

Figure 6. Displacement profile of the considered TB model under square load for different $\boldsymbol{\varepsilon}$

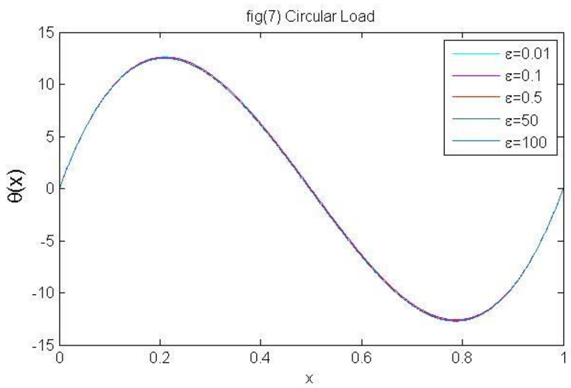

Figure 7. Rotation profile of the considered TB model under circular load for different $\boldsymbol{\varepsilon}$

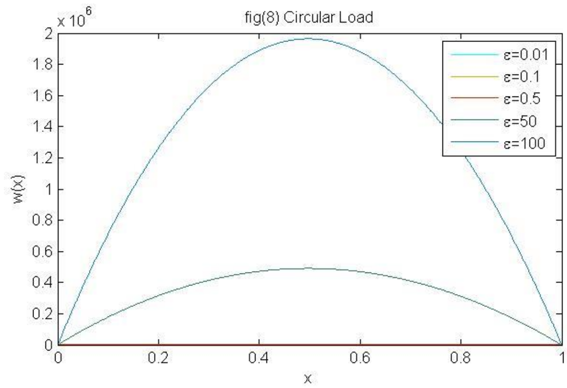

Figure 8. Displacement profile of the considered TB model under circular load for different $\boldsymbol{\varepsilon}$

The generalized analytical solution profiles from (13)-(14) with constants in (15)-(16) successfully lead to the expressions in Table 1 if the values selected are chosen as explained in Table 2.

Table 1. Exact expressions for rotation and displacement of fixed TB with L=1 under various load cases I-IV

Load case	$f(x)$	n	a_0	a_1	a_2	$a_3 = \cdots$	L
I	$100x$	1	0	100	0	0	1
II	$10 + 100x$	*1*	*10*	*100*	*0*	*0*	*1*
III	$100x^2$	*2*	*0*	*0*	*100*	*0*	*1*
IV	$100(4-x)(4+x)$	2	1600	0	-100	0	1

Finally, for validation since the theory of existence and stability of the elastic beam is well developed so far in literature and texts in structural engineering and that the TB model can be restricted to tend to the usual Euler-Bernoulli type elastic beam model if we assume that the rotation is nothing else than the slope of the displacement (deflection). We now validate the consistency of the compact form generalized exact analytical solutions for the considered fixed TB model by using the same approach on fixed elastic beam governed by the simpler relations (17)-(19) with the similar boundary conditions in usual dimensionalized form:

$$\frac{d^2M}{dx^2} = w \tag{17}$$

$$\frac{d\theta}{dx} = \frac{M}{EI} \tag{18}$$

$$\frac{d^2v}{dx^2}=\frac{M}{EI} \tag{19}$$

The boundary conditions due to fixed ends are: $\theta(0)=0, \theta(L)=0, v(0)=0, v(L)=0$

In (17)-(19), w is the load function, other variables are defined as earlier with restriction that $v'(x)=\theta(x)$ and $v=w$. This means that we have ignored the rotation effect of TB model and that the displacement is now denoted by $v(x)$ for brevity and $\theta(x)$ is simply the slope of deflection/displacement of the beam. After applying same strategy that we applied on TB model, we get general analytical solution for (17)-(19), the expressions for deflection and its slope are:

$$v=\frac{1}{EI}\left\{\sum_{i=0}^{n+4}\frac{a_i x^{i+4}}{(i+1)(i+2)(i+3)(i+4)}+c_1\left(\frac{x^3}{6}\right)+c_2\left(\frac{x^2}{2}\right)\right\} \tag{20}$$

$$\theta=\frac{1}{EI}\left\{\sum_{i=0}^{n+3}\frac{a_i x^{i+3}}{(i+1)(i+2)(i+3)}+c_1\left(\frac{x^2}{2}\right)+c_2 x\right\} \tag{21}$$

The constants of integration are:

$$c_1=12\sum_{i=0}^{n+4}\frac{a_i L^{i+1}}{(i+1)(i+2)(i+3)(i+4)}-6\sum_{i=0}^{n+3}\frac{a_i L^{i+1}}{(i+1)(i+2)(i+3)} \tag{22}$$

$$c_2=2\sum_{i=0}^{n+3}\frac{a_i L^{i+2}}{(i+1)(i+2)(i+3)}-6\sum_{i=0}^{n+4}\frac{a_i L^{i+2}}{(i+1)(i+2)(i+3)(i+4)} \tag{23}$$

When we apply uniform distributed load on the beam, then $we\ take\ w=a$, a is a constant. Also, we have:

$$n=0, a_0=a, \qquad a_1=a_2=\cdots a_n=0$$

Simplifying (20)-(23) in these specifications we have:

$$c_1=12\sum_{i=0}^{0+4}\frac{a_i L^{i+1}}{(i+1)(i+2)(i+3)(i+4)}-6\sum_{i=0}^{0+3}\frac{a_i L^{i+1}}{(i+1)(i+2)(i+3)}$$
$$=\frac{12a_0L}{(0+1)(0+2)(0+3)(0+4)}-\frac{6a_0L}{(0+1)(0+2)(0+3)}$$

$$c_1=\frac{12aL}{24}-\frac{6aL}{6}=\frac{aL}{2}-aL=-\frac{aL}{2}$$

$$c_2=2\sum_{i=0}^{0+3}\frac{a_i L^{i+2}}{(i+1)(i+2)(i+3)}-6\sum_{i=0}^{0+4}\frac{a_i L^{i+2}}{(i+1)(i+2)(i+3)(i+4)}$$
$$=\frac{2a_0L^2}{(0+1)(0+2)(0+3)}-\frac{6a_0L^2}{(0+1)(0+2)(0+3)(0+4)}$$

$$c_2=\frac{2aL^2}{6}-\frac{6aL^2}{24}=aL^2\left(\frac{1}{3}-\frac{1}{4}\right)=\frac{aL^2}{12}$$

$$v=\frac{1}{EI}\left\{\sum_{i=0}^{0+4}\frac{a_i x^{i+4}}{(i+1)(i+2)(i+3)(i+4)}+c_1\left(\frac{x^3}{6}\right)+c_2\left(\frac{x^2}{2}\right)\right\}$$
$$=\frac{1}{EI}\left\{\frac{a_0x^{0+4}}{(0+1)(0+2)(0+3)(0+4)}+c_1\left(\frac{x^3}{6}\right)+c_2\left(\frac{x^2}{2}\right)\right\}$$

$$v=\frac{1}{EI}\left\{\frac{ax^4}{24}+\left(-\frac{aL}{2}\right)\left(\frac{x^3}{6}\right)+\left(\frac{aL}{12}\right)\left(\frac{x^2}{2}\right)\right\}=\frac{1}{EI}\left\{\frac{ax^4}{24}-\frac{aLx^3}{12}+\frac{aL^2x^2}{24}\right\}$$

$$v = \frac{a}{24EI}\{x^4 - 2Lx^3 + L^2x^2\} \tag{24}$$

$$\theta = \frac{1}{EI}\left\{\sum_{i=0}^{0+3}\frac{a_i x^{i+3}}{(i+1)(i+2)(i+3)} + c_1\left(\frac{x^2}{2}\right) + c_2 x\right\} = \frac{1}{EI}\left\{\frac{a_0 x^{0+3}}{(0+1)(0+2)(0+3)} + \left(-\frac{aL}{2}\right)\left(\frac{x^2}{2}\right) + \left(\frac{aL^2}{12}\right)x\right\}$$

$$\theta = \frac{1}{EI}\left\{\frac{ax^3}{6} - \frac{aLx^2}{4} + \frac{aL^2x}{12}\right\} = \frac{a}{12EI}\{2x^3 - 3Lx^2 + L^2x\} \tag{25}$$

$For\ maximum\ defelction, v' = 0$, and we solve

$$\frac{a}{24EI}\{4x^3 - 6Lx^2 + 2L^2x\} = 0\ (or) 4x^3 - 6Lx^2 + 2L^2x = 0$$

It simplifies to: $x(2x - L)(x - L) = 0$.

So, critical points are: $x = 0, x = \frac{L}{2}, x = L$. The double derivative test produces:

$$v'' = \frac{a}{24EI}\{12x^2 - 12Lx + 2L^2\}$$

$$v''(0) = \frac{a}{24EI}\{2L^2\} > 0, \qquad mimima$$

$$v''\left(\frac{L}{2}\right) = \frac{a}{24EI}(3L^2 - 6L^2 + 2L^2) = \frac{a}{24EI}(-L^2) < 0, \qquad maxima\ occurs\ at\ \frac{L}{2}$$

$$v''(L) = \frac{a}{24EI}(12L^2 - 12L^2 + 2L^2) = \frac{a}{24EI}(2L^2) > 0, minima$$

Which is sufficient to show that the $imum\ deflection\ occurs\ at\ x = \frac{L}{2}$, which is:

$$v_{max} = v\left(\frac{L}{2}\right) = \frac{a}{24EI}\left\{\left(\frac{L}{2}\right)^4 - 2L\left(\frac{L}{2}\right)^3 + L^2\left(\frac{L}{2}\right)^2\right\} = \frac{a}{24EI}\left(\frac{L^4}{16} - \frac{L^4}{4} + \frac{L^4}{4}\right)$$

$$v_{max} = \frac{aL^4}{384EI} \tag{26}$$

The expressions in (24)-(26) clearly show that the specific equations obtained from the generalized analytical solution of the beam obtained through our approach is same as found in literature and standard texts of the theory of structures. Hence, the similar also holds for the TB model expressions devised in this study.

5. Conclusion

In this paper, we have derived exact solution of Timoshenko beam model for four distinct applied loads: Triangular, Trapezoidal, Square and circular first to be able to suggest generalized exact analytical solution without having to repeat the process each time for specific loads. We have devised and computed accurate solutions for rotation and displacement using these loads. We draw the conclusion that there is no locking phenomena after analyzing these findings. Results obtained subjected to five different values of ε, which is sole dependent parameter of the problem. The outcomes demonstrate the formulation's applicability to increasingly challenging beam deformation problems. The generalized expressions from this study will save invaluable time and computational effort to solve similar problems in future once the exact expressions are already available without any specifications of load as in this study. The case with varying types of support can be the subject of future research.

6. Acknowledgment

We acknowledge the efforts of conference organizers, reviewers for their valuable feedback and our university which encompasses an ideal mixture of scientists, mathematicians and engineers to solve the problems of real world in sustainable way and from every view-point.

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ID 84: Experimental Investigation of Mechanical and Microstructural Properties of Concrete Containing Bentonite and Dolomite as a Partial Replacement of Cement

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A B S T R A C T

In this study, the effect of bentonite (BT) and dolomite (DT) on the mechanical and microstructural properties of concrete was evaluated on nine mixes. Cement was replaced with bentonite and dolomite by weight with varying mix ratios. The mixes are divided as M1 (Control mix), M2 (2.5% BT), M3 (2.5% DT), M4 (5% BT), M5 (5% DT), M6 (10% BT), M7 (10% DT), M8 (2.5% BT and 2.5% DT), and M9 (5% BT and 5% DT). Concrete specimens were subjected to mechanical and microstructural analysis tests. Mechanical test results show that the addition of bentonite (2.5%, 5%, and 10%) leads to an increase in compressive strength (6.31%, 8.94%, and 13.15%) respectively. Similarly, the addition of 2.5% and 5% dolomite enhanced compressive strength by 10.52%, and 8.94% respectively, however, the addition of 10% dolomite reduced compressive strength by 6.8%. Replacement of cement with dolomite and bentonite individually also showed a small contribution to flexural and split tensile strength. Microstructural analysis shows that the addition of bentonite and dolomite filled the microstructure and refined the internal pores contributing to compressive strength. In addition, the replacement of cement with bentonite and dolomite enhanced the formation of CSH gel.

K E Y W O R D S:

Bentonite, Dolomite, Mechanical Properties, Microstructural Analysis

1. Introduction

The production of Portland cement has significantly increased to a large scale due to rapid infrastructure developments which have become a threat to the environment and sustainability. The depletion of raw materials and aggregates has imparted adverse effects on the environment. Pakistan being a developing country is facing serious threats of global warming and the cost of cement is also high. It is estimated that the demand for aggregates could reach up to 47 billion tonnes per year by the end of 2023 [1]. The production of cement requires an immense amount of energy to attain the required temperature (1450°C) [2]. It is estimated that the production of cement adds almost 7% to total emissions of carbon dioxide worldwide which is considered an important source of global warming [3]. The use of different pozzolans in concrete has increased in recent years due to their special characteristics such as high sulfate resistance, low heat of hydration, low permeability, and cementitious properties [4], [5]. Bentonite is a naturally available pozzolanic material found in Pakistan. It is estimated that over 36 million tons of bentonite are available in some districts of Pakistan which can be readily used as a natural pozzolana in concrete [6]. The bentonite can be used in concrete as a binder which improves early strength and plasticity. The study conducted by Memon et al.[3] and Mirza et al.[7] advocate the potential replacement of cement with bentonite which can increase mechanical the properties of concrete. The addition of dolomite in concrete also enhances the mechanical and microstructural properties of concrete. Dolomite contains a high concentration of Magnesium and Calcium carbonate which gives early strength and reduces the water-cement ratio which helps to improve the workability of concrete [8]. The study shows that adding 5% dolomite to concrete enhances concrete's crushing and tensile strength [9]. The addition of dolomite enhances the hardening properties of concrete and fills microstructural pores. Small particles of dolomite fill the pores due to its plastic nature and enhance the strength of concrete [10].

The study aims to analyze the effect of bentonite and dolomite on the mechanical properties of concrete reinforced with different dosages of PPF. In this study, cement was replaced with varying percentages of bentonite and dolomite. Bentonite and dolomite dust (powder) was obtained as a byproduct from the Kamsar crushing plant located at 2-3Km from the city of Muzaffarabad, the capital of Azad Jammu and Kashmir. The bentonite and dolomite are obtained at a large scale as a by-product from crushing plants which pose severe environmental threats to the residents of Muzaffarabad. The production of dust creates environmental pollution in Muzaffarabad and also contaminates water. Exposure to bentonite and dolomite dust may cause skin irritation and respiratory problems. A large quantity of these raw materials are produced at the site and their disposal is a grave concern. A very small quantity of dolomite is been used and recycled due to a lack of research. The study of existing literature shows there are very limited studies on the combined effect of bentonite and dolomite in concrete [7-10]. Therefore the replacement of cement with bentonite and dolomite was carried out to find an alternative binding agent that could help for sustainable construction. Bentonite and dolomite were added to concrete with different percentages and then concrete specimens were tested to determine compressive strength, flexural strength, and split tensile strength. In addition, the microstructural study of concrete samples was performed by using SEM. This study would help to determine the microstructural changes in concrete after the addition of bentonite and dolomite. Moreover, this study will contribute towards the development of a sustainable solution to the construction industry that is not only cost-effective but also has several positive environmental impacts.

2. Experimental Program

2.1. Materials & Mix Proportions

The cement (ASTM Type I) used in this research follows the requirements of (ASTM C150) [11]. Bentonite and dolomite were obtained from the Kamsar crushing plant located at 2-3Km from the city of Muzaffarabad. The maximum nominal sizes of fine and coarse aggregates were recorded as 4.75mm and 19mm respectively. Sieve analysis of fine aggregates was done according to the guidelines of ASTM C136/C136M-19[12]. Concrete was cast into nine different mixes having different mix ratios of bentonite and dolomite (see Figure 1, 2 and Table 3). The details of the mix proportion of different mixes are shown in Table 1.

Table 1. Mix proportion of concrete mixes.

Mix	w/c Kg/m^3	Water Kg/m^3	Cement Kg/m^3	Sand Kg/m^3	Coarse Agg. Kg/m^3	Bentonite %	Dolomite %
M1	0.55	113	205	414	856	-	-
M2	0.55	113	205	414	856	2.5	-
M3	0.55	113	205	414	856	-	2.5
M4	0.55	113	205	414	856	5	-
M5	0.55	113	205	414	856	-	5
M6	0.55	113	205	414	856	10	-
M7	0.55	113	205	414	856	-	10
M8	0.55	113	205	414	856	2.5	2.5
M9	0.55	113	205	414	856	5	5

Fig. 1: Casting of specimens

Fig. 2: Concrete specimens of different mixes.

Table 2: Chemical composition of cement, bentonite, and dolomite.

OXIDES	OPC (%WT)	BENTONITE(%WT)	DOLOMITE DUST(%WT)
SiO_2	55.55	54.5	17.6
Al_20_3	32.93	19.33	2.24
Fe_20_3	3.12	4.87	3.01
MgO	1.42	3.86	1.6
CaO	4.64	1.54	51.45
Na_2O	0.3	0.62	….
K_2O	1.3	0.45	2.01
MnO	…	….	0.03
TiO	….	0.33	0.36

3. Testing Procedure

The compressive strength of concrete cubes was determined according to the guidelines of EN-12390 [13]. Specimens were loaded by applying uniform load through a horizontal rubber pad. Adequate safety precautions were taken to prevent the exposure of bentonite and dolomite to hands and eyes during mixing. Compressive strength was determined by using a standard cube (150mm × 150mm × 150mm). The flexural strength of concrete beams was determined as per guidelines given by ASTM C78/C78M [14]. The beams of standard size (100×100×500) mm were used to obtain the flexural strength of concrete. Concrete cylinders having a size of (150×300) mm were used to determine split tensile strength according to the specifications of ASTM C496/ C496M-17 [15]. The microstructural properties of concrete samples were determined by using spectral electron microscopy (SEM). The SEM images of the concrete sample were taken at the resolution of 10 - 100 µm.

4. Results and Discussions

4.1. Compressive strength

The compressive strength of concrete specimens was determined after 7, 14, and 28 days of casting. There was a small change in the strength of the concrete after 7 days however, the difference in strength was evident at 14 and 28 days as compared to the control sample. The results obtained for compressive strength are shown in Fig 3. Study shows that the addition of bentonite by 2.5%, 5%, and 10% enhanced compressive strength by 2.7%, 8.3%, and 12.2% respectively after 14 days of casting. Similarly, the addition of bentonite by 2.5%, 5%, and 10% enhanced compressive strength by 6.3%, 8.9%, and 13.15% respectively after 28 days of casting. The increase in the compressive strength of concrete is attributed due to the pozzolanic reaction of bentonite with cement [16]. The reaction of calcium hydroxide and kaoline accelerates the formation of C-S-H gel which enhances the mechanical properties of concrete [10]. The study conducted by Inzamam Ul Haq et al. [1] shows that the addition of 10% enhances the compressive strength of concrete. S. Taklymi [17] confirmed that the replacement of cement with kaoline by 2/7% can increase compressive strength up to 6%. Results obtained in this study reveal that the addition of a small amount of dolomite also positively impacted compressive strength. The concrete mixes containing 2.5% and 5% dolomite exhibited 10.5% and 8.4% increases in compressive strength respectively when specimens were tested at 28 days. The improvement in compressive strength due to the addition of dolomite is regarded due to its filling effect which improved the density of microstructure by filling pores. Experimental results obtained in this study show that the addition of 10% dolomite in concrete reduced its compressive strength by 6.8%. Similarly, the concrete mixes M8 (2.5% BT and 2.5% DT) and M9 (5% BT and 5% DT) showed 18% and 24.7% less strength respectively as compared to the control mix. The trend of reduction in compressive strength is due to incomplete reaction as a result of the agglomeration of bentonite and dolomite which hindered hydration reaction which is also evident in microstructural images. The results derived from this study are in line with similar studies [18], [19]. Therefore, the results obtained for compressive strength suggest that optimum dosages of bentonite and dolomite for compressive strength are 10% and 5% respectively which can be used in concrete for affordable and sustainable construction, see Figure 3.

4.2. Flexural strength

The specimens of concrete beams were used to determine the flexural capacity of concrete and the variation in flexural strength of different mixes is represented in Fig.4. Study shows that the addition of small dosages of bentonite and dolomite showed little contribution towards flexural strength. Incorporation of bentonite in cement by 2.5% and 5% showed an improvement in flexural strength up to 2.20% and 0.20% respectively after 14 days. The improvement in flexural strength is due to the densification of the matrix due to the presence of fine particles of bentonite [20]. A concrete mix containing 10% bentonite showed a 6.4% reduction in flexural strength. High bentonite content retarded the pozzolanic reaction of cement with bentonite which resulted in the formation of unstable hydration products that led to a reduction in flexural strength which is also confirmed by a similar study carried out by A. Karimipour et al. [21]. The specimens containing 2.5%, 5%, and 10% dolomite showed 6%, 8%, and 4% improvement in flexural strength respectively when samples were tested after 28 days of casting. Similarly, the concrete mix M8 (2.5% BT and 2.5% DT) did not show any contribution to flexural strength and the mix M9 (5% BT and 5% DT) showed an 8% reduction in flexural strength as compared to the control mix. A similar study also reports a reduction in flexural strength at high dosages of bentonite and dolomite [22]. Hence the optimum dosage of bentonite and dolomite for flexural strength is 2.5% and 5% respectively, see Figure 4.

4.3. Split tensile strength

The results of split tensile strength obtained from testing cylindrical specimens are shown in Fig.4. Study reveals that the addition of bentonite in concrete has little contribution to split tensile strength however the high dosages of dolomite adversely affected the split tensile strength. It was observed that the specimens having a high dosage of bentonite and dolomite were susceptible to tensile load and ruptured at less load as compared to the control sample. Incorporation of bentonite in cement by 2.5% showed an improvement in split tensile strength up to 2.20%, however, the addition of 5% and 10% bentonite led to a decrease in split tensile strength by 2.9% and 9.2% respectively. Results show that specimens containing 2.5% and 5% dolomite in cement showed enhancement in split tensile strength up to 8.50% and 4% respectively, however, the addition of 10% dolomite led to a decrease in split tensile strength by 6.6% respectively when specimens were tested after 28 days of casting. Similarly mixing 5% bentonite along with 5% dolomite in cement exhibited 18% less split tensile strength as compared to the control sample. The decrease in tensile strength is due to the present high concentration of bentonite and dolomite which prevented complete hydration and reduced the quality of bonding between aggregates and matrix as evident from SEM images. Similar results were obtained in a study conducted by J.Luo [23]. Therefore the optimum dosage of both bentonite and dolomite for split tensile strength is 2.5%, see Figure 5.

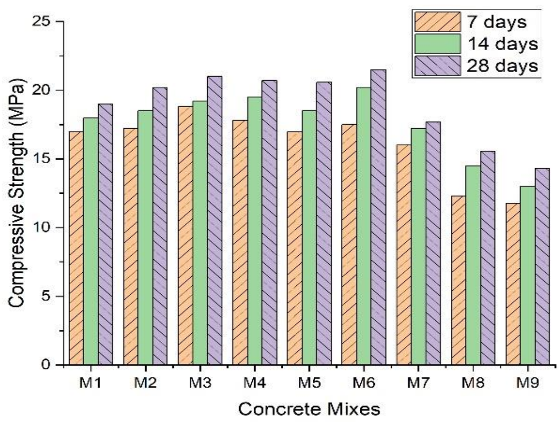

Fig. 3: Compressive strength of concrete specimens

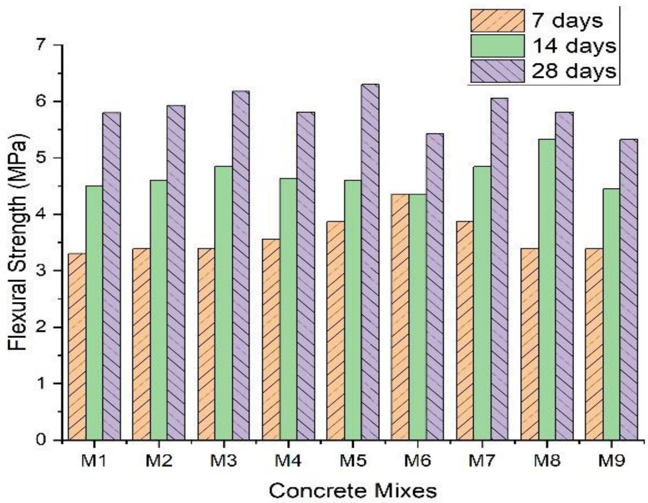

Fig. 4: Flexural strength of concrete specimens

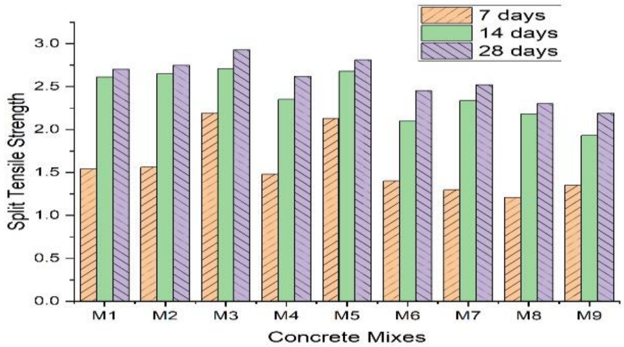

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Fig. 5: Split Tensile strength of concrete specimens.

4.4. Microstructural Analysis

The microstructural analysis of concrete specimens was performed by using scanning electron microscopy (SEM) to evaluate the effect of bentonite and dolomite on the morphological properties of concrete. The internal structure of the control sample having no replacement of cement is represented in Fig. 6(a) showing the formation of calcium hydroxide and ettringite. The SEM image of concrete containing bentonite is shown in Fig 6(b) revealing compact and dense microstructure. The voids in concrete were filled due to a pozzolanic reaction which created a high concentration of CSH gel by consuming calcium hydroxide. Increasing the dosage of bentonite from 2.5% to 10% created a homogenous mixture of concrete as evident in Fig 6(d). The samples containing dolomite also showed improvement in the microstructure of concrete by filling pores due to its filling action as evident in Fig 6(c) while showing a high concentration of calcium hydroxide. Higher dosages of bentonite and dolomite retarded the hydration process due to agglomeration with cement which resulted in weak microstructure as shown in Fig 6(e). The addition of bentonite and dolomite imparted a positive effect in developing the dense microstructure of concrete.

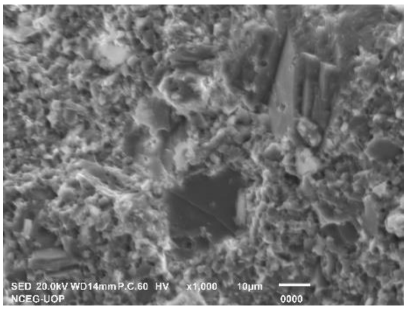

Fig 6(a): Control mix (M1)

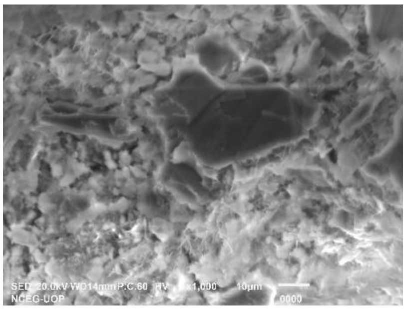

Fig 6(b): Mix (M2) containing 2.5% bentonite

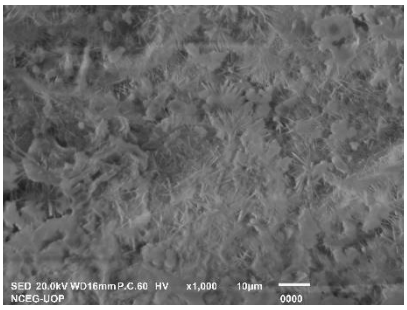

Fig 6(c): Mix (M3) containing 2.5% dolomite

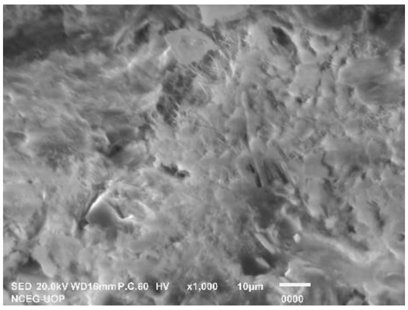

Fig 6(d): Mix M(6) containing 10% bentonite

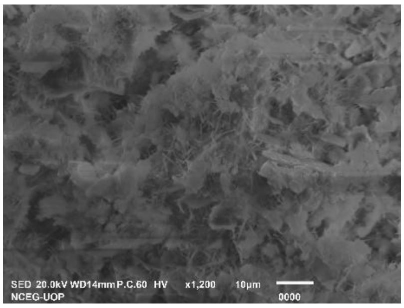

Fig 6(e): Binary mix (M9) containing 5% bentonite and 5% dolomite.

5. Conclusion

The following conclusions are made from this study.

1. Study shows that the addition of bentonite by 2.5%, 5%, and 10% enhanced compressive strength by 2.7%, 8.3%, and 12.2% respectively after 14 days of casting due to the filling effect of bentonite. Similarly, the introduction of bentonite in cement by 2.5% and 5% showed an improvement in flexural strength up to 2.20% and 0.20% after 14 days respectively.
2. The concrete mixes containing 2.5% and 5% dolomite exhibited 10.5% and 8.4% increases in compressive strength respectively when specimens were tested at 28 days. High dosages of dolomite resulted in low compressive, flexural, and split tensile strength due to retardation in the hydration reaction. The binary mixes of bentonite and dolomite showed little contribution to strength.
3. SEM images show that the addition of bentonite created denser microstructure and refined pores which enhanced the mechanical properties of concrete. The pore-filling property of dolomite also contributed to the crushing strength of concrete.
4. The study reveals beneficial aspects of incorporating bentonite and dolomite therefore, the use of optimum dosages of bentonite and dolomite can help to enhance the performance of concrete and reduce the consumption of cement which will help toward economical and sustainable construction.

5. Acknowledgment

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ID 85: Structural Design of RCC Building Using Integrated BIM-Based Design Workflow and Analysis Result Comparison Between ETABS and RSAP

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A B S T R A C T

Rapid computerization in the construction industry stressed the need for a new design methodology that was only possible through BIM. This study aims to develop an integrated design flow using the Autodesk system followed by structural design through the developed flow. Further, the study also aims at identifying and resolving clashes between architectural and structural models and incorporating analysis results comparison of Robot Structural Analysis Professional (BIM integrated software) and ETABS (conventional process software). The design was carried for gravity loads with 1.2DL+1.6LL combination. The architectural and primary structural models were created in Autodesk Revit, and the structural model created in Revit was then exported to Robot Structural Analysis Professional (RSAP) for structural design, which was then updated back in Revit. Finally, both architectural and structural models were exported to Navisworks for clash detections between the two. The results of the study revealed that BIM design flow provided better coordination between involved stakeholders, speedy clash detection, and resolved bi-directional interoperability issues using an extension (structural analysis toolkit). Additionally, design through BIM provided better visualization i.e., both 2D and 3D and final documentation in the shape of structural detailing of designed elements. Furthermore, Navisworks successfully identified coordinates and element clashes between architectural and structural models and provided a virtual 3D representation of the facility before the construction phase. The analysis results of RSAP and ETABS revealed that RSAP gives higher analysis results than ETABS due to the different analysis procedures of the two software packages.

K E Y W O R D S:

Building Information Modelling (BIM), Robot Structural Analysis Professional (RSAP), Clash Detection, Interoperability Issues, Parametric Model

1. Introduction

Every construction project from the design to the construction phase involves various professionals from different disciplines that work cooperatively to achieve the targeted and desired goal of the project. In the past construction projects were designed manually which would take a tedious amount of work and time with a greater possibility of human errors. Then with the advancement of computerization in the construction industry, construction projects were designed with the aid of software, and the professionals thus developed a conventional workflow through which they can communicate and coordinate the required information to achieve the project goals [1]. In the conventional workflow, the professionals from various disciplines work in segregation and communicate the required information usually through 2D drawing, resulting in loss of information, miscommunication, and limited visualization. Therefore to overcome all these shortcomings the construction industry is adopting a modern concept of Building Information Modelling (BIM) for the last two decades [2].

The BIM process provides a Building Information Model that acts as a common platform for all stakeholders of a building process. Some of the notable stakeholders are Engineers, Architects, Contractors, Building owners, Public authorities, and users [3]. Furthermore, BIM is a process generating a methodology that enables cross-discipline collaboration amongst various professionals to compile their work on a common database known as the federated model [1, 2]. BIM not only improves communication and coordination between key players but it provides a data-rich parametric model containing both geometric and non-geometric data and early clash detection[2, 3]. Although, BIM offers many advantages it also faces challenges like click f professionals, clients, and contractors having BIM knowledge, a lack of information, resources, guidelines, and standards on BIM application, and interoperability issues of all four levels of Business, process, service, and data [4].

During the construction phase, many problems arise due to shortcomings in the design phase because of poor communication and coordination between the draughtsman, architect, and structural engineer. This is where BIM can tackle all these shortcomings in the traditional workflow by generating a virtual prototype of the building with detailed architectural, structural, mechanical, electrical, and plumbing aspects which allow the team to coordinate and make better design decisions based on an actual accurate 3D model before the construction phase. Additionally, the model can be used by contractors for quantity take-off, scheduling, and phasing [5].

Therefore, this study is intended to develop a BIM-based design workflow for the AEC (Architecture, Engineering, and Construction) building industry covering structural design, clash detection, and quantity estimation using the Autodesk family to overcome the data interoperability issues target is related to the software integrity and information sharing between different software packages. Furthermore, this study will check the efficiency of BIM-integrated software by comparing ring with conventionally used software, which will help reduce the reluctance to adopt BIM by professionals.

2. Literature Review

According to [6] A project is to put the effort from designing to building. These efforts are done by various stakeholders of the involved discipline of the project to achieve a combined goal of the project. Therefore, for the achievement of project goals improved coordination and communication between various phases of the project and involved stakeholders are to be assured respectively. In the building sector, there is a tradition of applying widely used and accepted workflow and techniques in projects to achieve the targeted goals. Changes in this flow and techniques often happen slowly [3]. In the traditional building process, each phase is relatively separate from the other phase and each phase then contains lots of participants that work individually as shown in Figure 1. This results in the traditional flow to binge-consuming and inexpedient especially when the process is iterative [3]. On the other hand, to make the building process smoother, the BIM makes the phases more integrated as shown in Figure 2.

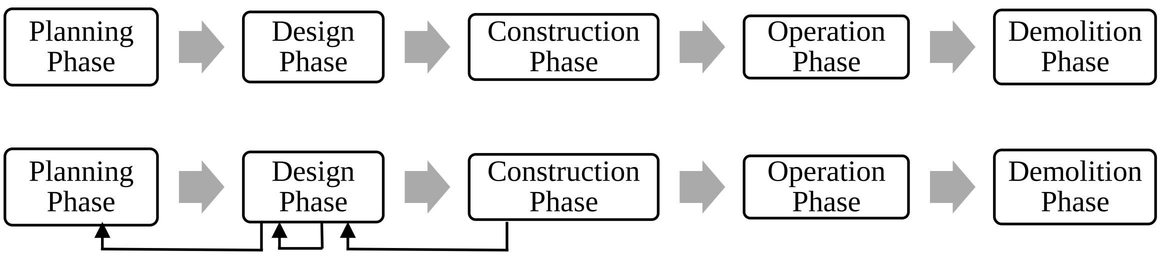

Fig. 1: Phases in Integrated Building Process (Nielsen & Madsen, 2010)

This integrated building process provides improved coordination between phases and improved integration between participants involved in each phase. This integrated building process can be achieved to make use of a common model that is only possible using the BIM process. This study is mainly focused on the implementation of BIM in the design phase. The main participants in the design phase are Architects, Engineers, and Draughtsmen. All these three participants tried different techniques and workflows from time to time depending on the ease of applicability and considering their benefits.

2.1. Classical Method of Designing

From many centuries till the second half of the 20th century the classical method of designing was adopted by architects and engineers for the design of projects. In the classical method, each involved participants work on separate drawing sheets to only perform their work using tools such as tracing paper for clash detection, papyrus and ink for drawing, and a simple abacus for calculation. The drawings were made on tracing papers. In the classical method, the architect was the sole responsible for the project [7].

2.2. Traditional Method of Designing

In the second half of the 20th century, the architect and engineers stopped using the classical method, techniques, and tools and started to use computer-aided design CAD. The first CAD systems were PRONTO and SKETCHPAD. Currently, the most used and accepted system is CAD/CAE systems. Computer-aided engineering CAE term is used for any software that is used for analysis and design by engineers [7]. In traditional workflow architects, engineers, and draughtsman work in three separate steps as shown in Figure[3]. The architect makes the architectural drawing that is then structurally analyzed and designed by a structural engineer and finally, the draughtsman makes the final draft i.e., highly detailed technical drawings. The architect and draughtsman use Autodesk AutoCAD for their work which is making 2D and 3D drawings. The structural engineer usually uses the CSI software products or any other analysis software to analyze and design projects.

Although, the CAD system has modernized the workflow and improved the process of clash detection through the use of separate layers in the CAD program by different professionals the traditional workflow takes too much time and is not always successful in terms of clash detection [7]. Additionally, traditional workflow lacks the level of coordination between the design participants. As every participant works on a separate model on a separate software and transfers the information to another participant through 2D drawings which in loss of information, miscommunication, and limited visualization. Therefore, to overcome and tackle the issues with the conventional workflow the construction industry started to adopt the integrated BIM workflow in the last two decades.

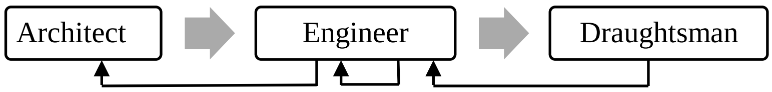

Fig. 2: Collaboration among participants in design phase (Nielsen & Madsen, 2010)

1.3. BIM-based Design

The journey from paper design to computer-aided design shows that the building sector always has space to accept innovations and techniques to optimize the building process and technical solutions. BIM is one of those innovations and techniques in the construction industry that will replace conventional design methods and workflows to better integrate the building processes and phases. In BIM-based design, the involved player uses a central BIM model for communication, coordination, and information sharing. The Central BIM model enables the architect, structural engineer, mechanical engineer, electrical engineer, plumber, quantity surveyor, and other players involved in the design to get the required information from and back update information to the central BIM model resulting in a data-rich model known as a parametric model as shown in Figure 3.

Although all these participants involved in the design phase of the building use different BIM-integrated software for their work but work on the same common BIM model. Each participant after finalizing his work back updates it to the central BIM model that the other participants involved can use for their work.

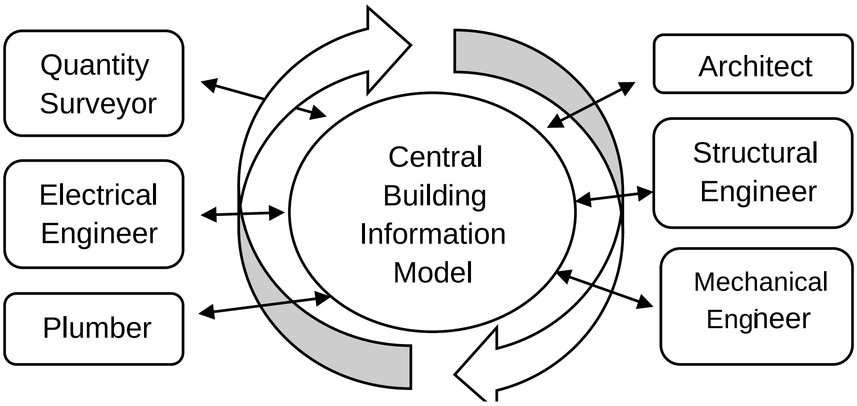

Fig. 3: Central Building Information Model and design participants of the building process

2.4. Building Information Modelling BIM

The definition of BIM proposed by different authors and in different research papers is given in 1.

Table 1. BIM definitions

	Author/Reference	Year	Definition
1	Coenders [8]	2009	"BIM as a vision and BIM as a software technology".
2	Sacks, Eastman, Lee, & Teicholz [9]	2018	"A modeling technology and associated set of processes to produce, communicate and analyze building models".
3	buildingSMART [10]	2017	"A new approach to being able to describe and display the information required for the design, construction, and operation of constructed facilities".
4	Nielsen & Madsen [3]	2010	"BIM can create such a model which contains all of the information needed about a structure, to optimize the building process".

From the above definition, BIM means different for different professionals in the construction industry. For some professionals, it is a software package, and for others, it is a process of information sharing and documenting the project information during different phases of the project. In addition to this, some have misconceptions about BIM that it is a 3D model of architectural design and is only used for building projects [3, 11]. Furthermore, the definition proposed by [8] "BIM as a vision" evaluated by [12] concludes that the current level of BIM software in practice has a large space for improvement in terms of ease and accuracy in interoperability among different software packages, that needs to be improved to make it true.

Conclusively, BIM can be defined as a vision, process, and modelling technology that improves communication, coordination, information sharing, documentation, and visualization of a project between different phases of the project and involved stakeholders in each phase to form a data-rich parametric model that is a virtual digital representation of the real project facility to be built. Along with parametric modelling, BIM also offers clash detection of all three types which are heavy, light, and technological clashes through the help of a common database known as a federated model [2, 7].

BIM offers more than a 3D model of an architectural design that adds extra information like time and cost information to the 3D model making it a 4D and 5D model respectively. Furthermore, the BIM 6D model is devoted to sustainability, 7D to facilities management, and nD to model-based analysis that helps in early decision-making. Thus, the final product of BIM is a virtual data-rich and intelligent model also called a parametric model that tends to adopt changes to the 3D model quickly and easily. [2, 3, 7, 13, 14].

Although BIM offers many advantages, it also faces challenges like a lack of professionals, clients, and contractors having BIM knowledge, a lack of information, resources, guidelines, and standards on BIM application, and interoperability issues of all four levels of business, process, service, and data. Therefore, this study is focused on developing a BIM-based integrated design workflow for building projects to overcome the data interoperability issues that are related to software integrity and information sharing between different software packages.

3. Research Methodology

BIM completely integrates all the phases of construction from planning to demolition which makes the final product (building or any other structure) more efficient and economical. Though BIM covers all the construction phases, this study mainly focuses on the analysis, design, and design coordination (clash detection) of an RCC building through BIM workflow and its comparison with conventional workflow.

Out of the various systems, the Autodesk system (Revit, RSAP, and Navisworks Manage) was preferred to execute the BIM process and CSI software packages (ETABS, CSI SAFE, and CSI Detailing) were used to execute the conventional process. The Autodesk software was used in a specific sequence to execute the BIM process as shown in Figure 4.

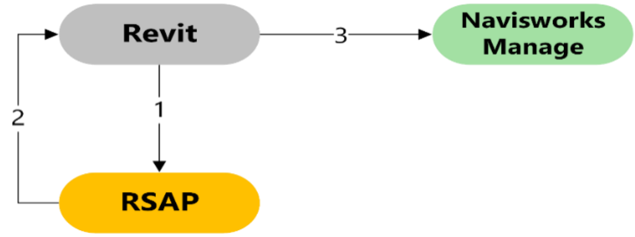

Fig. 4: Software sequence to execute BIM process

Initially, the architectural and structural models were prepared in Revit. The structural model should be aligned with the architectural model concerning coordinates and levels. The initial workflow in Revit is shown in Figure 5.

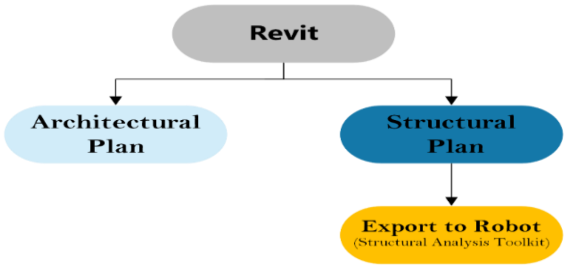

Fig. 5: Initial work in Revit

The structural model was exported to RSAP through the 'Structural Analysis Toolkit' which links Revit with RSAP and allows sending a model from Revit to RSAP and vice versa. Interoperability issues can occur here, but its probability is less as this issue is minimal in the forward direction. These interoperability issues must be solved for the complete transfer of the model without any missing components. The sequential workflow in RSAP is given in Figure 6.

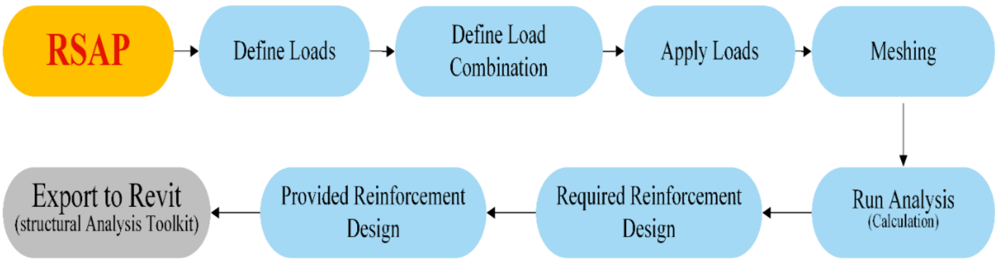

Fig. 6: RSAP workflow

After the successful transfer of the model to RSAP, the next is to define and apply the loads on the structural members according to ACI Code. The load combination was defined, and the slab meshed into a preferable size. The model was then calculated for analysis. The required and provided reinforcement was then designed for all the structural elements. The structural drawings can be generated at this point. After the structural design, the model was updated in Revit through the 'Structure Analysis Toolkit' which exports all the analysis and design results from RSAP to Revit. Here, the interoperability issues can be higher because the model is now exported in the reverse direction. There can be a missing member(s) or information related to it such as reactions, stresses, reinforcement details, etc.

Foundation was provided in Revit as designed in RSAP and rebar was shown in the structural members of the building. For this purpose, an additional toolkit was installed in Revit named 'Autodesk Extensions' or 'Navigate Rebar Extension'. This extension allows us to visualize the reinforcement of members in the structural model. For the design coordination check, both models i.e., architectural, and structural were exported in NWC format from Revit and were collectively appended in Navisworks Manage as NWF format. The NWF format contains both models in a single file with an editable and workable interface while a similar NWD format is un-editable. Later, the test was run to check the clashes among different components of the two models. The clashes can either be checked for the whole model or any user-defined sets.

Here the BIM process ends and to compare it with the conventional workflow, the analysis results were compared between the two. ETABS and CSI Detailing software packages were used as a conventional method of design. The structural model was developed and analyzed in ETABS by applying the same loads and load combination as in RSAP.

4. Results and Discussion

4.1 Development of BIM-Based Design Workflow for Building

To develop a BIM-based design workflow many software systems, used for architecture design, structural design, and clash detection were studied. Autodesk system was selected for the study because it provides educational license and gives great interoperability within its own family than other systems.

In this study, a BIM-based design flow was developed by creating a sequence in which the Autodesk software packages would be used. This design flow is explained in the methodology section in detail and shown in Figure 5. This BIM-based design flow provided improved coordination between the architect and structural designer in terms of information sharing. The design flow gave a great breakthrough in terms of interoperability. The flow successfully shared architectural and structural information from Revit to RSAP and vice versa i.e. successfully solved the bi-directional interoperability issue. For clash detection, Navisworks Manage successfully identified clashes between architectural and structural models which were later resolved in Revit, and finally a parametric with zero clashes was created. This parametric model can be further used for other BIM dimensional analyses such as scheduling (4D), Cost analysis (5D), and (nD) analysis. Models prepared in Revit and that exported to RSAP and Navisworks are shown in Figure 7, Figure 8, and Figure 9.

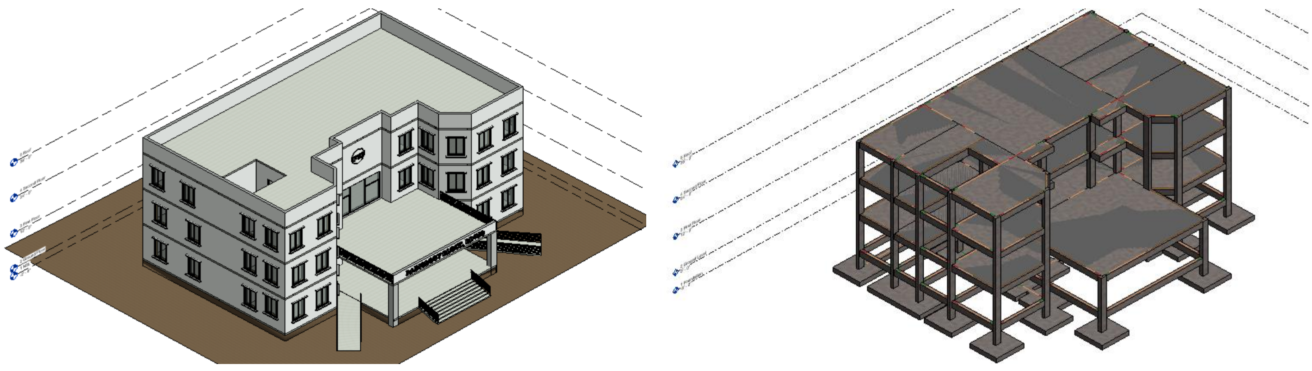

Fig. 7: Architectural and Structural Model in Revit

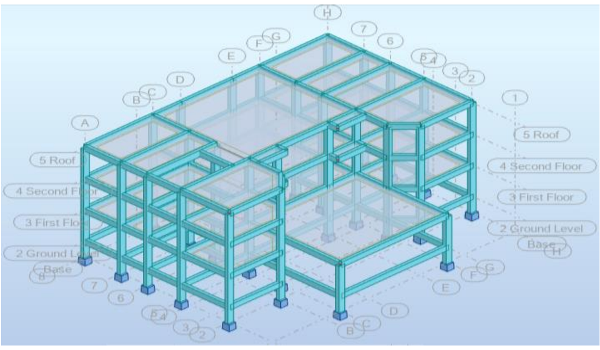

Fig. 8: Structural model in RSAP

Fig. 9: Parametric model in Navisworks manage

4.2 Clash Detection through Navisworks Manage

The structural model designed in RSAP was updated in Revit and was later exported to Navisworks along with the architectural model. A 3D parametric model was established by appending these models and the cross-discipline clashes were identified that occurred due to the integration of models. Initially, the clashes appeared due to the improper coordinates of individual models. The models were displaced in the horizontal plane; however, they were in position concerning the vertical plane i.e., having the same floor levels. Figure 10 illustrates the model clashes due to coordinates.

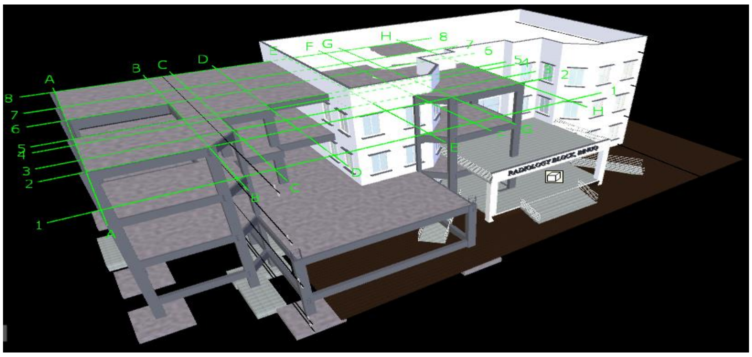

Fig. 10: Clash due to improper coordinates

This issue of coordinates was resolved in Revit by adjusting the entire structural model with the architectural model but there were still some clashes between the elements of the models. A detailed clash report was generated to quantify and locate clashes. The clashes are shown in Figure 11. These clashes were later resolved by adjusting the elements (structural and non-structural) without compromising the intended design and finally, a parametric model was obtained with zero clashes.

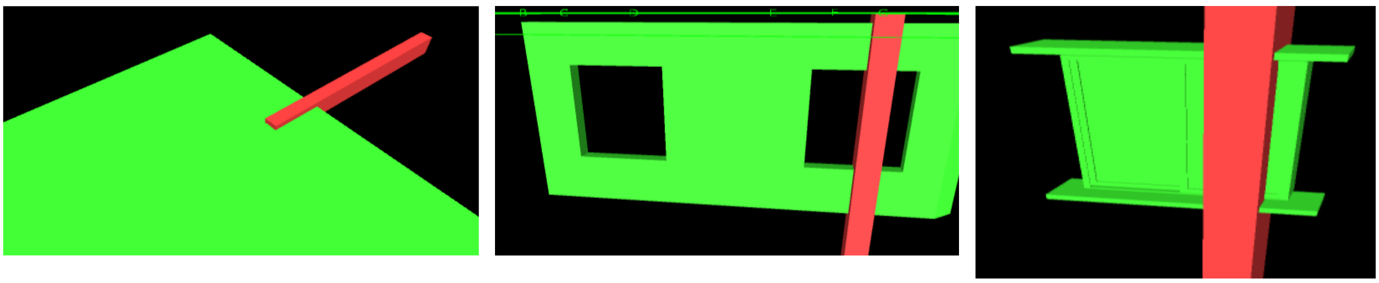

Fig. 11: Clashes between the elements of architectural and structural Model

4.3. Analysis Comparison between ETABS and SAP

In this study same building was designed for similar gravity loads and combinations through CSI ETABS: a conventionally used software and RSAP: a BIM-integrated software.

4.3.1. Absolute Maximum Nodal Displacement and Base Reaction

From the comparative results of nodal displacements, as shown in Figure 12, it can be seen that CSI ETABS yield lesser displacement values than RSAP in the x and y directions but higher in the z-direction with 1.36 inches for CSI ETABS and 1.777 inches for RSAP. A similar trend was observed in the comparative results of base reaction, where CSI ETABS yield lesser reaction values in the x and y directions but higher values in the z-direction with 297.533 Kips for CSI ETABS and 338.95 Kips for RSAP as shown in Figure 13.

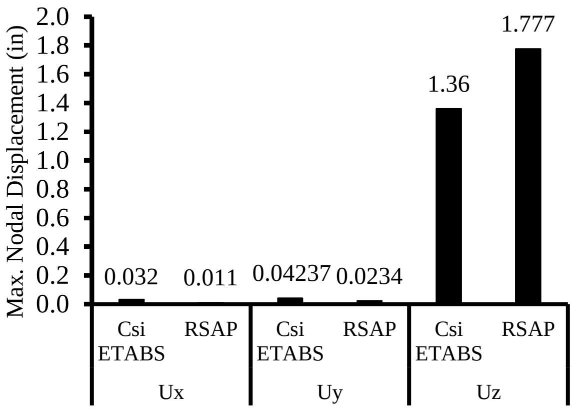

Fig. 12: Absolute maximum displacement

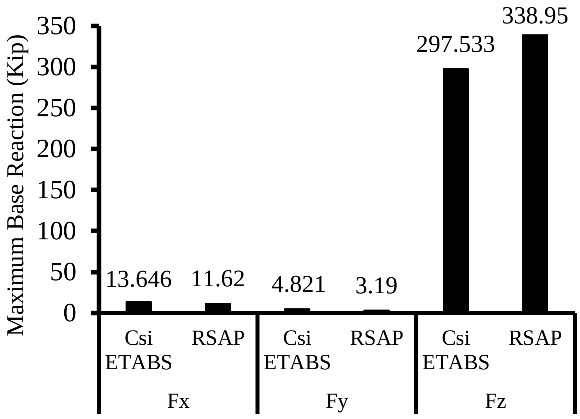

Fig. 13: Maximum base reaction

4.3.2 Spandrel Beam Comparison

This study uses the top spandrel beam as a reference for shear force and bending moment comparison. The spandrel beam was subjected to 0.36 kip uniformly distributed load and loads from the adjacent slab, where the slab was loaded by 30 lbs. floor finish and 60 lbs. live load. Additionally, the applied loads were magnified by a load combination of 1.2D.L and 1.6L.L. The length of the spandrel beam is 85 feet with 5 spans.

From Figure 14, ETABS and RSAP give maximum positive and negative shear values at the same location, but the RSAP values are almost three times bigger than the ETABS shear values. ETABS considers the beam as a bar element while RSAP considers it as a shell and meshed object. From Figure 15, ETABS and RSAP give maximum values at the same location, but RSAP positive BM values are 20.0861 kip-ft. and negative BM values are 32.7581 kip-ft. bigger than ETABS values. Since the beam section especially the depth of the beam contributes to resisting the shear forces and beams are designed for bending moment and shear force values, therefore, the design section and reinforcement quantity of RSAP design result yields higher than ETABS design.

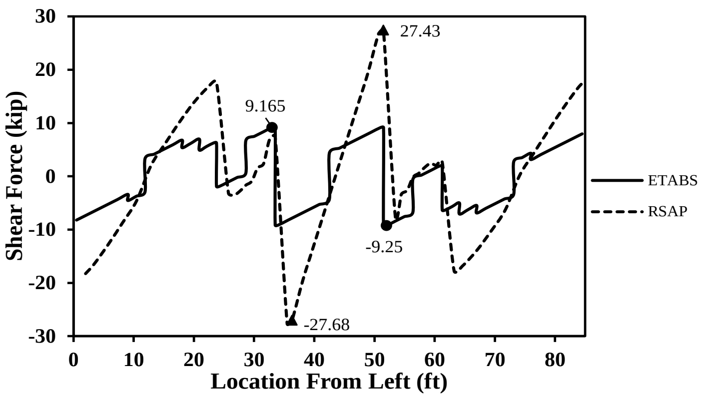

Fig. 14: Shear force diagram

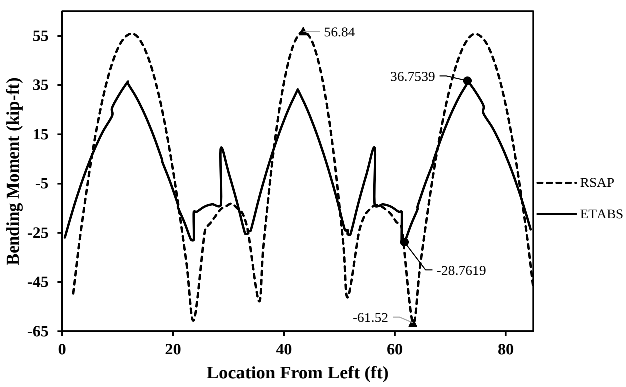

Fig. 15: Bending moment diagram

4.3.3 Column comparison

To compare the column design of RSAP and ETABS a specific column was selected and evaluated. The detail of the column is given in Table .

Table 1: Column design details

	Section	Max. Axial Force (kip)	Max. Moment "My" (kip-ft.)	Min. Moment "Mz" (kip-ft.)	Reinforcement Ratio (%)
CSI TABS	15”x18"	190.359	31.81	19.44	1
RSAP	24”x24"	277.3	-90.3	-6.31	1.04

Therefore, due to the higher axial force from the analysis of RSAP the design section and reinforcement ratio is bigger than ETABS. Additionally, ETABS designs a column for the maximum axial force at the base of the column for each story level that is designed each story column for its maximum axial force but contradicts, RSAP takes the column from the base to the top of the building as one column and designs the entire column for the maximum axial force at the base of that column. In short, RSAP design columns for higher axial forces thus yielding bigger cross sections and reinforcement quantity making RSAP column design much safer but more uneconomical than ETABS.

5. Conclusions

The integrated BIM-based design workflow developed in this research was found to be a useful design methodology in terms of information sharing, coordination between stakeholders, clash detection, and clash resolution. Further, the developed design workflow of Autodesk system successfully solved the bi-directional interoperability issue using an extension i.e., Structural Analysis Toolkit. Navisworks Manage successfully identified and resolved clashes (coordinates and element clashes) between architectural and structural models and finally, a parametric model was created with zero clashes. Hence BIM efficiently identifies, inspects, and reports clashes in a project and tells mistakes that normally would be revealed on site. Furthermore, the BIM clash detection process is faster and simpler than the conventional process. The results show that despite the same inputs (loads and load combination), most of the analysis results (base reactions and moments, shear force, bending moment) of RSAP are bigger than ETABS due to the different analysis procedures of the two software packages. ETABS models the slab as a diaphragm while RSAP models it as a meshed shell object. ETABS considers the beam as a bar element while RSAP considers it as a shell and meshed object. The results also vary due to different mesh options in both software. From the BIM workflow scenario, one of the main advantages of RSAP, as compared to ETABS, is that it is integrated with other BIM software and allows the transfer of data smoothly without any interoperability issues. In terms of structural detailing, RSAP is very efficient than ETABS and does not require any external software for structural detailing. Its structural detailing and visualization of designed elements are clearer and more understandable than ETABS.

5. Acknowledgment

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ID 97: Effect of Recycled Porcelain-Ceramic Aggregates on Concrete: A Review

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A B S T R A C T

Due to recent increasing industrialization and urbanization, effective waste management is one of the most problematic issues faced by today's world. By reducing the degradation of natural resources brought on by the extraction of natural aggregates, ceramic waste from construction sites presents a sustainable and efficient endeavor for environmental problems. A profusion of research has been attempted to analyze the suitability of ceramic wastes from various sources as a possible alternative to natural aggregates in concrete. This paper provides an organized and contemporary review of ceramic aggregate concrete physical and mechanical properties. Based on conducted review research it can be said that ceramic aggregate concrete has identical physical and mechanical attributes to conventional concrete. It has been highlighted that ceramic aggregates can be used to create medium and high-strength concrete in place of natural aggregate. This also revealed that the compressive strength, permeability properties, bond strength, etc. of the concrete utilizing ceramic aggregate exceeded the necessary standards, confirming the feasibility of using ceramic waste as a successful alternative to natural aggregates in structural concrete. However, there is a need to explore the mechanical properties of ceramic waste concrete structural members to comment on its sustainability for structural applications.

K E Y W O R D S:

Ceramic Waste Aggregate, Ceramic Aggregate Concrete, Physical Properties, Mechanical Properties, Durability, Review.

1. Introduction

The use of earthenware materials such as tiles, clean fixtures, and other waste products has evolved in modern construction techniques [1]. Additionally, research is being done to improve the strength and longevity of concrete. Materials made from renewable resources have developed in response to worries about resource depletion and global pollution. To reduce the building industry’s environmental impacts and conserve natural resources, eco-friendly materials are currently the subject of extensive research. Similar problems with capacity and the environment arise from disposing of demolition concrete waste in landfills. Finding appropriate substitutes to make concrete is therefore urgently needed [2].

Ceramic is a trendy furnishing material right now. But when ceramic approaches the end of its useful life, it no longer has any value and is just wasted. Ceramic wastes also come from subpar production and poor workmanship, along with outmoded furniture products. Every day, growing amounts of ceramic waste are produced, and the ceramic industries are now under pressure to find a practical way to dispose of it. If these materials are not properly disposed of, they will have a severe effect on the environment. Construction businesses are under pressure to find a suitable method of disposing of these pollutants [3].

The remaining modern items used in substantial production, particularly as unrefined components, are one of the most effective approaches to utilizing these inorganic squanders, as the total has a large volume portion for concrete, around 80%–85% of a typical substantial blend, and it has a significant influence on the compressive strength as well as other assets. Ceramic aggregates have mildly low development coefficient and are resistant to scraped patches and intensity. Additionally, ceramic items are highly durable, strong, and resistant to wear, heat, and fire. Therefore, using these contemporary wastes in place of aggregates in concrete could be a workable solution for the waste evacuation process [3].

Various scientists possess effective endeavors to build a lying starting point for prospective works, examining the physical characteristics of ceramic aggregate [4], [5], [6] and mechanical properties of ceramic aggregate concrete [7], [8], [9], [10]. To optimize the usage of ceramic wastes in structural concrete, the investigation of ceramic aggregate concrete will be planned in a way that will simultaneously be productive for present researchers and valuable for the next ones. This paper reviews ceramic waste's suitability to be used as aggregate and its effectiveness as coarse and fine aggregates in concrete. In addition, various ceramic aggregate properties are also examined and contrasted with those of natural aggregates. A literature review on the mechanical characteristics of concrete made with ceramic aggregates is also provided.

2. Characteristics of Porcelain Ceramic Aggregates

Porcelain ceramics are less dense, have high porosity, and have high strength. Due to its attractiveness, heat resistance, and strength, the most recent ceramic product is made from clay, feldspar, granite, and silica under intense pressure and heat for use as flooring and facade material in buildings. High-temperature baking transforms porcelain ceramics into vitreous materials with very little porosity and very little water absorption, which are frequently referred to as "manufactured stone." Due to their extreme strength, they are typically dumped and released into the environment as waste, as shown in Fig. 1, because they can't be easily recycled back into the production process [11].The characteristics of the ceramic aggregates that constitute ceramic aggregate concrete greatly influence its attributes (physical, mechanical, and durability). The chemical composition of porcelain ceramic tile aggregates is shown in Table 1.

Table 1. Porcelain Ceramic's Chemical Breakdown [12]

Chemicals	Breakdown %
Lime (CaO)	1.70%
Silica (SiO2)	68.60%
Alumina (Al2O3)	24.5%
Magnesium oxide (MgO)	2.50%
Iron tri-oxide (Fe2O3)	0.80%
Sulphur tri-oxide	0.12%
Loss of ignition	1.78%

Fig. 1: Waste porcelain ceramics

3. Influence of Porcelain-Ceramic Aggregate on the Physical Properties of Concrete

The properties of the various ceramic aggregates that constitute ceramic aggregate concrete heavily influence its physical, mechanical, and durability properties, see Table 2.

Table 2: Qualities of ceramic waste aggregates

References	Ceramic aggregate source	Ceramic aggregate type	Bulk density/ density (kg/m3)	Water Absorption %
[13]	Sanitary ware	Fine (Max)	2210(Loose)	6.1
[14]	Sanitary ceramic waste	Fine(0-4mm)	2360(Loose)	1.5
[15]	Ceramic tile	Coarse (Max 20mm)	1325(Compact)	4.5
[16]	Wall tile, floor tile	Coarse (Max 4.75mm)	1060(Loose)	6.3
[17]	Ceramic tile waste	Coarse (Max 31.5mm)	-	11.5

3.1 Specific Gravity

Any material's specific gravity is determined by comparing its density to that of water [18]. The ranges for specific gravities of coarse and fine ceramic aggregate are 2.20–2.50 and 2.26-2.58, respectively [19]. [20] demonstrated the maximum specific gravity of (2.58) in the finest ceramic aggregate, while [21] recorded an intrinsic value of (2.50) for coarse ceramic aggregate. [22] claimed that the lowest specific gravity for doable ceramic aggregate was 2.26, According to [23], coarse ceramic aggregate has the lowest specific gravity, 2.20. Ceramic aggregates often have a lower specific gravity than natural aggregates.

3.2 Density/ Bulk Density/ Particle Density

The density variation of ceramic aggregates is illustrated in Table 1 for distinct sources and types (see Figure 2). As shown in Table 2, researchers noted that the bulk densities of ceramic aggregate, both coarse and fine, were (1010.0 – 2969.0) kg/m3 and (966.0 – 2401.0) kg/m3. The majority of the study found that ceramic fine and coarse aggregates had lower bulk densities than equivalent natural fine and coarse aggregates. Additionally, it was found that ceramic aggregates' particle densities were lower than those of natural aggregates, and it has been demonstrated that ceramic aggregates manufactured from absorbent ceramics frequently have a greater bulk density value (>2000 kg/m3). While aggregates made from electrical insulators and insulator bush have a bulk density that fluctuates between 1069 and 1325 kg/m3, another factor is that these aggregates are made from insulator bush. The bulk densities of recycled brick aggregate and ceramic tile ranged from 966 to 2050 kg/m3 and 1060 to 2401 kg/m3, respectively.

3.3 Water Absorption and Moisture Content

Ceramic aggregates take up water in a diverse range of ways, as demonstrated by Table 2, depending on their kind and source [3]. According to the findings of various studies, ceramic aggregates are better at absorbing water than natural aggregates. Ceramic aggregates' high porosity is the cause of their high-water absorption capacity. The level of moisture in ceramic aggregates from different sources, as well as the workability and consistency of the concrete, are influenced by the aggregates' water absorption. To effectively build a concrete mix, it is therefore vital to determine the amount of water absorption that ceramic particles must have [3].

Fig. 2: (A) Ceramic Aggregate's flaky shape; (B) Ceramic Aggregate's (right) angular and uneven shape in comparison to natural Aggregate (left)

3.4 Porosity

The three aggregate characteristics of porosity, water absorption, and specific weight are strongly related to one another. [24] As a result of their greater porosity, aggregates absorb more water and have a lower specific weight [25]. Researchers noticed higher porosity in ceramic aggregates when contrasted with normal aggregates. The porous form of sanitary ceramic aggregate particles is depicted in Fig. 3 with irregularly shaped and sized pores. According to [26], sanitary ceramics have a porosity of 0.32 (% volume), whereas rocks have a porosity of 0.23 (% volume). Because of their high porosity, ceramic aggregates can retain water in their pores, bringing about inner restoration and subsequently further developing concrete hydration of cement. [27] High-porosity ceramic aggregates result in a reduction in the transparent thickness of reused ceramic cement and, as a result, a reduction in the structure's self-weight, which is advantageous for creating long-range structures [28].

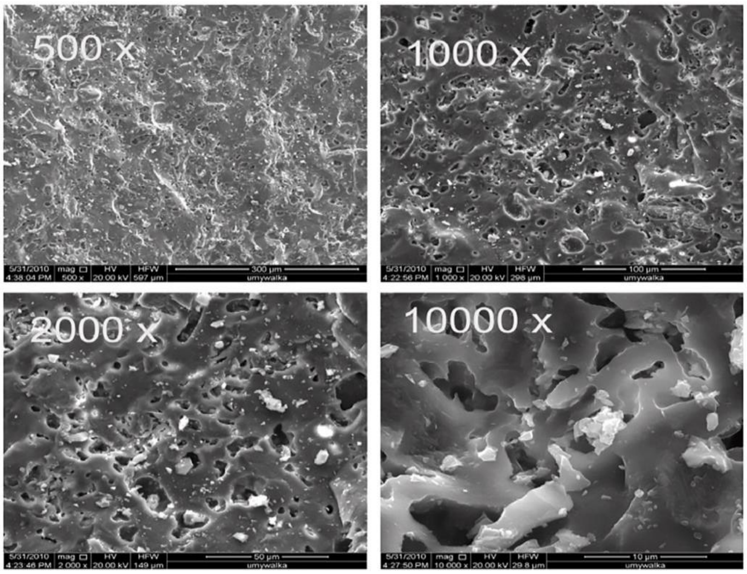

Fig. 3: Under a scanning electron microscope, a sanitary ceramic aggregate particle's porous structure may be viewed [8].

4. **Influence of Porcelain Ceramic Aggregates on Mechanical Properties of Concrete**

4.1 Compressive Strength

The significant attribute for compressive strength of structural concrete has been carefully examined in studies including ceramic waste aggregate. Various amounts of ceramic coarse and fine aggregate, various hardening times, and different testing circumstances have all been investigated by researchers to produce different classes of strength [29]. According to [30], the amount of coarse aggregate made of sanitary ceramics added to the concrete mix enhanced the concrete's compressive strength. The average 4-week compressive strength of concrete with a percentage of the coarse sanitary aggregate of 0, 15, 20, and 25% was found to be 35.87, 37.24, 38.53, and 39.83

MPa, and some of the compressive strengths are discussed in the graph as shown in Fig. 4. The authors argue that sanitary ceramic coarse aggregate's irregular shape, as shown in Fig. 2, offers a greater specific surface than natural aggregate, increasing the concrete's mechanical strength and influencing a strong bond between the cement paste and ceramic aggregate.

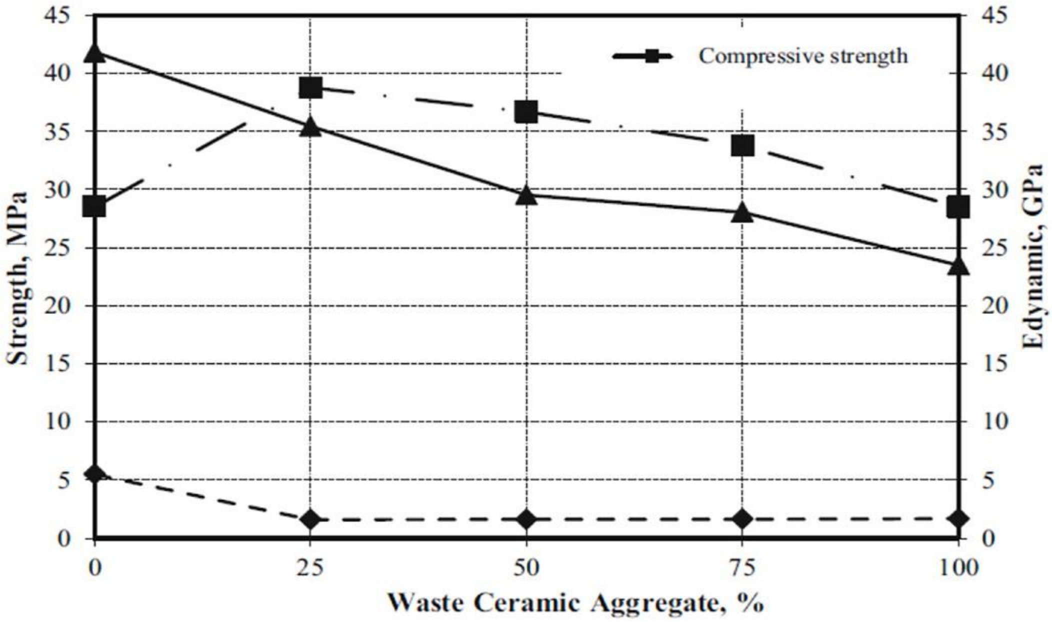

Fig. 4: Concrete's compressive and flexural strengths as well as its dynamic modulus of elasticity [31].

4.2 Splitting Tensile Strength

The concrete's splitting tensile strength dictates the pattern of progressive cracking that arises under tensile stress, together with a way to infer the amount of load that causes the crack in the material [32]. Using ceramic aggregate in concrete has a less significant impact on the splitting tensile strength than using ordinary concrete. Similar to what was seen for compressive strength, [10] found that the volume of fine and coarse tile aggregate inclusion augmented the splitting tensile strength of concrete. They stated that the addition of ceramic aggregates altered the mixture's pore structure, resulting in an increase in capillary pores and a decrease in the porous structure [26]. According to [26], concrete with 15%–25% coarse sanitary ware aggregates had a 12%–25% higher splitting tensile strength than reference concrete. They contend that the higher specific surface area and irregular shape of ceramic aggregates result in a stronger bond between the aggregate and slurry, which in turn contributes to the high strength of ceramic aggregate concrete.

4.3 Flexural Strength

Flexural strength is a gauge of a material's resistance to distortion under bending stresses. It indicates the maximum stress in materials under collapse loading [33]. In comparison to ordinary concrete, Concrete produced with ceramic tiles as coarse aggregate seems to have a 32.2% enhanced flexural strength, according to [30]. Additionally, [34] discovered that aggregate concrete had higher flexural strength (5.640 - 6.950 MPa) in comparison to control concrete (5.2 MPa). According to studies by [35] and [23], 100% coarse tile aggregate concrete has a stronger flexural strength than conventional concrete of all ages. The discussion above illustrates the fact that ceramic waste can be more effective replacement for natural aggregate and has particular advantages over the control mix.

5. Conclusion and Recommendations

To evaluate whether the ceramic waste is a potential aggregate for concrete, the currently available literature was reviewed. The results of these experimental results reveal that ceramic waste might be an effective replacement for natural aggregates in concrete. The following conclusions are reached in light of the literature reviews.

1. Depending on their source, ceramic aggregates may possess a smooth surface texture, be porous, lumpy, angular, flat, or flaky in shape, and typically reddish or white in colour.
2. Ceramic aggregates' specific gravities in fine and coarse particles, which are typically lower than those of natural aggregates, are 2.26 and 2.58 and 2.20 and 2.50, respectively. The volume weights of ceramic aggregates, whether they be fine or coarse, are typically (1010.0) and (2969.0 kg/m3) and (966.0 – 2401.0 kg/m3). Furthermore, ceramic aggregate particles' density ranges from 1032 to 2640 kg/m3. Ceramic aggregate is extremely absorbent because it has a higher porosity than natural aggregate. As assessed by the source, water absorption by ceramic aggregates differs widely and typically ranges from 0.18% to 18.91%.
3. Because of the comparatively higher permeability of ceramic aggregates than natural aggregates, the absorbency, and permeability of concrete are enhanced by the inclusion of all varieties of ceramic aggregates.
4. The proportion of aggregate used raises the compressive strength, split tensile strength, and flexural strength of ceramic aggregate concrete.

5. Although there is less awareness about using porcelain ceramic waste to reduce CO2 emissions in the industrial sector, this might change with the assistance of brochures, advertising, and media exposure. The inadequate definition of mix design proportions is a second reason causing a lack of use.

Given the current knowledge of ceramic aggregate concrete, additional research is needed in various areas before ceramic waste aggregate may be used effectively in manufacturing concrete. The flexure and shear performance of concrete members constructed with ceramic particles should be thoroughly investigated. Additionally, it is possible to investigate the deflection properties of Ceramic Aggregate concrete beams and slabs. And is possible to study the performance of reinforced prestressed concrete members made from ceramic waste under static and fatigue loads. Further research will be needed to examine the long-term mechanical and durability characteristics of ceramic aggregate concrete.

6. Acknowledgment

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ID 107: Effect of Acid and Chloride Attack on Durability Properties of Mortar Containing Fly Ash

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A B S T R A C T

This paper represents the detailed experimental investigations on durability properties of cement mortar cubes containing various dosages of fly ash. Cement was replaced with 5%, 10%, 15%, 20% and 25% fly ash. Different tests of durability such as water absorption test, acid attack test, and chloride penetration test were performed at 28 and 90 days. It was noticed that the addition of 10% fly ash reduced the water absorption capacity of mortar by 31% and 15% at 28 and 90 days respectively, however, an increase in fly ash dosage beyond 10% increased the water absorption capacity of mortar. The addition of 25% fly ash in mortar showed 42% and 46% more resistance to acid attack individually after 28 and 90 days of immersion in acidic solution. Similarly, the addition of 25% fly ash in cement mortar reduced the chloride penetration by 33% and 27.8% at 28 and 90 days respectively due to a reduction in porosity. The microstructural analysis of samples show that the presence of optimum dosage of fly ash in cement has increased the formation of CSH gel which filled the micro-pores and improved the durability characteristics of cement mortar which suggests the potential use of fly ash in reinforcing mortar in extreme environmental conditions.

K E Y W O R D S:

Fly Ash, Cement, Acid Attack, Chloride Penetration

1. Introduction

The use of different industrial by-products such as fly ash has got warm attention nowadays due to its cementitious properties. The use of ordinary portland cementitious (OPC) materials is very common nowadays in the construction industry, however, the production of OPC severely affects the environment due to the emission of carbon dioxide [1]. The expansion of industrial activities led to an increase in the production of fly ash in recent years. It is estimated that around 780 million tons of fly ash are produced every year globally, however, only 17-20% of fly ash is used for various purposes [2]. The main constituents of fly ash are silica, alumina, and some oxides of iron and magnesia which contribute to the formation of alumino-silicate-hydrate gel [3]. The use of fly ash in concrete and mortars as supplementary cementitious material is also preferred due to several engineering benefits which include an increase in workability, increase in pozzolanic activity, and reduction in heat of hydration [4]–[6]. Numerous studies focused on the study of the durability properties of concrete to determine the behavior of fly ash-based composites in alkaline and acidic solutions, which proved that fly ash performed very well due to the formation of ettringite [7 -9].

The current status of research suggests that there have been various studies on the use of fly ash in concrete which mainly encompasses its mechanical and morphological characteristics, however, due to change in environment the durability of cementitious materials still face numerous challenges [8]. Most of the building materials are porous which becomes susceptible to environmental changes leading to the deterioration of the whole structure. Similarly, the use of mortar as a finishing surface is highly likely to damage due to the application of environmental and physical actions. The available literature does not provide sufficient information about the optimum dosages of fly ash for chloride and acid attack. The current study aims to determine the durability properties of cement mortar by performing different tests such as water absorption test, chloride penetration test, and acid attack test. Different mixes were prepared in which cement was replaced with 5%, 10%, 15%, 20%, and 25% fly ash. The reinforcing behavior of cement and fly ash was also studied through microstructural analysis. This study would also help to design the optimum dosages of fly ash to reinforce mortars for extreme environments.

2. Experimental Program

2.1. Materials & Mix Proportions

Locally available *Fauji* Cement was used in this research. The cement (ASTM Type I) follows the requirements of (ASTM C150) [9]. Locally processed class F fly ash meeting the standard of ASTM C 618 manufactured at 'Port Qasim Power Plant Karachi Pakistan' was used in research. The maximum nominal size of fine aggregates is 4.75mm which follows the specifications of ASTM C778 [10]. The amount of fly ash is calculated by weight (Kg/m^3) and volume (%) of the total mix. The casting and drying of mortar cubes having the size of (70×70×70 mm^3) was done carefully as shown in Fig.1. The mix proportion of different materials is shown in Table 1.

Table 1: Mix proportion of mortar mixes

Mixture	w/c	Water	Cement	Sand	Fly Ash	
		Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	%
Control	0.5	234	468	1414	0	0
F1	0.5	234	445	1414	23	5
F2	0.5	234	421	1414	47	10
F3	0.5	234	398	1414	70	15
F4	0.5	234	374	1414	94	20
F5	0.5	234	351	1414	117	25

Fig. 1: The casting of specimens

2.2 Methods

2.2.1 Water Absorption Test

The water absorption test on mortar cubes was performed after 28 and 90 days of the casting according to the guidelines of ASTM C1403. Cubes were kept in water at 23±3 C° for 48 hours. After the soaking period cubes were surface dried with a cloth and weighted as W_1 known as saturated surface dry weight. Cubes were transferred to an electric oven and remained there for 24 hours. The temperature maintained in the oven was 100±5C°. After a specified period, dry weight of cubes was recorded as W_2 by using electric weight balance having precision up to 0.01g. Finally, water absorption of mortar was calculated by using equation no (1) in terms of percentage.

$$W.A = (W2 - W1/W1) \times 100 \qquad (1)$$

2.2.2. Chemical attack test

Cubical specimens of 70mm size after 28 and 90 days of casting were subjected to acid attack test. A diluted solution having 3% hydrochloric acid was prepared in which mortar specimens were immersed for 7, 14 and, 28 days. After completion of the specified period of immersion, each sample was oven-dried to obtain its reduction in dry weight. Furthermore, calculation of the reduction in mortar mass is followed by using equation no (2)

$$Loss\ in\ Mass\ (\%) = (Mi - Mf/Mi) \times 100 \qquad (2)$$

where M_i is the initial dry mass before the acid attack and M_f is the final mass after a specified period of acid attack.

2.2.3. Chloride penetration test

To inspect chloride penetration 70mm mortar cubes were used at 28 and 90 days strength after casting. Cubes were immersed in water for 14 days at a temperature of 15±3 C°. After curing they were sinked in 5% NaCl solution for 90 days. After the immersion period in NaCl, cubes were divided from a center into two equal parts by using a concrete cutter. A diluted solution of 0.1 normality of silver nitrate ($AgNo_3$) was sprayed over the surface of the cleaved cube. A white silver-colored precipitate of $AgNo_3$ is formed as a result of a reaction with chlorides penetrated in mortar. This precipitate is known as silver nitrate. The percentage of area covered with $AgNo_3$ was calculated by taking measurements from the edges of the cube in mm. Three specimens from each batch were subjected to a chloride penetration test.

2.2.4. Microstructural analysis

SEM test was conducted to study the microstructural properties of mortar. SEM images were taken at different resolutions ranging between 5-50 µm to study the microstructural properties of specimens.

4. Results & discussion

4.1 Water absorption

The mortar cubical specimens having a size of 70mm were used to determine water absorption capacity after 28 and 90 days after casting as shown in Fig.2. Variation of water absorption of specimens having different dosages of fly ash is shown in Fig.3. Results of water absorption were calculated in terms of percentage increase or decrease with respect to the controlled sample. The addition of lower dosages of fly ash reduced water absorption capacity and then the water absorption capacity of mortar increased as the concentration of fly ash increased. It was noticed that the addition of 10% fly ash led to a decrease in water absorption capacity by 31 and 15% when tested at 28 and 90 days respectively. The reduction in water absorption capacity is due to the filling action of fly ash as a result of pozzolanic activity as evident from the microstructural study of mortar samples. However, further increase in fly ash dosage beyond 10% increased water absorption capacity of mortars. Results obtained in this study reflect that increase in fly ash dosage by 25% significantly increased water absorption by 24 and 21% when inspected at 28 and 90 days respectively. Research carried out by various researchers suggests that an increase in fly ash dosage increases porosity and water absorption capacity. It was reported by A. Mardani et al. that the incorporation of 60% fly ash increased porosity and water absorption capacity by 25.3 and 33.34% respectively when analyzed at 56 days [11]. Similarly, the findings of P. Dinakar et al. [12] confirms that high volume fly ash replacement with cement drives to increase in porosity and water absorption capacity.

Fig. 2: Mortars specimens subjected to water absorption test

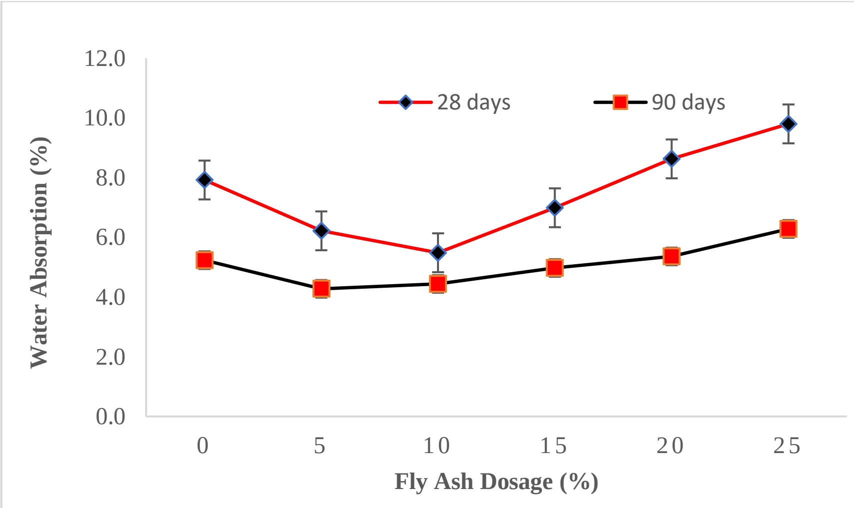

Fig. 3: Water absorption of mortar cubes having fly ash

4.2 Acid attack

To study the effect of acid on mortars three specimens of each mix were exposed to an acidic solution. Reduction in the mass of each mix was recorded after 7, 14 and, 28 days as shown in Fig.4. Resistance against acid attack was increased by adding a high volume of fly ash. The addition of 25% fly ash in mortar showed 42% and 46% more resistance against acid attack as compared to the control mix at 14 and 28 days respectively. The study shows that the mortar specimens containing 5%, 10%, 15%, 20% and, 25% fly ash lost 7.1%, 5.8%, 4.9%, 4.6% and, 4.5% of their mass after 28 days of immersion period in acidic solution respectively as compared to control sample which lost 8.4% of its mass. It was found that the control mix of mortar having 468 kg/m^3 of cement which has zero replacement of fly ash became more susceptible to acid attack. The results obtained by V. Sata et al.[13] and Z. Li.et al [14] also show that the presence of fly ash in cement matrix has improved its stability in an acidic environment due to low water absorption and low calcium content. The analysis of microstructural images of mortar containing fly ash shows that the presence of fly ash has accelerated the formation of hydration products that filled the matrix by connecting pores. The study carried out by P. Dinakar et al. [12] shows that an increase in cement content by 400 kg/m^3 or above shows more vulnerability to acid attack and reduces specimen weight considerably as compared to mixes containing fly ash.

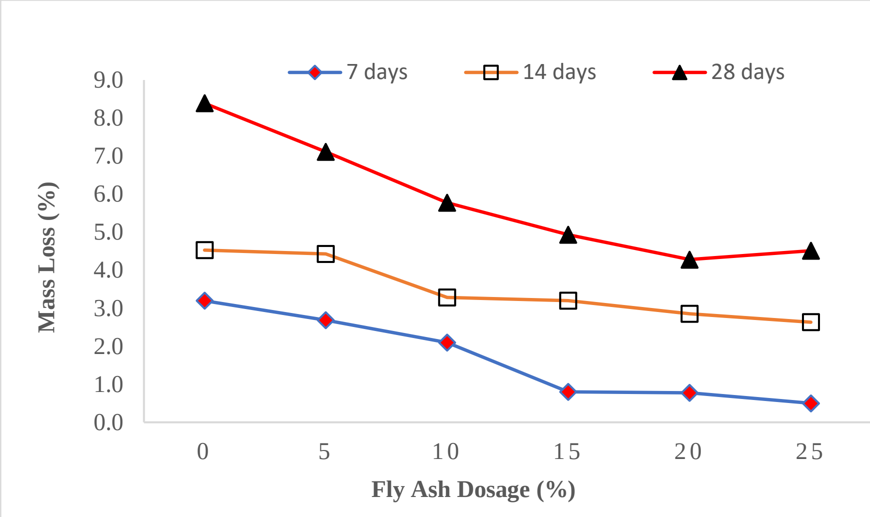

Fig. 4: Mass loss of specimens due to acid attack

Fig. 5: Acid attack on mortar having fly ash

4.3 Chloride penetration

Chloride penetration in cement mortars is an important phenomenon which is needed to be addressed to maintain the durability of structure because mostly mortars come directly into contact with the external environment. In this research affinity of mortars to chloride, penetration was studied through the immersion method. Three specimens of each mix from three batches were kept immersed in 5% NaCl solution for 28 days. The addition of fly ash in different mixes showed resistance to chloride penetration. Depth of chloride penetration steadily decreased upon the addition of higher dosages of fly ash as shown in Fig.6. The reduction in the amount of chloride penetration is due to the presence of calcium in fly ash which increases silicate content by providing sufficient resistance to chloride penetration. The results obtained in this study show that the addition of 25% fly ash in cement mortar leads to a decrease in chloride penetration by 27.8%. This is due to the reason that fly ash improves porosity and strength due to the availability of Fe_2O_3 and Al_2O_3 [15]. The microstructural studies conducted by Qaing Fu et al. [16] and Mijia Yang et al. [17] also confirm the filling effect of fly ash due to expansion of basic silica gel and merging of capillary pores by creating a uniform and dense microstructure.

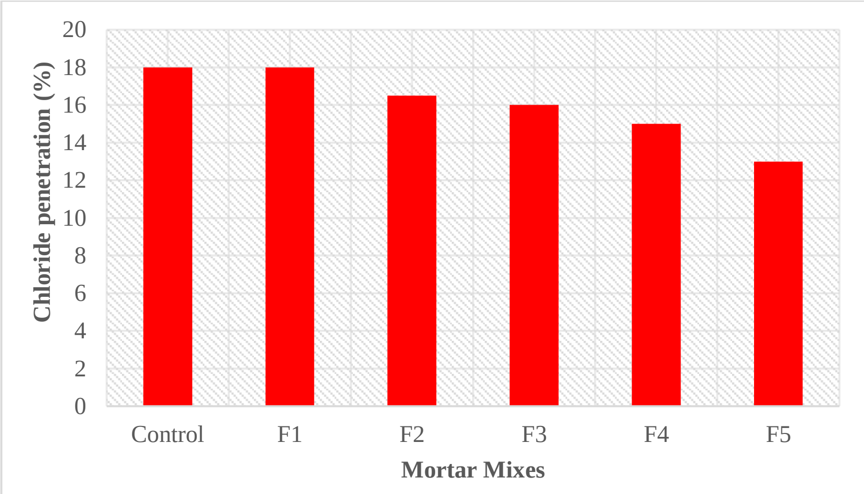

Fig. 6: Chloride penetration test on mortar mixes containing fly ash

4.4. Microstructural analysis

The microstructural analysis was performed on the control mix and the mix containing fly ash. The analysis of the control sample of mortar shows needle-shaped crystals of ettringite and prismatic crystals of calcium hydroxide, however, there has been the formation of micro-cracks and voids as shown in Fig.7. On the other hand, the addition of 10% fly ash accelerated ettringite formation and C-S-H gel which reinforced the matrix by binding the hydration products as shown in Fig. 8. The voids in mortar were filled due to a pozzolanic reaction which created a high concentration of CSH gel by consuming calcium hydroxide. The presence of fly ash particles filled the pores which resulted in the formation of a uniform and dense microstructure.

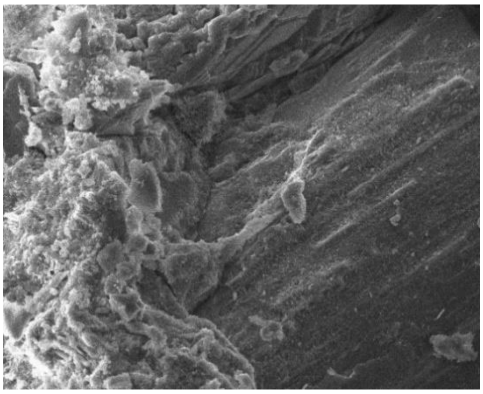

Fig. 7: SEM image of control specimen containing at 20µm.

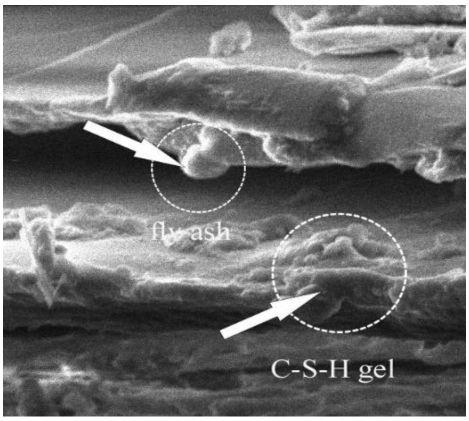

Fig. 8: SEM image of specimen containing fly ash at 10µm.

5. Conclusion

The following conclusions are made from this study.

- The addition of 10% fly ash reduces the water absorption capacity by 31% and 15% at 28 and 90 days respectively.
- The addition of 25% fly ash in mortar showed 42% and 46% more resistance to acid attack individually after 28 and 90 days each of immersion in acidic solution.
- The addition of 25% fly ash in cement mortar reduced the chloride penetration by 33% and 27.8% at 28 and 90 days due to a reduction in porosity and an increase in the amount of CSH gel.
- Microstructural images show enhancement in ettringite formation and C-S-H gel which reinforced the matrix in some ways by binding the hydration products.
- The improvement in durability properties of mortars suggests the use of fly ash in reinforcing mortars in extreme environmental conditions.

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ID 112: Utilization of Bacterial Concrete for Repair Works

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A B S T R A C T

Concrete is the primary material used in construction industry all over the world. Unfortunately, due to the nature of its usage concrete often faces situation in which it loses its strength and becomes cracked. Water seeps into concrete through these cracks and cause issues such as steel erosion which leads to lose of concrete strength over time. To overcome this critical issue concrete needs to be reinforcement with a method that allows it to self-repair these cracks through an automatic and environmentally friendly approach. Traditional methods such as application of crack healing binder agents and repair works are used for concrete repair, but these actions cannot be applied in all situations and most of them are not environmentally viable. Thus, to overcome this issue the biological function of calcite precipitation which produces calcium carbonate, a natural binding agent found in a bacterial strand called Bacillus Sphaericus is utilized. Consequently, the development of a Self-Healing Concrete also called as Bacterial Concrete or Living Concrete and investigation of its effects was crucial. The aim of the study is to check the survival of the bacteria namely Bacillus Subtilus in concrete with the presence of carrier compound and investigate the self-healing mechanism of the organism and its effects on mechanical properties of concrete.

K E Y W O R D S:

Self-healing concrete, Bacterial concrete, Repair works, Crack healing etc.

1. Introduction

Concrete is universally used construction material because of its ability to sustain over long period and it also possess several unique traits that can improve its performance[1]. Unfortunately, cracking is a common phenomenon in concrete due to its low tensile strength which reduce its performance, strength, and durability[2]. Since cracks provide a direct path of contact for water and other salts that can be potentially harmful and promote corrosion in reinforcement of concrete [3]. Moreover, without immediate and appropriate treatment of cracks tend to expand further and require costly repairs [4]. Various techniques are available for repairing cracks but several of them have drawbacks such as health hazards and different coefficient of thermal expansion [1]. Therefore, a reliable and efficient method must be sought to cope with such problems. A self-repairing material which can treat the cracks and fissures in concrete can address the subject problem [5]. Therefore, it was necessary to create Self-Healing Concrete, also known as Bacterial Concrete or Living Concrete.

One of the fundamental weaknesses of concrete is that small cracks appear in concrete and these cracks are inevitable. Cracks causes corrosion by the seepage of water and other salts, thus reduces the life of concrete [7]. Because of this issue there was a need to develop an inherent biomaterial which should also possess the ability to self-repair to help resolve the cracks and fissures problems in concrete. Bacterial concrete is one such material, which can successfully alleviate the problem [8]. Moreover, the added benefit of bacterial based self-healing concrete is that any mineral precipitation induced due to microbial activities is a natural process with zero pollution because of this it is a very desirable technique [9]. Bacteria gradually clog the holes and fissures in concrete due to the anionic nature of their cell wall, which causes significant metal deposition (calcite) on the surface of the wall.[10]. The criteria of bacteria selection was the survival chances of bacteria in high alkaline environments these included specimens such as B. Pasteurii, Bacillus subtilis and B. spharicus, these bacterium are commonly found in other study samples as well [7]. Similarly, the selection is also dependent on the survival capability of bacteria in harsh environment as of concrete [11].

In an environment with a pH value of 10 or above, the majority of microorganisms die [7]. During the data collection phase the bacterial strain of genus Bacillus was found to be quite effective in high alkaline environments. This strain is able to survive in the harsh environment due to its ability to form spores that are similar to plant seeds [12]. The spores have a thick wall and are able to stay dormant until they come into contact with water and activate due to seepage through cracks in concrete [1]. When the pH of alkaline concrete is amid 10 to 11.5 the bacterial spores are found to be activate and begin the natural calcification process, which begins concrete healing. Bacteria which have survived in alkaline environmental are listed below.

1. B. Pasteurii
2. Deleya halophila
3. Myxococcus Xanthus
4. B. Megaterium
5. Halomonasrurihalina

The literature review of various studies found that the category Bacillus can survive in very alkaline conditions [9]. Self-healing by microorganisms involves the breakdown of urea by ureolytic bacteria like Bacillus Sphaericus or the precipitation of calcium carbonate in cracks by direct action of bacteria species like Bacillus Subtilis on calcium compounds like calcium lactate. [13]. Concrete and microbial precipitation of calcium carbonate are compatible, and the production process is environmentally friendly. [14]. Additionally, as oxygen is consumed throughout the process, the likelihood of reinforcement or steel corrosion is decreased. [10]. Other characteristics of the Bacillus genre, such as its ability to tolerate wetness and produce spores, make it suited for use as a self-healing agent in concrete.. Therefore, most research studies used Bacillus as bio-agent for calcite precipitation [8].

A white crystalline salt known as calcium lactate, with the chemical formula C6H10CaO6, has two lactate anions, H3C(CHOH)CO-2, for every calcium cation, Ca2+.[11]. Various hydrates are a result of this reaction and the most common among them being the pentahydrate C6 H10 CaO6·5H2O. Calcium lactate is used as a food additive with the E327 code and is mostly utilised in medicine to address calcium deficiencies. Some cheese crystals also contain calcium lactate [10].

Chemicals comprised of the two elements iron and oxygen are known as iron oxides. There are 16 different types fo iron oxygen bonds known in science [15]. Catalysts, pigments, thermite, iron ores and haemoglobin are just a few examples of the many different chemicals that use iron oxide in their manufacturing process. These iron oxides and oxide-hydroxides are crucial in numerous geological and biological process and thus are chemicals in high demand [16]. The most common form of iron oxide is the rust that occurs on metal. Iron oxide is used in the field of metallurgy and in paints and varnishes. It can also be used in some cases as a pigment or paint for coloured concrete [12]. When used as a food colouring, it has E number E172. The purpose of using Iron Oxide in the study is to ensure the survival of the bacteria in harsh environment, i.e., providing the bacteria with a carrier compound [14].

1.1. Bio based self-healing mechanism

The usage of the chemical process of precipitation to achieve calcium carbonate is the underlying idea behind self-healing concrete. The four major factors that affect the characteristics of the concrete are the concentration of calcium ions, the pH of the solution, the concentration of dissolved inorganic carbon, and the availability of nucleation sites [7]. The first three character traits are related to concrete mix properties and the last trait is connected to the bacteria itself [13]. Bacterial Precipitation is achieved through the conversion of calcium compounds such as calcium lactate and through hydrolysis of urea [14]. In the first mechanism crack openings allow oxygen and bacterial solution to penetrate inside concrete this solution reacts and convert calcium lactate into calcium carbonate and carbon dioxide [12]. If there are portlandite particles present during reaction, they would help increase the carbon dioxide yield which produces more calcium carbonate which may be used for further repairing or healing[16]. This is best applied in the case of fresh concrete in which there are abundant anhydrate calcium hydroxide particles[15]. The second mechanism is the precipitation of calcium carbonate through hydrolysis of urea which results in ammonium and carbonate which strengthens the bonds and fills the cracks [10]. The process is dependent on major factors such as availability of moisture, crack area or width to be healed, age of concrete and survival of bacteria in long term [9]. Table 1 shows the previous studies done by various researchers in the past regarding the width of the cracks healed and shows various techniques by which the cracks were healed.

Table 1: Past studies on bacterial concrete

Approach	Width of Crack Healed	References
Natural	Healing of crack below60µm wide was reported	Yang [19]
Autogenic (Supplementary Cementitious materials)	Crack width below200µm reported	Huang [11], Van titleboom [12]
Autogenic (Polymer Self-Healing)	Crack width up to 138µmfilled completely	Elmoaty [13], Snoeck[14]
Other (Biological and chemical)	Healing of crack widthup to 0.22mm was reported	Stuckrath[15]
Microbiological Approach	Healing of Crack widthof 0.970mm	Wang[20-21]

When bacteria (Bacillus subtilus) are incorporated into concrete, they enter a dormant stage that like seeds [2]. Mostly bacteria need air for their activation, if cracks occur it should provide necessary exposure. As soon as cracks appear, bacteria in the area around them begin precipitating calcite crystals. [3]. The spores of the bacteria germinate when they come into touch with water and nutrients when a concrete structure is broken and water begins to seep through the cracks that emerge in the concrete. [4]. After activation, the bacteria start feeding on its nutrient calcium lactate [5]. Oxygen is consumed by the bacteria as they feed, and soluble calcium lactate is transformed into insoluble limestone. On the surface of the crack, the limestone solidifies, filling it, see Figure 1 [2].

Fig. 1: Bacteria based calcite precipitation

1.2. Bacterial based self-healing concrete

Cracks are inevitable in concrete; larger cracks need to be retrofitted or repaired because they seriously affect the strength whereas micro cracks are somewhat problematic [17]. The microcracks are a major cause of steel corrosion due to seepage of water because of increased permeability and porosity [5]. The ability to heal microcracks in concrete is related to the composition of the concrete mix [1]. In particle mixtures with high binder content show better healing properties which can be attributed to delayed hydration or secondary hydration process which is caused my unused binder agents and their contact with water which seeps through the microcracks [17]. As high-binder content mixtures appear to have self-healing capability it is also limited to cracks with a width smaller than 0.2 mm [6]. This is a very limited responsive to an otherwise very extensive problem as any crack above the 0.2mm threshold cannot be repaired with the techniques and it also depends highly on the chance that small non-hydrated cement particles lying exposed at the crack surface meet water [9]. Another limitation put forward due to standard practices is the limited use application of binder agent in the concrete mix. Any mix batch with inappropriate portions is scraped and a new batch is created [10].

This phenomenon lead to the development and exploration of other avenues of concrete mix. Moreover, studies have conducted research on various ideas on development of a sustainable concrete mix. The prevailing thought behind self-healing concrete currently is a concrete mix based on mineral producing bacteria [6]. This technique was observed to effectively seal any surface cracks [2].

The bacterial mix can be administered through spray and direct injection in damaged surfaces [10]. Due to the inclusion of manual and external influences the study such cannot be considered as a true healing concrete [13]. To further develop the best self-healing agent other studies were observed. The best outcome was to use a self-healing bacteria as the binding agent in the concrete mix. In one particular study the strand of Bacillus genus alkali-resistant bacteria was used in the concrete mix [14]. The bacteria was activated due to seepage of water from cracks and other extremities[7]. The spores then multiplied and started to utilize pre-existing organic materials and this lead to excessive production of calcium carbonate which helped fill up the crack [16]. However the results were based on fresh concrete mixes (7 days cured) thus came the question of bacterial viability and activity in a long term unprotected environment needed to be tested [4]. The bacterial reliability when embedded in concrete is about two months. To overcome this issue the study carried out tests based on porous clay particles filled with bacterial spores and organic minerals was carried out. [8]. It is theorized that bacterial spores are better protected through light weight aggregates and thus have longer life spans this can lead to more opportunities to act as self-healing concrete when added to the concrete mixture [15].

2. Research Methodology

2.1 Data Collection

To achieve the aim of the study, 45 cubes of 4″ size and 45 cylinders of (4″ × 8″) size specimens were cast. Out of 45 specimens, 15 of them were without bacteria to determine compressive strength, while the other 15 which were bacteria induced to compare the compressive strength with ordinary concrete. Similar procedure was followed for the cylinders, 15 of them were cast to determine the tensile strength, while the other 15 which were bacteria induced to compare the tensile strength with ordinary concrete. The remaining 15 cubes and 15 cylinders were to observe the self-healing mechanism and the survival of the bacteria.

Ordinary Portland Cement (ASTM Type-I) was used, and the content of cement was dependent on the amount and size of the coarse aggregate and water. The properties of cement like consistency, Initial Setting and Final Setting time were tested in the laboratory and the results are shown in Table 1.

Table 1: Cement setting times

Consistency	0.29
Initial Setting Time	80 minutes
Final Setting Time	186 minutes

The fine aggregates tested according to ASTM standards and sieved from 600-micron were used. The test for specific gravity, unit weight (Loose & Compacted) and water absorption were performed. The particle size distribution of the fine aggregates was performed by sieve analysis using a mechanical shaker. Table 2 and 3 show the results of the performed tests.

Table 2: Cement properties

Specific Gravity	2.7 gm/cm^3
Unit Weight (Loose)	1782.15 kg/m^3
Unit Weight (Compacted)	1813.84 kg/m^3
Water Absorption	2.46%
Fineness Modulus	2.983

Table 3: Sieve analysis results

S. No:	Sieve Size	Weight Retained (gm)	Weight Retained (%)	Cumulative Retained (%)	Passing (%)	Cumulative Passing (%)
1	37 mm	0	0	0	100	100
2	25 mm	720	14.60	14.60	85.4	85.4
3	19.5 mm	1765	35.80	50.40	64.2	49.6
4	12.5 mm	1635	33.16	83.56	66.84	16.44
5	9.5 mm	620	12.58	96.14	87.5	3.86
6	4.75 mm	185	3.75	99.89	96.25	0.11
7	PAN	5	0.11	100	99.89	0

The purpose of adding Calcium Lactate was to provide a "Feeding Agent" to the Bacteria during healing purpose. As the crack appears, the Bacteria feeds upon Calcium Lactate and produce Calcium Carbonate.

$$C6H10CaO6 + 6O2 \rightarrow CaCO3 + 5CO2 + 5H2O$$

$$CO2 + Ca\ (OH)2 \rightarrow CaCO3 + H2O$$

3.2. Bacillus subtilis

Bacillus subtilis was selected for the investigation because it met the requirements for life in a harsh atmosphere. Gram-positive bacteria have the capacity to produce spores under unfavourable circumstances. It is the best choice because of the spore formation's resistance to intense mechanical pressure and an alkaline environment. Bacillus species can produce spores that can remain latent for more than 200 years. In order to introduce these bacteria in various incorporation techniques in concrete, bacterial solution (bacteria in nutrient bath), which has been specifically prepared and processed to ensure spore development in regulated microbiology laboratory, is typically employed.

3.3. Specimen ratio

The study mix deign ratio of bacterial solution and cement was used in the current study. The ratio for the design mix was 1: 2: 4 with a water content of 0.4. The quantities of other constituents are described in Table 4.

Table 4: Bacterial properties

Description	**Quantities**
Bacillus Subtilus	4.75% @ 7ml per specimen
Calcium lactate	5% by weight of cement
Iron Oxide	Mixed in traces with bacterial solution
Admixture(Superplasticizers)	1% by amount of water

Table 5: Proportion for cube testing

4.27 % of W/C 7ml	**Normal Cubes**	**Healing Cubes**
15 Cubes	15 Cubes	15 Cubes
Total= 45 Cubes		
Bacteria Consumed= 105ml	Bacteria Consumed= 0ml	Bacteria Consumed= 150 ml
Total Bacteria Consumed= 255ml		

Table 6: Proportion for cylinder testing

4.27 % of W/C 7ml	**Normal**	**Healing**
15 Cylinders	15 Cylinders	15 Cylinders
Total= 45 Cylinders		

Bacteria Consumed= 105ml	Bacteria Consumed= 0ml	Bacteria Consumed= 150 ml
Total Bacteria Consumed= 255ml		

3.4. Preparation of Test Specimens

All the specimens used in this research maintained a standard size as per ASTM criterion. For each concrete mix, a total of 45 Cubes (4 inches × 4 inches) and 12 Cylinders (4 inches × 4 inches) were used to perform the various tests in the concrete laboratory. There were 15 controls mix ordinary cement concrete cubes and 30 bacterial induced self- healing concrete cubes. For the tensile strength test, all the specimens were induced with the bacteria. The brief details of the test specimens used to perform various tests are given below in Table 5-7.

Table 7: Test specimens

Tests	Specimen Size	No: of Samples	Curing Period (Time of Testing)
Compressive StrengthTest	4 inches × 4 inches	30	3,7 & 28 Days
Tensile Strength Test	8 inches × 4 inches	12	3,7& 28 Days
Survival of the Bacteria (Pre- Crack)	4 inches × 4 inches 8 inches × 4 inches	15	3,7 & 28 Days

The steps towards achieving a perfect concrete mix are stated below:

- The ratios used for the preparation of concrete were 1:2:4 at a water cement ratio of 0.4. Each mix was supposed to cast 45 cubes of size 4"x 4" and 45 Cylinders of size 8" x 4".
- The mix proportions according to the mix designs were calculated for equivalent 45 Cubes and 45 Cylinders. An extra 15% of the total quantity was added to avoid shortage of the concrete mix due to wasting or any unwanted activity.
- The concrete mix was allowed to mix properly in a rotary drum. During the mixing, the calculated amount of bacterial solution including calcium lactate and Iron Oxide were added.
- The mixed concrete mass was then taken out form the drum into a flat tray, and then mass was filled in the moulds.

3. Results and Discussion

3.1 Results of Comprehensive and Tensile Strength Tests

The results indicate the direct relation between the amounts of the bacteria being used in the concrete mix. The greater the quantity of the bacteria, the greater will be the strength. The research showed that the inclusion of bacteria in concrete improves its natural healing and hydration properties at a greater extent. Furthermore, the healing process is faster during the early days after the preparation of concrete. The Pre-Cracking of the concrete allows the bacteria to start the germination process and it lasts if the amount of calcium lactate available at its surrounding has been completely consumed. The presence of carrier compound greatly affects the behaviour and survival of the bacteria. A carrier compound keeps the bacteria safe and protects it from the harsh and alkaline environment of concrete.

3.1.1 Compressive Strength

According to the research study findings the bacteria improved the comprehensive strength and the healing properties of the specimen the 28 days average compressive strength was increased by 16%. However, the average compressive strength at 3 and 7 days compressive of both the ordinary and bacterial concrete did not show any significant increment, see Figure 2. To further analyse its behaviour, the concrete cubes were cast at pre-cracked at 3 and 7 days to check the healing procedure and the survival of the bacteria. It was found that the average compressive strength of the concrete after the activation of the bacteria to heal the cracks consequently enhanced its compressive strength as shown in Figure 2 and 3. It can be observed that compressive strength has shown improvement with respect to time due to the presence of calcium carbonate.

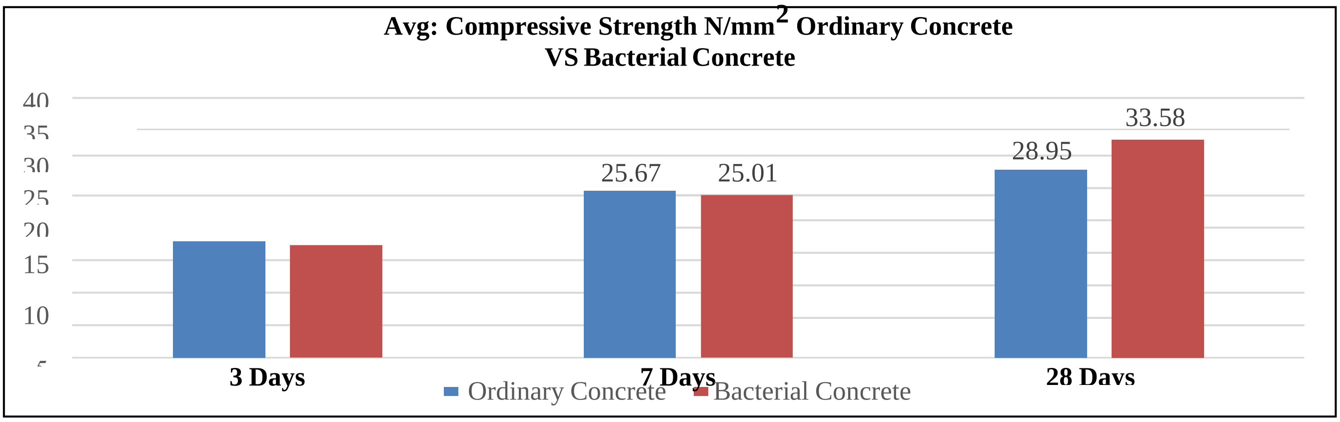

Fig. 2: Average compressive strength

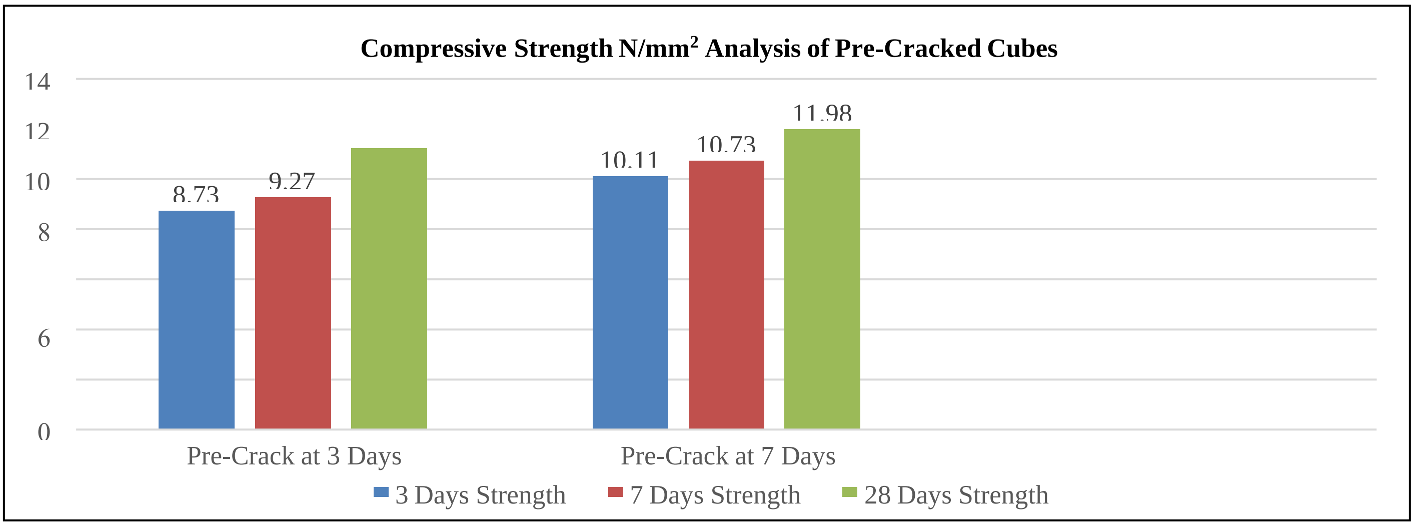

Fig. 3: Pre-Cracked compressive strength

4.1.2 Tensile Strength

According to the findings of the study, bacterial concrete was found not only to improve the healing properties of the cement concrete but also shown a remarkable increment in the tensile strength of 29% in 3 Days Split tensile and 14.4% increment in 7 days Strength. The results of the study are show in Figure 4.

5. Conclusion

According to the study the Bacterial Concrete is sufficient to be used in water retaining structures, underground tanks, basement structures, sub structures, & other possible structures where maintenance by ordinary means is either inconvenient or uneconomical. The results give 16% increment in the compressive strength of the concrete after a period of 28 Days whereas 29% in 3 Days and 14.4% in 28 days increment in split tensile strength. Each bacterium of the Bacillus Genus possesses a unique healing and strength quality. However, there are some families of this Genus which are found to decrease the strength of the Concrete up to 35% including B. Spharicus (reference). Therefore, it is recommended to test the healing properties of the bacteria before incorporating it directly in the concrete mass. Furthermore, there was no germination of bacteria at a Pre-Crack period of 28 Days, which means that it becomes hard for the bacteria to survive because of the absence of the carrier compound. The concrete showed no healing when the cubes were pre-cracked after 28 days form the time of their preparation. The handling of the microbial organisms can be risky sometimes. It is recommended that the proper Microbial Testing of the bacteria should be done. Before its usage in the research purpose as sometimes, the bacterium can be pathogenic. The research investigated that the inclusion of iron oxide as a carrier compound imparts a negative impact on the preparation and hardening of concrete.

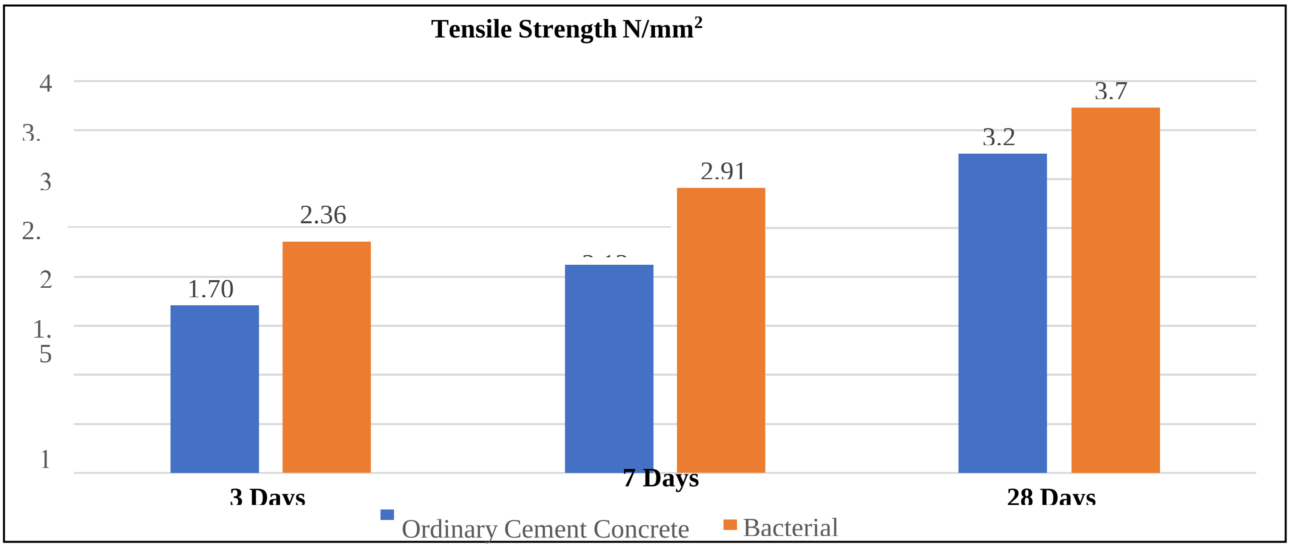

Fig. 4: Tensile strength

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ID 114: Enhancing Mechanical Properties of Concrete Using Industrial Waste Materials

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A B S T R A C T

The construction industry is currently investigating unused products suitably and operationally, which would minimize the use of cement and concrete constituents and eventually reduce the cost of production, known as green concrete. An intelligent solution is to use waste materials as a substitute. The waste marble dust powder and glass powder are types of solid waste from various sources (Marble processing and glass cutting process). These can be utilized as alternatives to concrete constituents. This research focuses on enhancing the mechanical properties of concrete by replacing cement with waste marble powder (WMP) and replacing sand with waste glass powder (WGP). 0%, 5%, 10%, and 15% cement was replaced by waste marble powder, and 0%, 10% and 20% of sand was replaced by waste glass powder. It was concluded that the concrete's compressive strength and split tensile strength increased. Workability was improved by adding 10% waste glass powder (obtained from dry processing) as the sand replacement at early ages. The compressive strength and split tensile strength at 7 days and 28 days decreased by replacing waste marble powder with cement, and workability also decreased. The cumulative effect of these wastes improved the mechanical properties. There is a strong relationship between the strength and quantity of waste glass powder and waste marble powder.

K E Y W O R D S:

Waste Marble Powder, Waste Glass Powder, Compressive Strength, Split tensile Strength, Sustainable Concrete, Solid Waste Materials

1. Introduction

The need to maximize the use of Portland cement in high-quality concrete, the rising costs of the energy necessary for its production, and growing interest in understanding the causes of concrete deterioration have helped maintain interest in supplementary cementitious material [1]. A variety of qualities are achieved by adding mineral and chemical admixtures to concrete. In addition to imparting many other beneficial features like improved split tensile strength, air entrainment, and water resistance, these chemicals may either speed up or slow down the pace at which the concrete hardens [2]. A sizeable quantity of solid waste and gaseous pollutants are also released during cement manufacturing. Additionally, a significant quantity of waste is created during the mining and processing of marble. Because of its smaller size and/or uneven shape, 30% of marble (in the case of untreated stone) is wasted during processing. Produced waste has harmful effects on the environmental, including air pollution, water pollution, and soil fertility [3]. Recycling waste materials like glass, marble, and wood is the most effective way to reduce their negative effects on the environment [4]. Directly releasing pollutants into the environment might have negative effects on the ecosystem. The importance of recycling wastes has therefore been highlighted. To use natural resources more effectively and preserve the environment from waste deposits, waste can be used to create new goods or used as admixtures [5]. In addition to saving landfill space, using industrial solid waste as a partial replacement for aggregates in building projects also lessens the need to mine natural raw materials [6].

The use of waste materials and industrial by-products in construction are in demand and becoming important. Sustainable construction, government and public awareness leads to use of waste materials in construction. Increase in demand of construction population and demolition of buildings and other form of waste materials being generated in high amount [7]. Marble wastage is a solid waste product of the manufacturing of marble that can be utilized as a filler in cement when making concrete [8]. With a partial replacement of cement by weight, marble dust powder can be added to M20 grade concrete [5]. In concrete Marble Dust Powder and Quartzite Dust Powder have been used widely and there is various research has been done on use and their effects on concrete. Marble Dust Powder and Quartzite Dust Powder can be used as partial replacement for fine aggregates or cement in concrete mix [7]. Sand is becoming more scarce everywhere these days. Marble dust powder is therefore applicable. Construction projects may substitute fine aggregate up to 50% of the time. The material is very reasonably priced per ton [9]. The use of Marble Dust Powder as a partial sand substitute in the preparation of concrete and its different effects on the mechanical characteristics of the concrete are proved [10]. Using marble dust in place of sand or cement progressively improves the mechanical and physical qualities of concrete, especially when the water-to-cement (w/c) ratio is low [11] [12].

According to the laboratory research, marble dust powder can substitute cement, increasing concrete's compressive strength and split tensile strength by up to 10% [5, 7, 8, 13]. Waste marble dust was added to concrete as a constituent ingredient, and the resulting mixture had a satisfactory slump [14]. Strength of green concrete can be enhanced by the intrusion of waste concrete (from demolished structures) and waste marble and it also reduces the unit weight of concrete. It may be used to develop the lightweight concrete to reduce dead load of structures [15]. Waste Glass dust is a non-biodegradable substance, and its placement on the ground pollutes the soil. Waste glass can thus be utilized instead of some coarse and fine aggregates to avoid these issues with disposable materials [16]. Glass cannot biodegrade, hence landfills do not offer a sustainable alternative. Therefore, it is imperative to use leftover glasses [17]. By partially substituting one or both of the elements, glass may be added to concrete in a variety of ways. Glass may be added to the controlled concrete in the form of crushed or powdered glass, either with or without the inclusion of admixtures or plasticizers [16]. Waste glass also exhibits pozzolanic activity when reduced to a size finer than 600 µm. Early in the hydration process, it combines with lime to produce more CSH gel, which results in a denser cement matrix. Thus, early alkali consumption by glass particles contributes to a decrease in the alkali-silica reaction, increasing the stability of concrete [17]. Glass may be utilized as a pozzolanic material with particles smaller than 75 µm since it is an amorphous material with a high silica content [18]. Because waste glass powder is non-degradable and has excellent physical, mechanical, thermal, and mineralogical qualities that allow it to be employed in a wide range of manufacturing, it started to dominate arguments about the viability and effectiveness of its recycling [19]. Utilizing ground glass powder can lessen the need for cement, the energy demand resulting from its usage, the influence on construction and building air pollution, and the CO2 emissions [20, 21]. There have been several attempts to substitute coarse aggregate, fine aggregate, and cement in the concrete industry with waste glass. It is possible to utilize the fine glass powder in place of more expensive components.20% of glass powder smaller than 100 µm in size might substitute cement in concrete without having a negative impact [22]. Glass can produce harmful alkali-silica reaction issues since it is unstable in the alkaline environment of concrete [27, 28]. By processing it into a fine glass powder (GLP) for use as a pozzolanic material in concrete, this feature has been taken advantage of. The strength of cement concrete is increased today by using glass powder as a cement alternative [8]. Among the leading waste as a substitute for concrete, glass improves the strength. Also helps to improve the thermal stability of concrete structures [23]. Glass powder increases strength by decreasing the porosity and unit weight of concrete [17]. Industrial and agricultural waste materials can be used in varying proportions as substitute for concrete ingredients [24]. The compressive strength increases by 40% and 18%, dry density decreases by 4% and 5% and water absorption increases by 28% and 36%, if 10% cement is replaced by marble powder and glass powder, respectively [25].

4. Research Methodology

In this stage, various experiments have been performed to determine the properties of materials. All experiments were performed according to ASTM guidelines. The tests that have been performed on the materials are mentioned below in the Table 1.

Table 1: Tests performed

Materials	**Test name**	**Standard**	**Test Result**
Cement	Standard consistency test	ASTM C 187-04	29.5%
	Initial and Final Setting time test	ASTM C 191-04b	43 Minutes 241 Minutes
	Fineness modulus of cement	ASTMC-430-17	
Fine Aggregate	Sieve Analysis and Determination of fineness modulus	ASTM C 136	2.35
	Bulk density	ASTM C 29	Loose Bulk Density 1344.14 kg/m3
			Compacted Bulk Density 1490.09 kg/m3
	Specific gravity	ASTM C 128	2.42
Coarse Aggregate	Sieve Analysis and Determination of fineness modulus	ASTM C 136	2.18
	Bulk density	ASTM C 29	Loose Bulk Density 1652.089 kg/m^3
			Compacted Bulk Density 1584.062 kg/m^3
	Specific gravity	ASTM C 127	2.59

2.1 Materials

Cement is mixed with sand to make mortar for masonry works and used with gravels and aggregates to produce Concrete [26]. In our project, Bestway cement confirming ASTM C150-19a has been used for concrete. Bestway Cement Limited is a British firm Bestway Group, a Pakistani building material company. The company is based in Islamabad, Pakistan. Throughout the research, Bestway cement is readily available in local markets of Lahore. Margalla crush has been used as coarse aggregate in preparing the samples. A Mix combination of 19mm + 12mm has been used for research work. Sand can also refer to a soil type or textural class, i.e., soil with more than 85% of its bulk made of sand-sized particles [27]. The sand used as fine aggregate is Lawrencpur sand, which is well-graded and well-protected to keep its moisture content.

The volume of waste glasss powder (WGP) has expanded significantly along with the use of waste glass goods. Waste glass is typically separated into colorful and clear categories. Most trash glasses that are colorless can be recycled successfully. During the glass cutting, the waste powder is collected, in the form of slurry. Afterward, this slurry is dried and ground to a fine powder, and this powder is passed from sieve no. 200 this is called wet process of WGP collection. However, during the dry processing of WGP collection, small pieces of waste glass were collected from several shops, other sources, and ground to make a fine glass powder. After making fine powder of the WGP was passed from sieve no. 200. Waste marble powder (WMP) is a fine white powder produced during marble cutting and later dumped in a landfill. For experimental purposes, it is collected from the nearby marble industry. Tap water is used for experimental purposes. The chemical and physical properties of cement, WGP and WMP are illustrated in Table 2.

Table 2: Chemical and physical properties of cement, WGP and WMP [2]

MATERIALS	SIO2	Al_2O_3	Fe_2O_3	CaO	MgO	L.O. I	Specific gravity	Colour	Fineness
Cement	21.70	3.58	1.5	63.20	3.20	1.90	3 – 3. 2	Grey	< 90 μm
WGP	71.4	2.53	0.36	11.1	1.59	0.82	2.42 – 3.01	Light gray	< 75 μm
WMP	3.00	0.14	0.39	52.28	0.50	42.60	2.5	White	<50 μm

2.2 Sample Preparation

The trial mix was prepared to investigate the workability and compressive strength at 7-day curing with partial replacement of sand with WGP at 0%, 10%, and 20%. The samples have been cast with the partial replacement of cement with Waste Marble Powder at varying levels of 0%, 5%, 10%, and 15% at 10% WGP, strength is checked at 28-day curing. Specimens casted according to ASTM C-31. After the specimens are hardened, the casted specimens are demolded carefully after 24 hours of their drying period so that there must be no damage to the specimen. These samples are cured using curing tanks, and left for the desired time-period e.g. 7 to 28 days. Curing is necessary for the proper hydration of Concrete and for maintaining its temperature. The cured samples are then removed and left in the open air for drying before testing. The concrete slump test evaluates how fluid new concrete is before it hardens. The Concrete is then poured into three layers in a cone of scale (100mmX200mmX300 mm) and compacted by a tamping rod with 25 blows per layer, then the cone is lifted carefully, and a decrease in the height of the cone (slump) is measured. Compressive strength is the ability of a material or structure to withstand loads that tend to contract rather than lengthen it. A universal testing device is frequently used to determine compressive strength test BS EN 12390–3:2019. The split tensile Strength Test IS 5816 1999 is a method of determining the split tensile strength of Concrete using a cylinder that splits across the vertical diameter. The controlled mix is 0% WGP 0%WMP.

3. Results and Discussion

3.1 Compressive strength test

A trial mix was prepared to check the strength of WGP at varying levels. Cubes were prepared, cured, and compressive strength was evaluated. It was found that 10% replacement of WGP gives maximum strength when WGP is collected from dry process, as indicated in Fig 1.

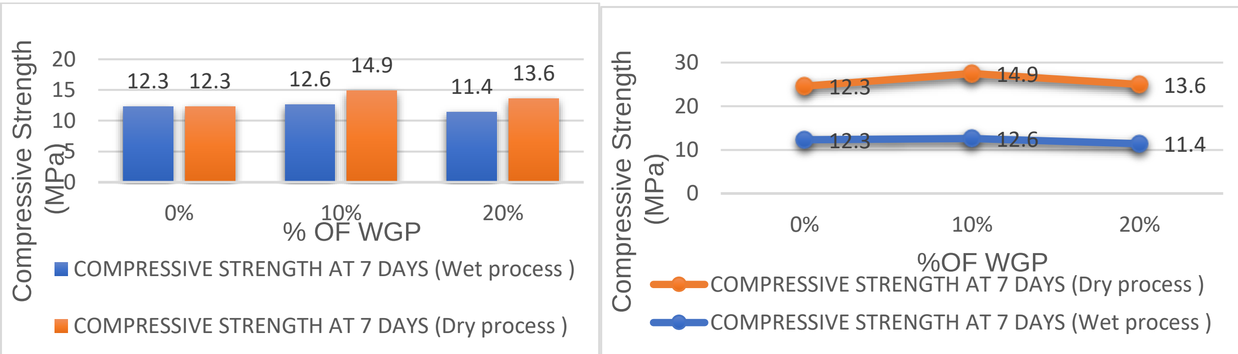

Figure 1: 7 days Compressive Strength of Concrete using WGP (trial mix)

It was observed from fig 1 that with WGP obtained from wet process at 10% replacement, the strength increases by 2.4% and at 20% replacement, the strength decreases by 7.3%. Meanwhile, the WGP gained from the dry process at 10 % and 20% replacement the increase in strength is 21.1% and 10.5%, respectively. So the optimum replacement level of WGP is 10% collected from the dry process.

This graph (Fig 2) presents the compressive strength of Concrete cubes after 7-day curing with cement replacement with WMP. The compressive strength at 0%, 5%, 10%, and 15% are 14.98 MPa, 14.69 MPa, 13.66 MPa, and 13.62 MPa, respectively. This graph also indicates that at 10% WGP 0% WMP, the compressive strength is 14.69 MPa, an 18.9 % increase compared to the controlled mix. When we increase the percentage of WMP, the compressive strength decreases up to 9 % as compared to the 10% WGP and 0% WMP, but it is still higher than controlled samples up to 10.3 %.

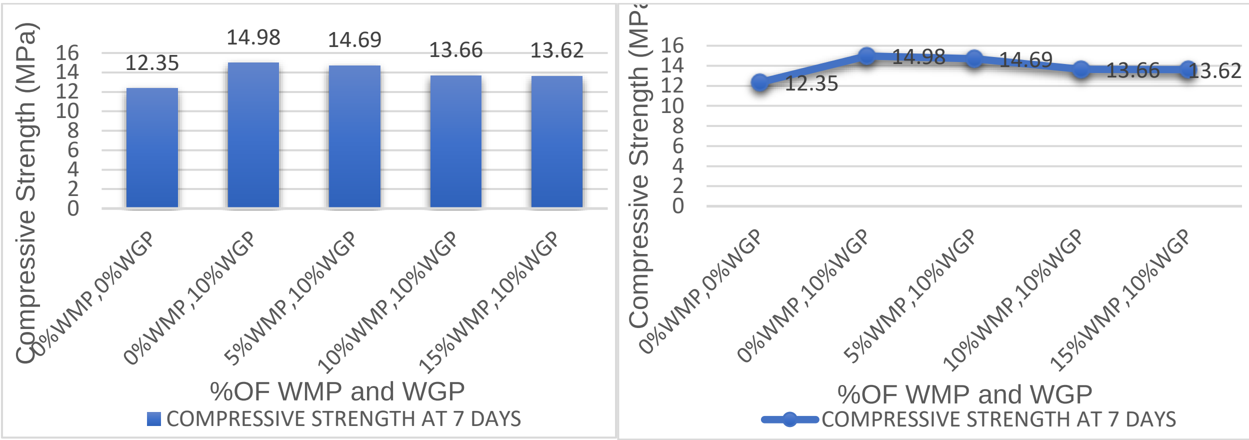

Figure 2: 7 days Compressive Strength of Concrete at varying % WMP and WGP

This graph (Fig 3) shows the compressive strength at 0%, 5%, 10% and 15% substitution of WMP with cement, which are 17.67 MPa, 17.33 MPa, 15.75 MPa and 14.76 MPa, respectively. This graph shows that at 10% WGP 0% WMP, the compressive strength is 17.67 MPa, a 21.3% increase compared to the controlled samples. When we increase the percentage of WMP, the compressive strength decreases, and at 15% WMP 10%WGP, the compressive strength decreases up to 16.4 % compared to the 10% of WGP 0% WMP which is 8.7 % lower than the controlled samples.

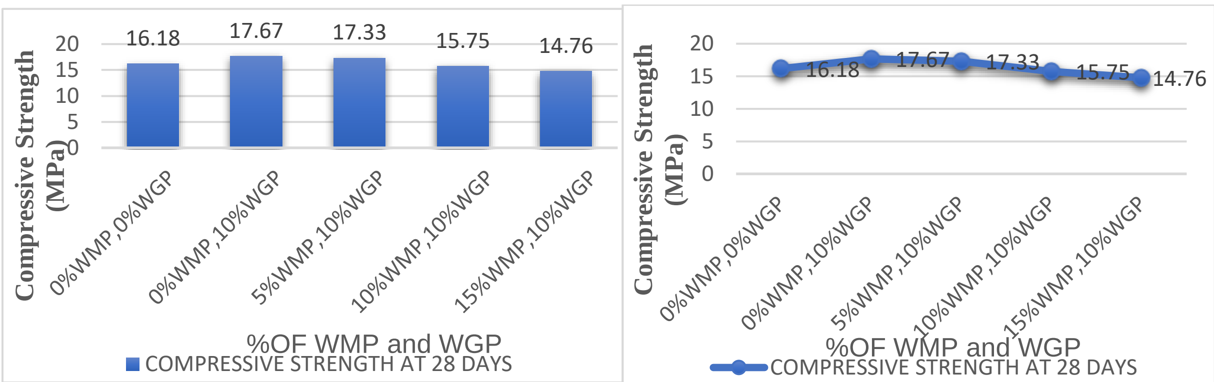

Figure 3: 28-days Compressive Strength of Concrete at varying % WMP and WGP

3.2 Split tensile strength test

Split tensile strength test was conducted as per IS 5816 1999. Cylinder specimens are used for this test. The graph (Fig 4) shows the split tensile strength at 0%, 5%, 10% and 15% substitution of WMP with cement, which are 3.52 MPa, 3.24 MPa, 3.23 MPa and 2.81 MPa, respectively. It shows that at 10% WGP and 0% WMP, the split tensile strength increases by 17% compared to controlled samples. When we increase the percentage of WMP, the split tensile strength decreases, at 15% WMP 10%WGP, the split tensile strength decreases upto 20% as compared to the 10% WGP and 0% WMP, and upto 6% as compared to the controlled samples.

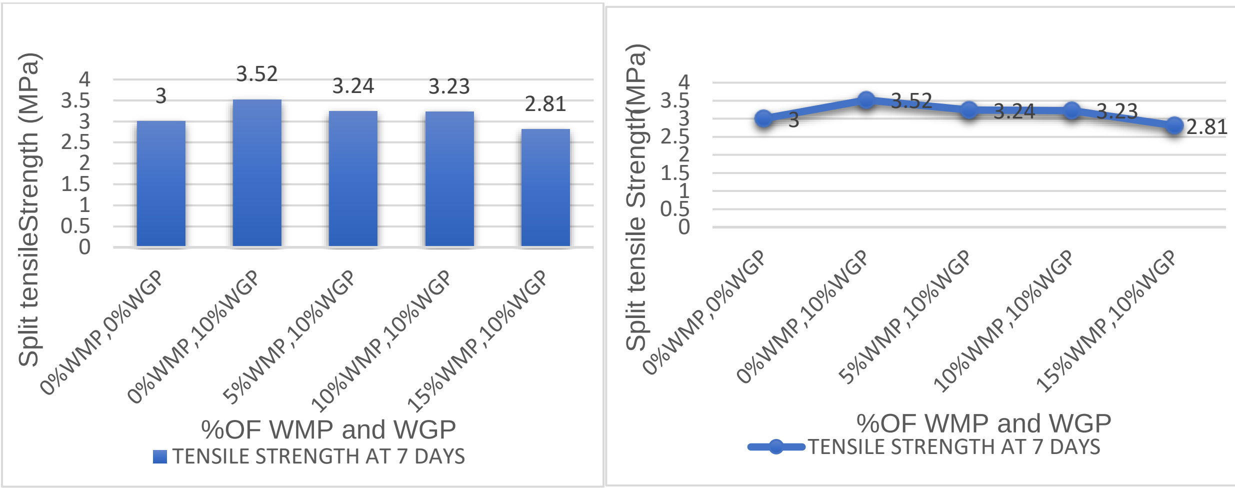

Figure 4: 7-days Split Tensile Strength at varying % WMP and WGP

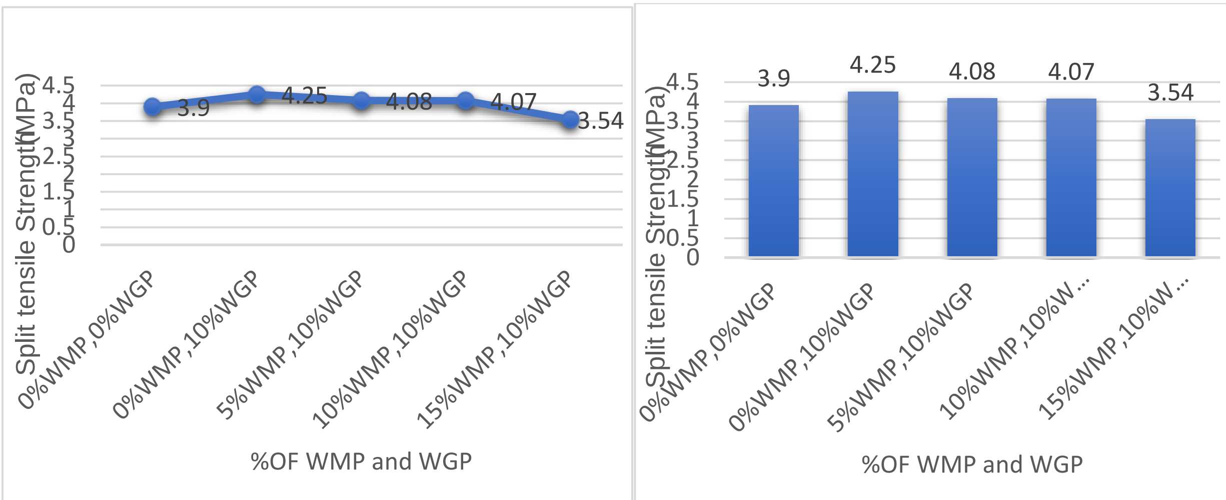

Figure 5: 28-day Split Tensile Strength at varying % WMP and WGP

The graph (Fig 5) shows that by adding the 10% WGP and 0% WMP the split tensile strength increased 9% compared to the controlled samples. When we substitute WMP, the split tensile strength decreases, and at 15% WMP 10%WGP, the split tensile strength decreases upto 16% as compared to the 10% WGP 0% WMP, and it is less than controlled mix upto 9%.

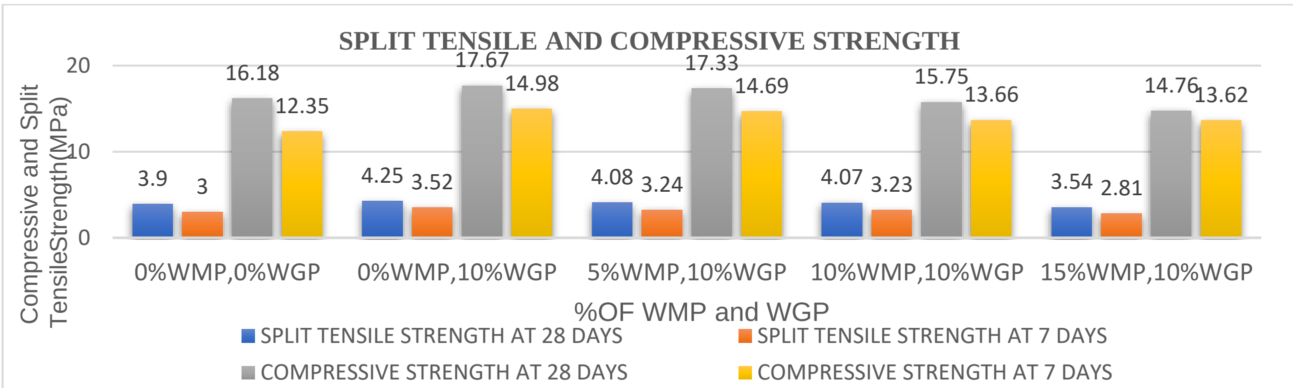

Figure 6: Compressive and Split Tensile Strength of Concrete at varying % WMP and WGP

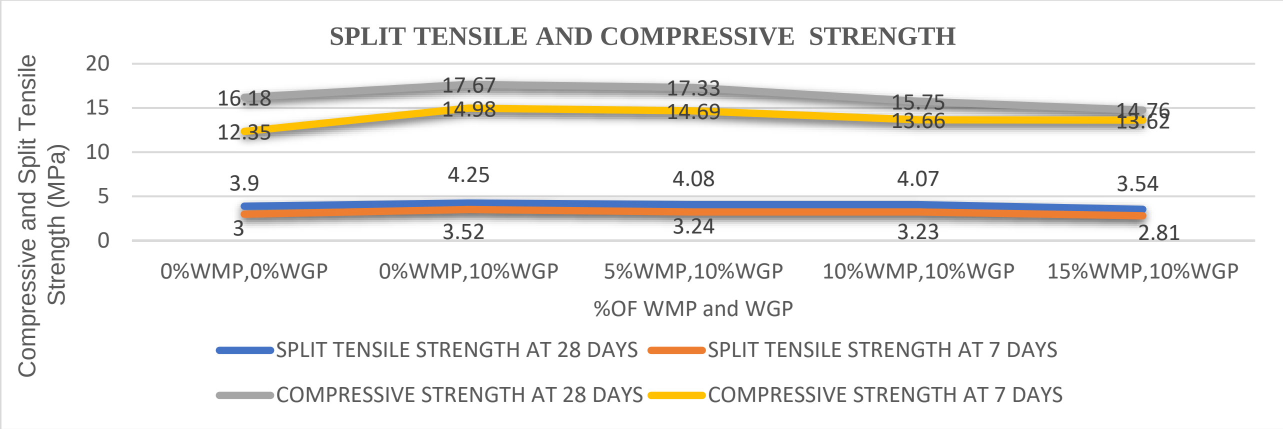

Figure 7: Compressive and Split Tensile Strength of Concrete at varying % WMP and WGP

Figure 6 and 7 shows that increasing the quantity of WGP increases the strength (compressive and split tensile) while increasing WMP, the strength (compressive and split tensile) decreases. The cumulative effect of waste material shows a decreasing trend but strength is still higher than the controlled samples at 15% WMP 0%WGP.

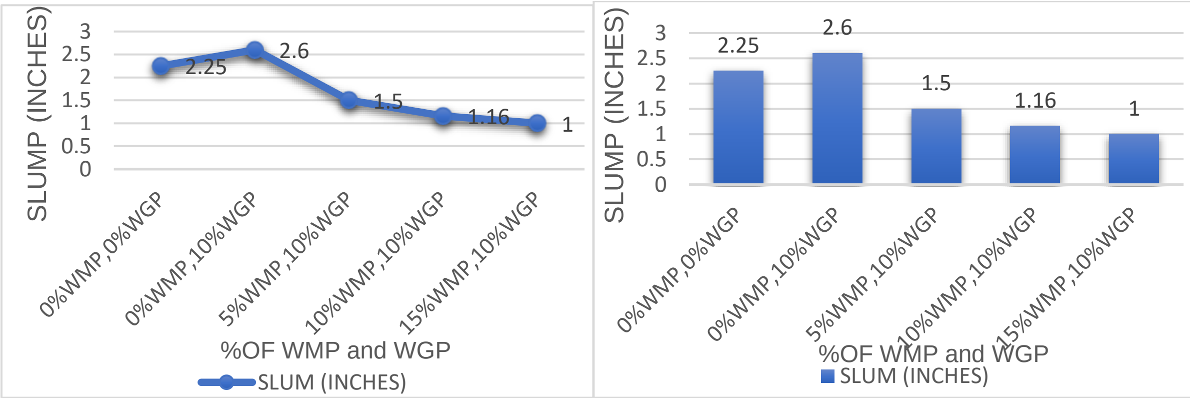

Figure 8: Workability of Concrete at varying % WMP and WGP

Graph (fig 8) shows that by increasing % of WGP, the slump value increase, at 10% WGP the slump is 2.6 inches. So, an increase is 15.5% as compared to controlled samples. By increasing the percentage of WMP i.e. 0%, 5%, 10%, and 15%, the values of slump are 2.6 inches, 2.5 inches, 1.16 inches and 1 inches, respectively. At 15% WMP 10%WGP the slump is 1 inch. So, a decrease is 55.5% as compared to controlled samples.

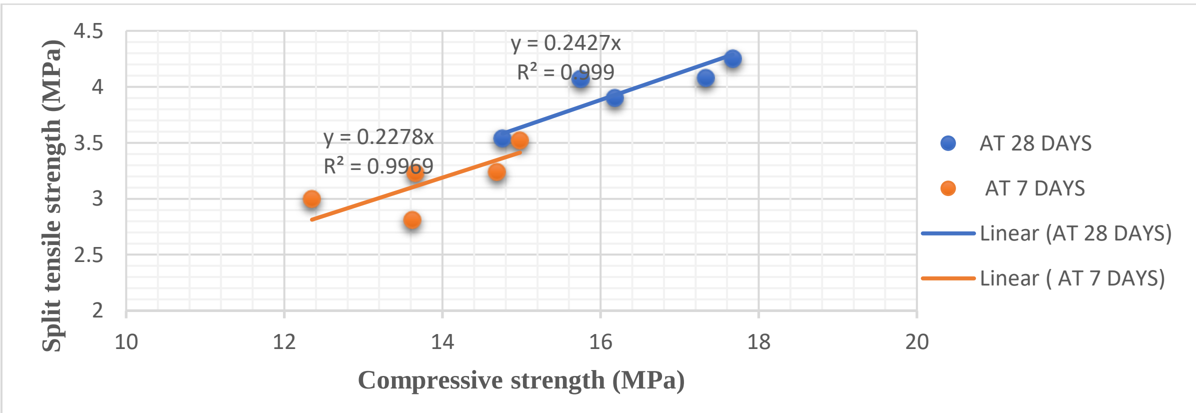

Figure 9: Correlation between compressive strength and split tensile strength at 7 and 28 days

Fig 9 shows a Correlation between the concrete's compressive and split tensile strength. The R^2 is 0.70206 for 28 days which shows a strong relation, while R^2 is 0.4555 for 7 days showing a weak linear relationship. This shows that in early stages, there is a weak relation between split tensile strength and compressive strength due to the presence of waste material added. But the ultimate compressive strength has a strong effect on split tensile strength. The split tensile strength can be calculated using the given equation shown in fig 9.

In fig 10, we can check the relation between WMP quantity vs strength (compressive and split tensile). The WMP has a strong relationship. The correlation is negative linear. Compressive strength and split tensile strength can be calculated at different dosage of WMP using the given equations in figure 10. By adding WMP the strength decreases because it does not contribute to the hydration process of cement and by replacing cement the quantity of cement is decreased, reducing the strength, so it is only a filler material. It is a good alternative to sand. Meanwhile, WMP decreases workability because of its irregular particle shape and larger particle size. The optimum dosage of waste in concrete is 10% WGP and 10% WMP because concrete was designed for 15 MPa compressive strength, the achieved compressive strength at 10% WGP and 10%WMP is 15.75 MPa which is still greater than required.

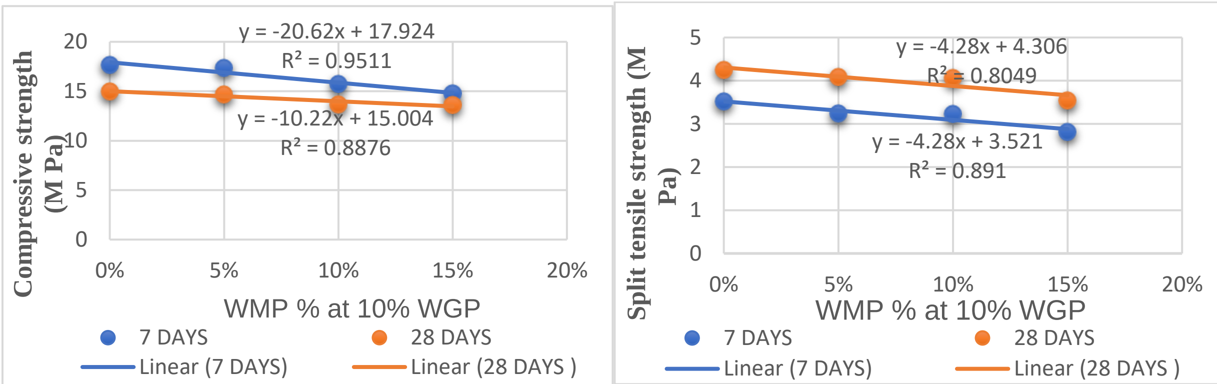

Figure 10: Correlation between compressive strength and quantity of WMP (left), split tensile strength and quantity of WMP (right) at 7 and 28 days

There is an increase in compressive strength and split tensile strength of concrete by increasing WGP but, after 10% of WGP the strength decreases. It is pozzolanic in nature, and it assists in the hydration process. However, the addition of an ample quantity of WGP, hydration becomes crucial for the concrete microstructure. The cement and WGP remain unhydrated between the hydrated cement particles. By the addition of WMP, strength decreases because it is not pozzolanic in nature and the no calcium silicate hydrate (CSH) gel is formed when mixed in concrete. The workability of concrete increases by adding WGP because of its finer particles, but the particle is angular in nature, so by adding WGP in bulk, the workability declines. The workability of concrete decreases by adding WMP. The strength of concrete is greatly influenced by size, shape and manufacturing of waste. The WGP collected from the wet process doesn't contribute to hydration process as its chemical process is already carried out. Conversely, WGP collected from the dry process increases the mechanical properties because of its pozzolanic nature.

5. Conclusion

Keeping in view, the research area of this project it can be concluded that WGP collected from wet process do not contribute in formation of calcium silicate hydrate (CSH gel) however, the waste glass powder from dry process contribute in hydration process of concrete, following conclusions have also been made:

- ü By increasing the amount of WMP, the values of slump are decreasing. At 15% WMP as cement replacement the slump is 1 inch and at 0 % WMP the slump is 2.25 inches. So, a decrease is 55.5%. By increasing the amount of WGP the values of slump are increasing, at 10% WGP as sand replacement the slump is 2.6 inches and at 0 % WGP as sand replacement the slump is 2.25 inches. So, an increase is 15.5%.
- ü By adding 10% WGP 0% WMP the compressive strength at 7 and 28 days' increased 21.3% and 9% respectively as compared to the controlled mix. By increasing the percentage of WMP, the compressive strength decreases and at 15% WMP the compressive strength decreased upto 9% and 16%, respectively, as

compared to the 10% WGP 0% WMP. However, it is still higher than the controlled mix upto 10% at 7 days and is less than the controlled mix upto 9% at 28 days.

- By adding 10% WGP and 0% WMP the split tensile strength at 7 and 28 days' increase 17% and 9%, respectively as compared to the controlled mix. When we increase the percentage of WMP, the split tensile strength decreases and at 15% of WMP the split tensile strength decreases upto 20% and 16% respectively as compared to the 10% of WGP 0% WMP, and it is less than controlled mix upto 6% and 9% respectively. So The compressive and split tensile strength at 7 days and 28 days are decreasing by the addition of WMP but it can be added from 5% - 10% as cement replacement with the addition of 10% WGP as sand replacement without compromising target strength.

5. Acknowledgment

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Smart Methods of Irrigation, Public Health and Geotechnical Engineering

ID 15: Water Monitoring System Using Internet of Things (IoT): Critical Review

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A B S T R A C T

Current advancements in sensor networks are crucial for environmental remediation. The Internet of Things (IoT) connects numerous devices that may share and collect data. IoT expands its capabilities to include environmental concerns in addition to the automation sector by utilizing industry 4.0. Polluted water has emerged as one of the most serious dangers in latest days since drinking water has been contaminated and polluted. Contaminated water may trigger a variety of illnesses in humans and animals, affecting the ecosystem's life cycle. This means, there is an increased demand for water which might affect the available sources of water at large. Therefore, effective management and monitoring of available resources of water is the need of the hour. This review paper includes the use of Internet of Things (IoT) technology for physical parameters of the water monitoring systems to manage and save scarce water resources. The traditional method to monitor water quality and quantity has been a quite difficult task involving a large amount of labor and cash. But the IoT application slashes human involvement and most of the procedural decisions are made by algorithms. Thus, smart methods for investigating water contamination are becoming increasingly significant with advancements in sensors, communication, and IoT technologies. A water monitoring system (WMS) is a low-cost and feasible system that uses IoT technology to analyse the quality of drinking water. The use of IoT tools for water monitoring will be a step in the right direction. Even though there are many great technological advancements for the surveillance of water quality, the research field is still challenging. This article aims to unveil the recent research for developing intelligent, energy-efficient, and highly effective water monitoring systems that will allow for continuous monitoring of water in less privileged areas of Pakistan. This article will assist researchers and administrative organizations in starting pertinent investigations of water in rural areas by utilizing a WMS.

K E Y W O R D S:

Internet of Things (IoT), Water Monitoring, Sensors Used for Water Monitoring

1. Introduction

Nowadays, it has become important to spread awareness about the implementation of the water monitoring system. Traditionally, the methods pertaining to bringing results are for instance, samples of chemicals, oils, mixed oxygen, pesticides, nutrients and metals. The physical conditions such as temperature, the flow of water, and erosion are also counted, and they give useful insight as well as biological facts [1]. The ordinary methods to quantify the problems of water bodies is to examine the pollutant which are present in the water bodies and their adverse effect on the environment [2]. IOT Technique is another method which is used to quantify and monitor the quality of water and this method is the prime focus of this paper. The World Health Organization (WHO) has already defined water quality monitoring parameters. However, the contaminating factors which degrade water quality are the progress of industrialization [3] and much reliance on the agriculture sector. Moreover, the uneven distribution of rainfall, floods, droughts, and lack of education and awareness about proper usage of water contribute to water contamination thus, worsening the situation. It has been assessed by the World Water Assessment Program that two million tons of human waste is disposed of into the water bodies. Coping with this issue is of prime importance. Fig.1 shows an overview of IoT based water management system.

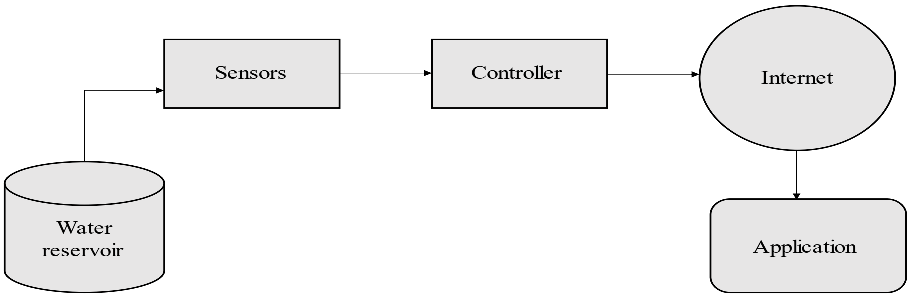

Fig. 1: Overview of a water management system

The IoT system depends on sensors, an application to visualize the data and a controller. The values such as turbidity, pH, total dissolved solids, and many other values are recorded by sensors that are connected to the controller. The controller- a small size computer- is connected with the internet, and networks that helps to execute, analyse and store the data. In Table 1 critical analysis is made of the techniques used for the water monitoring system through the Internet of Things.

Table 1: Source and types of municipal waste

Technique	**Problem-focused**	**Limitations**	References
Various sensors used with Advance RISC Machine (ARM) based multipoint control unit (MCU) controller	water pollution due to human waste, industrialization, and disaster is being assessed	use of an optical sensor to monitor the turbidity is not a reliable approach	[1]
System designed in Neural Network model; system operated by the use of Remote sensing technology	Water impurities assessed in the aspects of pH, oxidation and reduction potential (ORP), and conductivity	No interface system used	[4]
All the sensed data from sensors is passed to the raspberry pi using the zig bee protocol	Impurities being identified with the use of low power consumption and low bandwidth	data that is being measured has no proper representation	[2]
A WI-FI module, ESP8266 is being used which connects the microcontroller to the internet and all the Sensed data is being delivered to a web server	Apart from the temperature of the water, the level of carbon dioxide dissolved in water is also being assessed.	material that is being used is of high-power consumption	[5]
The Arm7 is connected to the data concentrator which is present in India's TWARD department and data is sent to the TWARD dept. via ZigBee module and their water parameters are monitored	To avoid the need of testing water quality manually	when it comes to maintenance the design aspects are complicated	[6]
The gathered sensed data from sensors is sent to the servers by Message Queuing Telemetry Transport. (MQTT) algorithm. This algorithm makes communication much more reliable	It is still a complex area to monitor water quality, so nave Bayes theorem is used to carry out an analysis	There lie some accessibility and security concerns regarding device authentication	[3]

2. Internet of Things System (IoT)

The IoT is an advance and smart computing concept that is used to build smart and intelligent system of interconnected computing devices and mechanical machines that are regulated by unique identifiers (UIDs). This system has an ability to transmit data over a network without the need of human-to-human interaction or human-to-computer interaction [7-10]. The IoT system has the potential to decrease human dependency and simultaneously can increase productivity [11]. The system is being used almost all around the world in various project development thus, helping in monitoring processes ranging from healthcare, surveillance, and environment [12]. There are many applications of IoT used for the real-time water monitoring system. S. Geetha (2017) used the IoT for real water monitoring in India [13]. Mahbubur (2020) used IoT to monitor the DO, salinity, turbidity, pH, and temperature in Bangladesh [14]. S. Uferah (2018) used IoT to monitor the surface water in Pakistan [15]. The IoT is comprised of mainly three prime phases which include sensing hardware, transmitting data over a network, and processing data [16]. As far as the approach of IoT system is concerned, it is more advance than the short-range management networks and communication networks that are used for tracking a location such as Global Positioning System (GPS), Laser Scanner, Radio Frequency identification Devices (RFIDs) and Infrared Sensors [17].

Fig 02 shows the relationship between IoT and other networks. The prime elements to collect data on objects in IoT system are using dimension codes and RFID sensors. Also, the Cloud Computing is used over various telecommunication networks and internet to analyse and process the real-time data of objects that is constantly being sent to carry out intelligent control of objects [10].Further, when it comes to storage and calculation in IoT system, choosing cloud computing is good because it is big-scale low-cost processing unit that is consist of Internet Protocols (IPs) for connections to communicate. The water monitoring system contains a wide distribution of network and monitoring sensors but with the utilization of cloud storage, there are fewer chances of the occurrence of any problem in storing data.

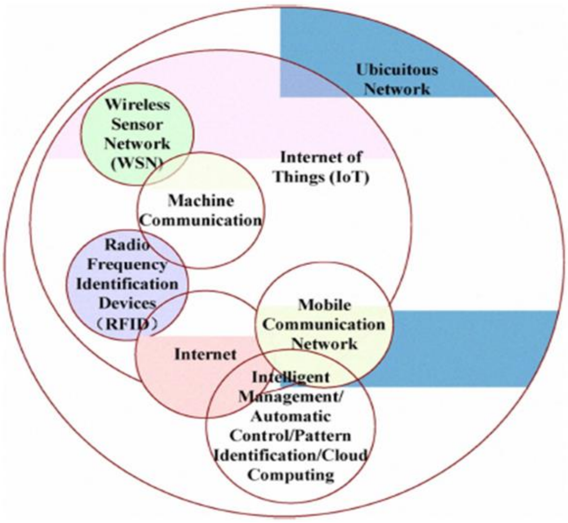

Fig 2: Relationship of the present network with IoT [3]

3. Sensor and types of sensors

. The availability of wide range of sensors in market has enabled IoT based system to measure different factors for example, temperature, humidity and range. The generally used sensors in water monitoring systems based on IoT are temperature sensors, pH sensors, and ultrasonic sensors.

3.1 Ultrasonic Sensor

To measure the level of water in a tank or reservoir, Ultrasonic sensors are used. Also, an ultrasonic sensor is a distance measurement sensor that can be easily integrated with different controllers/ Ultrasonic sensor are widely used to measure real-time water level in a tank or reservoir.

3.2 Temperature Sensor

The essential control strategy against Legionella in water is Water temperature as stated by WHO guidelines [18]. It is advised that water temperature should be maintained in the range of 25–50 °C to avoid organisms' growth. This means that temperature plays an important role in identifying the quality of water. Hence, various temperature sensors are available to measure temperature of water of range from 50 °C to 125°C.

3.3 pH Sensor

Power of Hydrogen or pH sensors are used to check the alkalinity or acidity level of water. When water has pH value below 7 this implies that water has acidic contents. The pH value above 7, on the other hand, suggests alkalinity/basicity of water. A pH value equal to 7 shows neutrality and an optimal pH value recommended by WHO [19] is in the range of 6.5-9.5.

4. Water quality parameters

It is an arduous task to measure drinking water quality because it involves the measurement of various parameters. Some parameters can be measured easily whereas others require expertise and special hardware. The following are the generally used parameters to monitor water quality.

4.1 pH

The Power of Hydrogen (pH) value of water tells about acidic or basic nature of water. Its total values of pH are 14 which shows the basic solution. On the other hand, lower values of pH depict acidic nature. WHO recommends an optimal pH value in the range of 6.5 to 9.5. The pH electrode is usually glass and fragile. The pH sensor or pH probe is connected to the pH sensor module and a single conditioning board which gives an output of pH values. The analogue sensor (pH sensor) sends data to Arduino. The pH meter voltages range from 0 to 5, where 0 indicates highly acidic and 5 indicates a highly basic solution. So, 2.8 is multiplied by voltages and gets the expected pH value.

4.2 Dissolve Oxygen (DO)

The oxygen dissolves in the water in different ways such as through water aeration, and ambient air diffusion. The amount of oxygen dissolved in water can be utilized to gauge water quality. The quantity of dissolved oxygen in streams and rivers is higher than the amount in stagnant water. The highest quantity of DO causes rusting in pipes but makes the water taste better. The DO sensor is connected to Arduino. It applies to many fields such as aquaculture, agriculture, environmental monitoring, and so on. The DO is one of the essential parameters for water quality. A low level of DO causes breathing problems which can endanger the lives of aquatic life.

4.3 Turbidity

Turbidity is the measurement of water clarity. In other words, it is the prime test to judge the quality of water. It is generally measured in the Nephelometric Turbidity Unit or Formazin Turbidity Unit (FTU). The turbidity level of drinking water should never exceed 5 NTU as provided in WHO guidelines.

4.4 Conductivity

The ability or potential of water to conduct electricity is called conductivity. The conductivity indicates what is dissolved in the water. For drinking water, the conductivity values should not be greater than 400ls/cm.

4.5 Total Dissolve Solids

TDS stands for Total Dissolved Solids. In water, sometimes organic or inorganic materials are dissolved and the measurement of the amount of these dissolved materials is known as TDS. The TDS value is higher when there is an abundant presence of organic or inorganic dissolved material in water. Water becomes potable when the TDS value is 500mg/L, whereas, it is unsuitable to drink water having a TDS value greater than 1000mg/L.

4.6 Temperature

Temperature impacts significantly the quality of water. The limit of temperature for drinking water as suggested by WHO is 30°C.

4.7 Salinity

Salinity can be defined as the quantity of dissolved salt in water. It is detrimental to human health when there is high salinity in water. The suggested salinity value of drinking water is not more than 200ppm.

5. Conclusion

An effective water management system especially for smart cities and higher institutions and their ambiences has become crucially important these days. To meet the challenge, the use of IoT devices is becoming rapidly popular because of their economical appliances. In this paper, a water monitoring system using IoT was described along with all other prevailing water monitoring systems. Different parameters of water, water level, and pH level were identified, and evaluation of all other water measurement systems based on these input variables was performed. The confrontation like power saving for real-time measurement was still there. Therefore, IoT and machine learning-based systems for smart water management is also suggested as a future remedy for all the issues. The possibility of including machine learning aspects can increase the efficiency of the smart management system. In the same way, the authenticity of prediction for water management systems for agricultural purposes and flood control is also a confrontation. Quantifying water economic scarcity (WES), especially in the field of irrigation using IoT devices can further be researched.

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ID 33: Modification of Plasticity and Compaction Characteristics of Shale by Lime

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A B S T R A C T

The complex problem for any civil engineering work is when the structure which is laying on the soil is weak. Jamshoro shale is an example of such problematic soil, which gets expanded as soon as it is exposed to moisture and shrinks back once it dries. Such phenomenon is very critical for the structures and road networks built on shale forming settlements and cracks. Such kinds of soil must be stabilized by chemical or mechanical techniques to make them strong enough to carry the loads and resist settlements and cracking. The stabilization of the ground by utilizing or adding any chemical agent is a sustainable approach; it strengthens the soil properties without replacing or wasting the soil present. In this research, the treatment of lime with shale is been performed to observe the modification of the geotechnical features of the soil. The different proportions of Hydrated Lime 0%, 7%, 8%, and 9% were mixed by the dry soil weight to investigate the impact of lime on the compaction and plasticity characteristics of the shale. Various tests such as the modified proctor test, liquid limit test, and plastic limit test performed in the laboratory. From the results, it was observed that the properties of Jamshoro shale such as plasticity index, optimum moisture content, and maximum dry density enhanced. Plasticity index of shale dropped to 2% from 24%. That suggests lime can be used as an economical and eco-friendly stabilizing agent.

K E Y W O R D S:

Soil Stabilization, Lime, Compaction, Expansive soil, Plasticity.

1. Introduction

1.1 Background

The constructions are being built on different soil types at various depths. Soils support the foundations of several civil engineering constructions. Likewise is used in the sub-grades of roadways. The stability of buildings is influenced by the geotechnical characteristics of the soil; the soil-bearing capacity measures how much load the present soil can support. The type of being used affects a soil's carrying capacity [11]. Therefore, the soil on which the building is resting, or the soil being used in the sub-grade of road embankments must have enough strength so the structure's serviceability should be assured. Such soil is regarded as problematic soil because the weak foundations damage the buildings and create a settlement, which causes cracks and swelling of structural components [10]. The structures on this soil create pavement or road, distresses and building disasters.

The failure of structures is risky as far as human lives are concerned. Indeed, this kind of problematic soil should be improved, modified, stabilized, or replaced to make a stable foundation for the structures. However, the engineering approach is to consider the economy of the project. Due to high transporting costs, soil supply is occasionally not cost-effective; as a result, that approach is not recommended. The most often utilized method for strengthening the earth is soil stabilization [5]. A complex hurdle in civil engineering projects is when the soil found beneath is expansive. Expansive soil tends to swell when it interacts with the water, and it shrinks back when the moisture content is reduced. Due to this expansion and contraction behavior, the soil will deform, and settlements will occur. Due to excessive settlements, cracks have appeared in the buildings built on this soil. The swelling has also been identified in some structures due to soil expansion [12]. While the subgrade of road works is also shale, the rutting occurred to the pavements. These problems have been identified for the existing structures on this soil.

Fig 1: Cracks developed in MUET boys hostel due to excessive settlement

Fig 2: Rutting occurred in M-9 motorway due to weak subgrade soil

The damages to structures are due to the low bearing capacity of the soil. Therefore, this research is conducted to stabilize the soil by adding lime with various percentages (7%, 8%, and 9%) and analyzing the impact of lime on the properties of Jamshoro shale.

1.2 Aim and Objectives of the study:

This study uses lime, a freely available mineral, to improve soil properties. The main objective of the study is to determine how adding varying amounts of lime would affect the Jamshoro soil's compaction properties.

The soil is treated with Lime to study the variations in properties of the soil. The main objectives of this study are as follows.

- To analyze the effect of lime on the maximum dry density of Jamshoro shale.
- To analyze the effect of lime on the optimum moisture content of Jamshoro shale.
- To analyze the effect of lime on the plasticity characteristics of Jamshoro shale.

2. Literature Review

In a research study by Ashok Kumar (2017) et al. on Jamshoro shale, where various percentages of lime (i.e., 0%, 1%, 2%, 4%, 6%, 8%, 10%, and 12% by dry weight of soil) were added into soil. It was concluded that by adding lime up to 12%, the maximum dry density (MDD) was decreased from 1.70 g/cc to 1.59 g/cc, and the optimum moisture (OMC) content was increased from 18.22% to 22.24% for the addition of 12% of lime content. It was ended that lime used in the soil will require more compaction effort [4]. Pathan et al. (2017) carried out a study on Jamshoro soil by adopting a microbial-induced calcite precipitation method for modification of soil properties. The bacterium used in this research was Sporosarcina pasteurii (Bacillus pasteurii) added to the nutrient solution at different percentages (1%, 2%, and 3%). Different amounts of the bacteria—50ml, 100ml, and 150ml—were introduced then left for curing for 7 days. The bacterium mixed with the soil causes cementation among the soil particles and therefore enhances their properties. The results concludes that at 1% (50ml) addition of bacterium increased the maximum dry density value to 2.12 g/cc from 1.94 g/cc while optimum moisture content was reduced to 5.5% from 9.45%. At 2% and 3% bacterium addition, the MDD value was decreased to 2.1 g/cc and 2.08 g/cc respectively. It was concluded that the best results for the dry density are obtained at 1% of bacterium addition [7].

Another research was carried out on Nigerian lateritic soil by Emmanuel Sunday Ajayi (2012) by using lime content of 0%, 2.5%, 5%, and 7.5% concentrations respectively. Five specimens were prepared for each concentration of lime content and tests were performed according to British standards. The results of five specimens showed that at the natural condition the maximum dry densities ranged from 1.59 g/cc to 1.89 g/cc and their optimum moisture contents ranged from 3.72% to 13.94%. With the addition of lime, it was observed that at 2.5% addition of lime the

MDD was decreasing, and OMC was increasing for all five specimens. Similarly, further addition of lime that is 5% and 7.5% showed depletion in MDD and an enhancement in the OMC values [6]. Ravi et al. (2016) researched clay soil in India, where copper slag 10%, 20%, and 30% were added to the soil by dry weight of the soil. The results obtained from the research were that maximum dry density was increased from 1.597 g/cc to 1.752 g/cc, and optimum moisture content was increased from 12% to 18% and which was later decreased to 14% at the addition of 30% of copper slag. It proved to be a good stabilizer for the clayey soil [13].

Jafer et al. (2013) researched soft subgrade soil found near the south of Hilla city. The soil was treated with a series of various percentages of lime (0%, 3%, 6%, 9%, and 12%) and micro-silica flume (0%, 6%, 12%, and 18%) to examine the effect of these additives on the properties of soft soil. It was shown that at different proportions different properties were enhanced. Considering the consistency limits of soil, the liquid limit value reduced to 33% from 53% when the amount of lime-micro silica flume was 12-0% used. Likewise, the plastic limit value increased to 41% from 27% at 9-18% of the additive proportion. On the other hand, the plasticity index values decreased to 1.21% from 26% when the lime-micro silica flume percentage was 9-6%. The reason behind the changes in consistency limits was concluded because of the flocculation and pozzolanic reaction. The effect of additives on compaction parameters was that maximum dry density and optimum moisture content were observed that at all the proportions of the mix the values of maximum dry destinies were decreasing. The MDD value decreased to 1.32 g/cc which was initially 1.6 g/cc at the addition of 9-18% of the additive mix. While the optimum moisture content value had different behavior at different proportions [12].

3. Research Methodology

3.1 Materials Used

The subsequent section interacts with the different materials utilized in this research to inquire about the use of chemical agent on the aspects of soil’s physical and geotechnical behaviour, see Table 1. Materials to be used, are Jamshoro soil, and hydrated lime.

Table 1: Physical Properties of Jamshoro Soil

Physical Properties	**Values**
Natural Moisture Content	9.13%
Liquid Limit	57%
Plastic Limit	33%
Plasticity Index	24%
Group	A-7-5
Free Swell Index	40%
Fine-Grained (-#200)	95%

3.2 Laboratory Testing

The soil collected from the pit is preserved from the moisture content. The index properties of the soil are determined using the AASHTO and ASTM standards under codes D-1140 for gradation, D-4318 for atterberg limits, and D-4643 for determining moisture content [1-3]. Table 1 shows the index properties of soil.

3.2.1 Proportions of the mix

The soil sample is then treated with lime by mixing different percentages of lime (i.e., 0%, 7%, 8%, and 9%). The proportions of lime are based on the dry weight of the soil passed through the No.4 sieve (4.74mm dia). Hydrated lime used is passed from the No.40 sieve (0.425 mm dia). After mixing of soil and lime following tests were performed in the geotechnical laboratory of the Civil Engineering Department of Mehran University of Engineering & Technology.

3.2.2 Atterberg Limits

At varying moisture concentrations, clayey soils react differently, which can be described by empirical techniques called Atterberg limits. The term "Atterberg limit" refers to the various moisture concentrations at which the soil's consistency shifts between states. The soil's consistency tells how firm it is. Although consistency is resistant to distortion or rupture, it is closely connected to soil durability. The corresponding basic water content parameters make up the Atterberg limit [1].

3.2.3 Modified Proctor Test

Modified Proctor Test is conducted to come up with the compaction of various soils and the characteristics of the soil with an adjustment of water content; furthermore, the relation among Dry Density and Moisture Content. For the modified Proctor test, a rammer weighing 10 pounds (4.5 kilograms) and an 18-inch fall are used to crush the dirt into the mold in five layers (45 cm). The modified proctor exam is governed by AASHTO T180-90 and ASTM D1557-91 standards [2].

4. Results and Discussion:

4.1 Effect of Lime on Plasticity Characteristics of Jamshoro shale:

Figure 3 illustrates the effect of 0%, 7%, 8%, and 9% of lime on the liquid limit of shale. The liquid was found to be 57%, 66%, 58.7%, and 56.6% at the respective proportions.

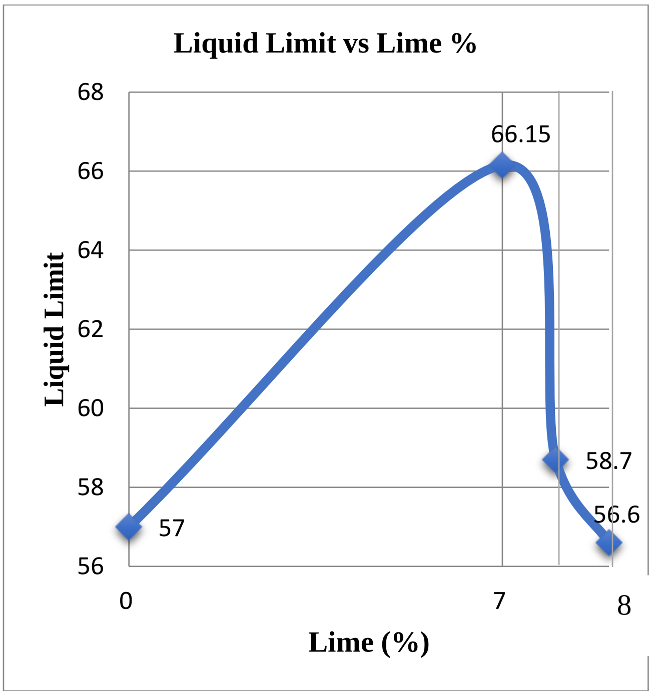

Fig 3: Impact of lime on liquid limit of Jamshoro shale

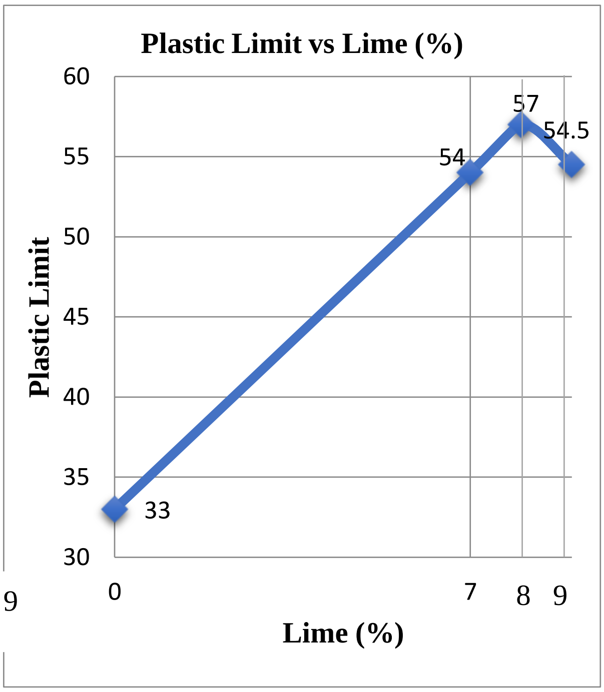

Fig 4: Impact of lime on plasticity limit of Jamshoro shale

The plasticity limit of Jamshoro shale was obtained at 33%, 54%, 57%, and 54.5% with the addition of 0%, 7%, 8%, and 9% of lime. Figure 4 shows the variation in the effect of lime on the plasticity limit. Fig 5 shows the impact of lime on the plasticity index of the Jamshoro shale which decreased up to 8% and then rises a bit at 9% lime. At 0%, 7%, 8%, and 9%, the PI of jamshoro shale was obtained 24%, 12%, 2%, and 3% respectively.

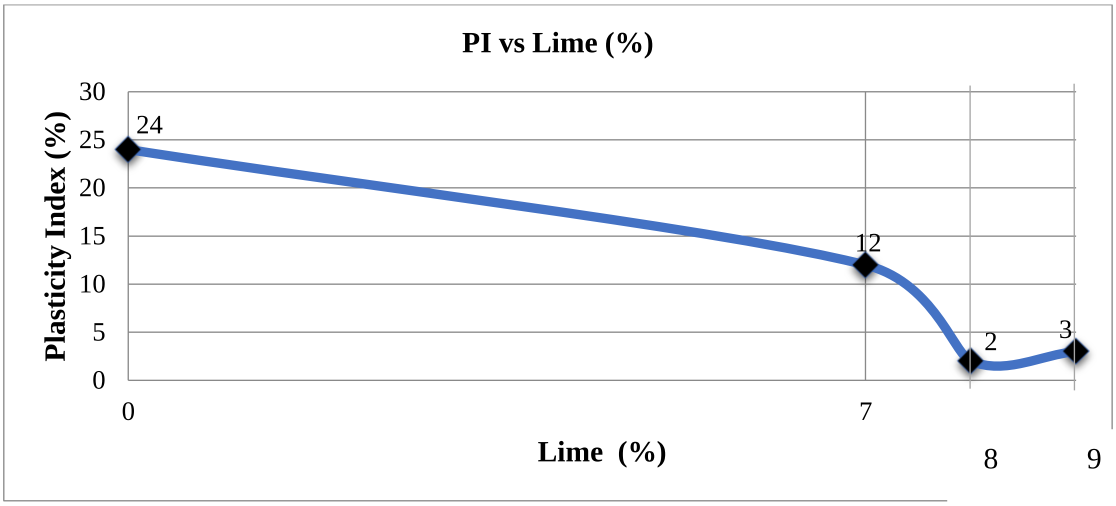

Fig 5: Impact of lime on the Plasticity Index of Jamshoro shale

4.2 Effect of Lime on Compaction Characteristics of Jamshoro Shale:

Fig 6 and 7 illustrates the impact of lime concentration on the maximum dry density (MDD) and optimum moisture content (OMC) of the Jamshoro shale respectively. The MDD of soil was decreasing with the lime addition. It was obtained 1.71g/cc, 1.55g/cc, 1.54g/cc, and 1.54g/cc at 0%, 7%, 8%, and 9% lime addition respectively. The OMC of the Jamshoro shale was increasing with the inclusion of lime amount. At the addition of 0%, 7%, 8%, and 9% of lime the OMC was obtained 18%, 21.7%, 22%, and 22.7% respectively.

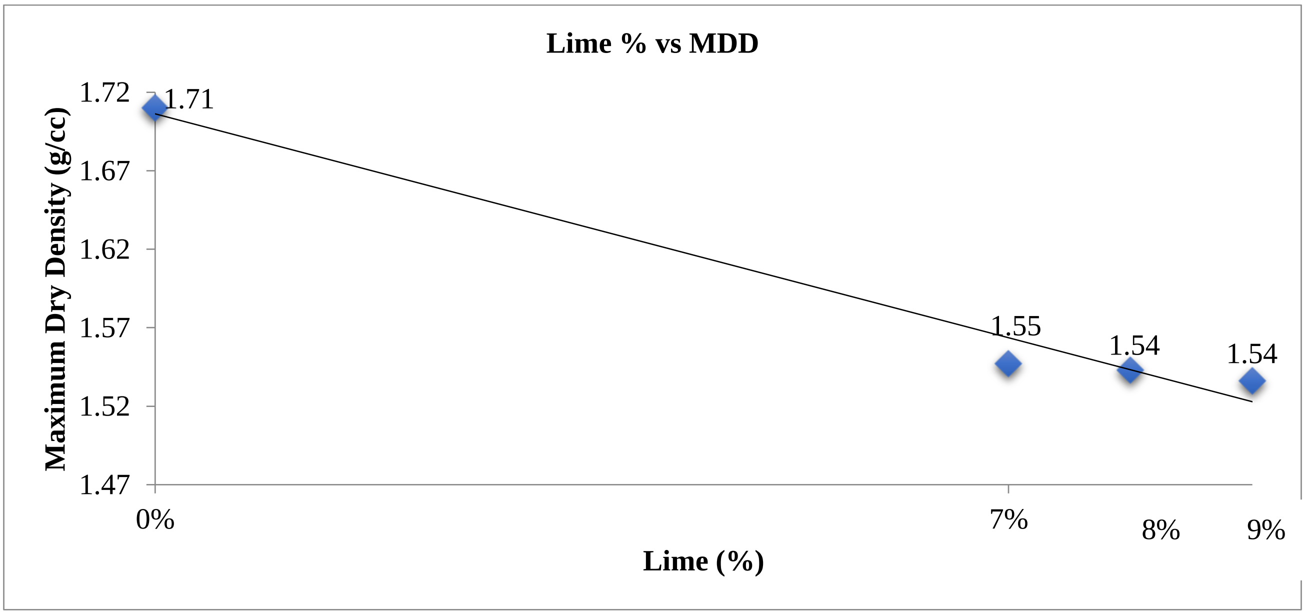

Fig 6: Impact of lime on Maximum Dry Density (MDD) of Jamshoro shale

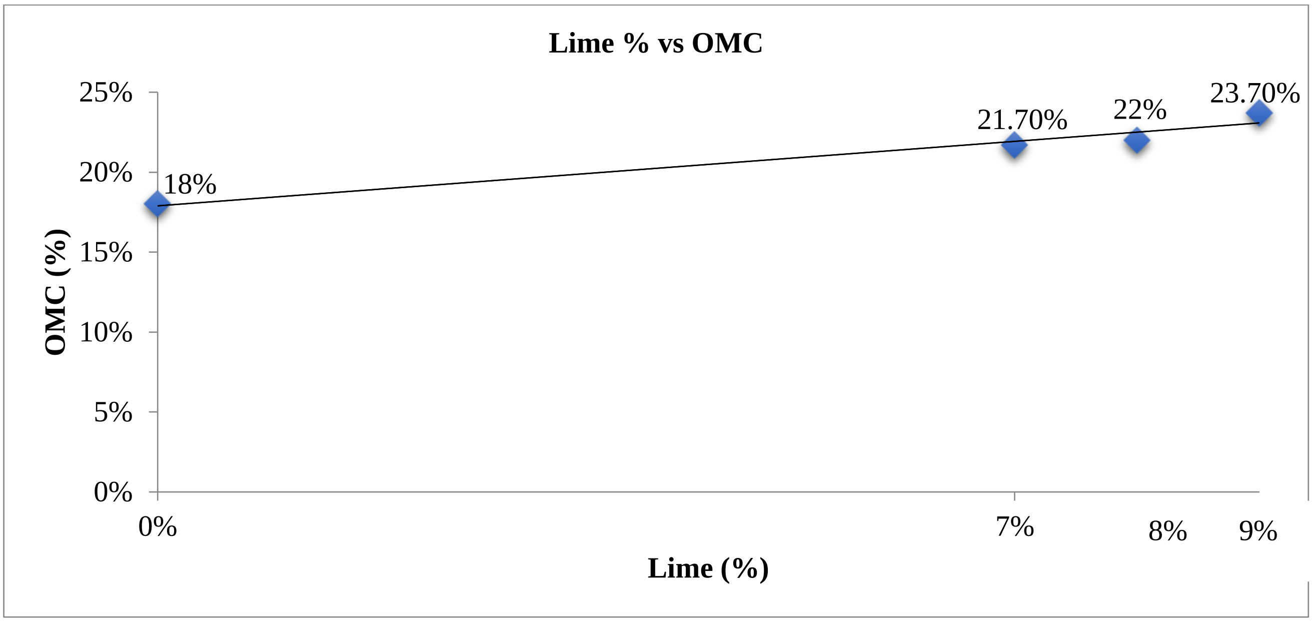

Fig 7: Impact of lime on Optimum Moisture Content (OMC) of Jamshoro shale

5. Conclusion

In the research, lime-treated soil was used to improve the properties of shale. Various tests were performed in the geotechnical laboratory. The results of the experimental work conclude that,

- Considering the atterberg limits of shale. At different proportions of lime the values of liquid limit and plastic limit kept increasing. But, up to a certain point afterwards the values showed decline. As we can observe, the liquid limit increased to 66% first and then dropped to 58.7% and 56.6% at 8% and 9% lime proportion respectively. Similarly, plastic limit was increased up to 57% at 8% lime addition. Further addition of lime reduced the plastic limit to 54.5%.
- The plasticity index was dropping by the addition of lime quantity in the shale from 24% at 0% lime to 2% at 8% lime. Although, the further addition increased the plasticity index.
- Optimum moisture content of naturally present soil was 18%. The addition of lime percentages continuously showed a considerable increment in the value of OMC to 21.70% at 7% lime addition, 22% at 8% lime addition, and 23.70% at 9% lime addition in the soil.
- The results of modified proctor test showed that the maximum dry density of soil was abruptly changed with the addition of various percentages (7, 8, and 9%) of lime. The maximum dry density MDD was reduced to 1.55g/cc from 1.71g/cc at 7%. The value further reduced to 1.54g/cc at 8% lime addition and remained steady afterwards.

The use of lime for the treatment and stabilization of soil suggests that it may be used for the ground improvement of shale. It is recommended that the plasticity characteristics of the shale are enhanced at 8% of lime addition. However, the OMC kept increasing and MDD was decreasing suggesting that it will require extra effort for the compaction. Lime being cheaply available can be an economical way to strengthen the weak soil beneath the structures and make them durable.

6. Acknowledgment

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ID 81: Determination of Water Requirements of Some Major Crops in Sindh by Using CROPWAT Model in Sindh

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A B S T R A C T

There is a global water crisis brought on by trends in urbanization and population increase. Systems for irrigation are essential for boosting crop productivity and guaranteeing food security. Human-caused desertification and water shortages have made the world's existing water scarcity much worse, having a huge influence on food production. Greater water use efficiency is required in both rain-fed and irrigated agriculture as a result of the global water crisis and rising food demand. In order to conserve the few water resources, it is therefore the most demanding requirement for the farming community to utilize some sort of irrigation planning. The goal of this study is to use the CROPWAT model created by the FAO of the United Nations to determine the crop water requirements and irrigation scheduling for certain main crops in Sindh. In this regard, the principal crops grown in the Pakistani province of Sindh were chosen so that at least one crop from each category would be included in the study. As a result, wheat was designated as Rabi, rice as Kharif, sugarcane as perineal, and chilli and rapeseed mustard were chosen as cash crops. The CROPWAT model uses historical or new agricultural and climatic data to estimate crop water needs and schedule irrigation. The CROPWAT software used input crop data from a variety of online sources and published information, while the CLIMWAT tool, which is tied to CROPWAT, used climatic data that was included in CLIMWAT. Additionally, for each crop recorded at the DRIP Tandojam metrological station, the software employed average rainfall data from the relevant years. The results of water requirements for the crops were obtained through CROPWAT model are: Wheat (352.1 mm); Rice (1662.5 mm); Sugarcane (2184.5 mm); Chilli (714.4 mm); and Rape-seed Mustard (475.6 mm), while those by lysimeter were: Wheat (415 mm); Rice (1633 mm); Sugarcane 2150 mm); Chilli (808.9 mm); and Rape-seed mustard (424.87 mm). These findings show that the crop water requirements for wheat, rice, sugarcane, and chilli have decreased by 15%, 1.5%, 11.6%, and 1.7%, respectively, whereas rapeseed mustard has increased by 12%.

K E Y W O R D S:

Crop Water Requirement, Irrigation Requirement, Irrigation Scheduling, CROPWAT Model.

1. Introduction

In many countries, water shortages are emerging, including in Pakistan, and water for agriculture is becoming scarce due to the growing demand for fresh water as a consequence of population growth. In South Asia, Pakistan lies between 24° to 37° Northern latitude and 61° to 75° Eastern longitude. The average annual rainfall is 495 mm, most of which falls during the monsoon season. The country's total population is around 173.2 million, with nearly 64 percent of the population living in rural areas, where agriculture and allied industries are still the primary source of income (FAO, 2010). Sindh has a total land area of around 14.09 million hectares, of which 5.18 million hectares (37 percent) are cultivated (Agriculture Statistics, 2013-14). The summer season (Kharif), which begins in April-May and finishes in October-November, and the winter season (Rabi), which begins in October-November and ends in April-May, are the two major crop seasons in Pakistan. The main Rabi crops are wheat, gram, and barley, while main Kharif crops are corn, paddy, cotton, and maize.

Surface water for Pakistan's Indus Basin Irrigation System (IBIS) is mostly sourced from the Indus River and its tributaries. Only 106 MAF of the Indus River's 146 million acre feet (MAF) average annual flow is diverted to canals (WAPDA, 2007). Between 50 and 80 percent of Pakistan's total annual river flow is derived from snow or glacier melt, with the remaining 20 percent coming from monsoon rainfall. According to the WAPDA (2007), about 35 MAF flows towards the shore, 36 MAF are lost due to transmission losses such infiltration, evaporation, seepage, and spills, and 3 MAF are lost due to transmission losses in rivers.

Water resources are ineffectively managed in Pakistan when it comes to irrigation. This issue wasn't a big deal in the past because of the plenty of water and the relatively light rainfall levels. However, there seems to be a need to modernize the irrigation systems given the current water scarcity, low precipitation levels, and reduced flows in key canals. Irrigation scheduling and crop water needs (CWRs) are necessary to monitor irrigation demand. AQUACROP and CROPWAT 8.0 are examples of software modelling tools that scientists may use to assess CWR, crop evapotranspiration, and irrigation scheduling. In order to help irrigation engineers and agronomists with regular calculations for irrigation water studies and, more particularly, for the management and design of irrigation systems, the Food and Agriculture Organization (FAO) developed these computer software tools. Agro-climatic conditions, soil type, crop type, soil structure and textural conditions, and, to some extent, cultural practices all have an impact on how much water crops need. The criteria for irrigation water and the scheduling of irrigation for certain representative chosen crops for each crop season in Sindh is determined using the CROPWAT model in the current study: wheat for the Rabi season; paddy for the Kharif season; sugarcane as a perennial crop; chilly, rape-seed Mustard and sunflower as cash crops.

2. Materials and Methods

2.1 The Study Area

The district Hyderabad, Sindh, Pakistan is chosen as the study area (Figure 1). The province of Sindh consists of an area of 140,900 sq km between latitude 23-29 ° N and longitude 67-71 ° E. With the exception of the Arabian Sea in the southwest, the state is largely surrounded by land in all directions. It has borders in south with Rann of Kachh, in the east by Rajasthan, in the northeast by the province of the geographic region, and by Balochistan in the north and west. The barren Kirthar Mountains are in the extreme west; and the Great Indian Desert on the east partly called the Thar Desert.

Fig. 1: The Province of Sindh and its adjacent borders (Courtesy: Quora.com)

Agriculture of this region depends primarily on the water supplied by the river. The Sindh province falls within the subtropical region, with hot summer and cold winter. The maximum temperature from May to August is 46 °C, and the minimum temperature from December to January is 2 °C.

2.2 Estimation of Water Requirement

In general, the crop water requirements are determined from the interrelations of the ET, the form of soil, the bulk density of the soil, the unit of volume and the permanent wilt point of soil, and effective root zone of the project site.

The Penman-Monteith method was found to be the most accurate and consistent in all climatic conditions on both a monthly and daily basis by the Irrigation and Drainage Council of Environmental and Water Resources, based on the recommendation of the American Society of Civil Engineers (ASCE) Task committee, which was obtained after evaluating 19 estimating methods and carefully screened lysimeter data from 11 worldwide locations of different climates ranging from arid to humid conditions. Hence, Penman-Monteith equation, as illustrated below, as used in the CROPWAT model for the calculation of evapotranspiration of crop (ETc), used to estimate crop evapotranspiration.

$$ETc = Kc\ (ETo) \quad \text{(i)}$$

Where

ETc = Evapotranspiration of Crop

ETo = Reference Crop Evapotranspiration

Kc = Crop coefficient

2.3 CROPWAT Model Description

CROPWAT is a computer decision-support program that uses data from climate, crop, rain, and soil to calculate reference evapotranspiration (ETo), crop water requirement (CWR), irrigation scheduling, and irrigation water requirement (IR) using a set of equations developed by the Food and Agriculture Organization (FAO).

The software provides detailed information on different crop characteristics, local environment and characteristics of soil, which helps to establish irrigation schedules and to calculate the water supply scheme under irrigated and rain conditions for different crop patterns. The Penman-Monteith model is utilized. Information of the environmental conditions, such as the min- and max- temperature, mean relative humidity (percent), wind velocity (km/hr), hours of sunshine (h), rainfall data (mm), and measurements used to measure effective rainfall (mm) are utilized.

The basic function of software is to compute the crop water requirements, reference evapotranspiration, and irrigation of crops and systems. The consumer can model varied water supply conditions through a daily water balance, and estimate yield reductions and efficiencies in irrigation and rainfall. The FAO Penman-Monteith method relies on the measurement of reference evapotranspiration (ETo). The input file contains temperature (maximum and minimum), humidity, sunshine, and wind speeds monthly and ten daily. From ETo, crop water requirements (ET crops) are calculated over the growing season and crop evaporation rate estimates, expressed as crop coefficients (Kc), are assisted by well established procedures in accordance with the following equation

$$ET\ crop = Kc \times ETo \quad \text{(ii)}$$

Updated values for crop coefficients have been provided by the FAO. Crop irrigation needs are determined by forecasts of successful rain-fall, assuming the best water system. Inputs on the cropping pattern will make it possible to estimate the needs of the subject irrigation.

The CROPWAT model will measure the root region's daily water balance. Root zone depletion at the end of the day is concerned with the following equation

$$Dr_i = Dr_{i-1} - (P_i - RO_i) - l_i - CR_i + ET_{ci} + D_{pi} \quad \text{(iii)}$$

Where

Dr_i = depletion of the root region at the end of the day, i^{th} (mm)

Dr_{i-1} = Water content at the end of the preceding day in the root zone (mm)

P_i = rainfall on the day i (mm)

RO_i = surface soil runoff on day i (mm)

l_i = net depth of irrigation on day i which infiltrates the soil (mm)

CR_i = capillary rise from the groundwater Table on day i (mm)

ET_{ci} = crop evapotranspiration on day i (mm)

D_{pi} = Water wastage in the root region on the day i (mm)

2.5 Selected crops and Data Collection

Representative crops of each season were selected for the research and wheat was selected for the Rabi season; paddy for the Kharif season; sugarcane as a perennial crop; chilly and rape-seed Mustard as cash crops. As an essential CROPWAT model parameter, the crop constant values (Kc) are taken from the published information of DRIP, FAO handbooks, etc. Kc values are used for annual and seasonal crops for the initial, development, middle, and late growth phases. The same Kc value will be used for the entire year in the case of perennial crops.

3. Results and Discussion

In addition to crop types, cultivation dates, and soil type (silt loamy) information for five crops, the CROPWAT programme also uses climate data from Pakistan and meteorological station data from Hyderabad. All necessary information was input into the programme, and it then used that information to determine meteorological features including ET0, effective rainfall, total irrigation requirements of crops, and their irrigation schedules. In the tables and charts in the next section, further CROPWAT model results are displayed. Table 1 contains the information for the five crops that were examined. For each crop year in Hyderabad, Sindh, the climatic data are presented in Tables 2-6.

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3.1 Determination of the Crop Water Requirements

Crops require varied amounts of water demands based on their location, temperature, soil type, cultivation method, effective rain, and so on, and the total amount of water required by a crop over its life cycle is not evenly distributed. The irrigation water requirements (IRs) for the five crops under the study is in the following order according to the (mm/dec) unit:

Sugarcane (2184.5) > Rice (1662.5) > Chili (714.4) > Rape-seed Mustard (475.6) > Wheat (352.1)

3.2 Net Irrigation Requirement (NIR) and Irrigation Schedule

Irrigation management in the field is improved by understanding crop irrigation water requirements and irrigation time plans. Irrigation water management is the process of efficiently regulating the amount, pace, and timing of irrigation. Tables 2 to 7 shows the crop water requirements for wheat, rice, sugarcane, chili, and rapeseed crops in the field.

The Net Irrigation Requirement (NIR) is the amount of water required for crop development, or the amount of water required to achieve the soil's field capacity. Cropping patterns and climate have an impact on NIR. To transform the NIR into a Gross Irrigation need, data on irrigation efficiency is also necessary (GIR). During the application and transfer of irrigation water, various losses such as runoff, evaporation, seepage, and percolation occur. Leaching, ground preparation, and transplanting all need a certain quantity of water. As a result, CWR includes ET, as well as losses incurred during the application of water required for these objectives, as shown in Equation (iv). This computation aids farmers in deciding which crops to produce based on water availability.

$$NIR = ETc - Eff.\ rain \qquad \text{(iv)}$$

Table 1: Data of the five selected crops for the study

					Crop Growth Period (Days)			
Crop Name	Scientific Name	Planting and Harvesting Date	Critical Depletion Fraction	Rooting Depths (cm)	Initial	Development	Mid-season	Late Season
Wheat	Triticum	10 Nov-29 Mar	0.55	30	30	40	40	30
Rice	Oryza sativa	15 June-12 oct (transplanting)	0.20	40	20	30	40	30
Sugarcane	Saccharum officinarum	10 Oct-9 Oct	0.65	100	30	60	180	95
Rape-seed Mustard	Brassica Napus	10 Nov-9 Mar	0.62	50	30	40	30	20
Chilli	Capsicum frutescens	15 Apr-1 Sept	0.60	20	30	30	40	40

Table 2: Climatic data used for calculating crop water requirements and irrigation schedule of Wheat (1995)

Month	Temp (^{0}C)		Humidity (%)	Wind (km/day)	Sun (h)	Rad (Mj/m^2/day)	ET$_o$ (mm/day)	Rain (mm)	Eff. Rain (mm)
	Min	Max							
January	5.6	19.6	67	131	8.5	15.6	2.55	0.0	0.0
February	7.2	23.1	63	142	9.0	18.4	3.33	0.0	0.0
March	10.2	26.3	52	211	9.1	21.0	4.72	0.0	0.0
April	17.5	32.8	58	284	9.2	23.0	6.23	0.0	0.0
May	20.2	37.7	52	451	10.0	25.0	9.16	0.0	0.0
June	23.5	36.0	67	594	10.1	25.2	8.21	0.0	0.0
July	22.9	33.0	77	553	7.0	20.4	5.82	89.5	71.6
August	22.8	33.4	75	542	8.2	21.7	6.16	0.0	0.0
September	20.0	34.0	73	454	10.0	22.8	6.32	0.0	0.0
October	16.1	31.5	65	221	9.2	19.2	4.88	0.0	0.0
November	9.7	27.2	51	151	8.6	16.1	3.67	0.0	0.0
December	7.6	21.3	71	163	7.8	14.1	2.46	0.0	0.0
Average	15.3	29.7	64	324	8.9	20.2	5.29	89.5	71.6

Table 3: Climatic data used for calculating crop water requirements and irrigation schedule of Rice (2021)

Month	Temp (^{0}C)		Humidity (%)	Wind (km/day)	Sun (h)	Rad (Mj/m^2/day)	ET$_o$	Rain (mm)	Eff. Rain (mm)
	Min	Max							
January	10.9	25.2	45	190	7.5	14.5	3.62	1.0	0.8
February	13.7	29.0	43	190	8.1	17.3	4.44	4.3	3.4
March	18.9	34.7	39	233	9.0	20.8	6.41	0.2	0.2
April	23.0	39.3	36	294	8.4	21.9	8.43	4.7	3.8
May	26.3	42.4	42	467	9.7	24.5	11.19	3.8	3.0
June	28.2	40.9	53	613	8.3	22.5	10.74	9.7	7.8
July	28.0	38.4	60	570	8.0	21.9	9.00	43.3	34.6
August	27.2	37.1	62	553	7.3	20.3	8.16	46.1	36.9
September	25.9	37.4	58	467	8.4	20.5	8.06	23.3	18.6
October	22.4	37.6	43	233	9.0	18.9	6.57	6.0	4.8
November	17.0	32.5	42	156	8.1	15.5	4.43	0.5	0.4
December	12.2	26.8	48	173	8.1	14.4	3.58	3.9	3.1
Average	21.1	35.1	48	345	8.3	19.4	7.05	146.8	117.4

Table 4: Climatic characteristics used for calculating crop water requirements and irrigation schedule of Chili (2003)

Month	Temp (^{0}C)		Humidity (%)	Wind (km/day)	Sun (h)	Rad (Mj/m2/day)	ETo (mm/day)	Rain (mm)	Eff. Rain (mm)
	Min	Max							
January	10.5	25.0	59	124	9.0	16.2	3.30	0.0	0.0
February	12.8	27.2	57	144	8.1	17.2	3.84	0.0	0.0
March	17.8	33.1	51	218	9.1	21.0	5.71	0.0	0.0
April	23.6	39.0	38	284	10.1	24.4	8.59	0.0	0.0
May	26.2	40.4	50	463	9.1	23.6	9.91	0.0	0.0
June	29.3	38.8	63	609	8.1	22.2	9.08	0.0	0.0
July	28.0	34.1	77	492	5.1	17.6	5.74	89.5	71.6
August	27.5	34.3	74	596	8.1	21.5	6.51	0.0	0.0
September	26.3	34.6	68	433	8.2	20.2	6.63	0.0	0.0
October	19.5	36.2	43	254	9.2	19.2	6.39	0.0	0.0
November	14.4	29.1	55	138	9.1	16.7	3.85	0.0	0.0
December	11.7	25.4	56	137	8.1	14.4	3.20	0.0	0.0
Average	20.6	33.1	58	323	8.4	19.5	6.06	89.5	71.6

Table 5: Climatic characteristics used for calculating crop water requirements and irrigation schedule of Rape-seed mustard (2003)

Month	Temp (^{0}C)		Humidity (%)	Wind (km/day)	Sun (h)	Rad (Mj/m^2/day)	ET$_o$ (mm/day)	Rain (mm)	Eff. Rain (mm)
	Min	Max							
January	11.0	23.8	45	124	9.2	16.4	3.60	0.0	0.0
February	14.1	25.9	43	144	8.5	17.7	4.19	60.0	48.0
March	17.0	33.0	39	218	9.9	22.1	6.27	0.0	0.0
April	24.1	36.4	36	284	11.2	26.0	8.46	0.0	0.0
May	28.1	42.3	42	463	10.8	26.2	11.46	0.0	0.0
June	28.4	38.4	53	609	11.1	26.7	10.74	3.5	2.8
July	29.1	35.5	60	492	6.5	19.7	8.22	89.5	71.6
August	27.6	34.3	62	596	9.2	23.2	8.05	215.0	172.0
September	26.3	35.4	58	433	9.1	21.5	7.83	56.0	44.8
October	23.5	35.6	43	254	10.2	20.5	6.51	0.0	0.0
November	17.7	31.1	42	138	9.0	16.6	4.39	0.0	0.0
December	11.8	25.9	48	137	9.3	15.7	3.56	0.0	0.0
Average	21.6	33.1	48	323	9.5	21.0	6.94	334.5	267.6

Table 6: Climatic characteristics used for calculating crop water requirements and irrigation schedule of Sugarcane (1995)

Month	Temp (^{0}C)		Humidity (%)	Wind (km/day)	Sun (h)	Rad (Mj/m2/day)	ETo (mm/day)	Rain (mm)	Eff. Rain (mm)
	Min	Max							
January	5.6	19.6	67	131	8.5	15.6	2.55	0.0	0.0
February	7.2	23.1	63	142	9.0	18.4	3.33	0.0	0.0
March	10.2	26.3	52	211	9.1	21.0	4.72	0.0	0.0
April	17.5	32.8	58	284	9.2	23.0	6.23	0.0	0.0
May	20.2	37.7	52	451	10.0	25.0	9.16	0.0	0.0
June	23.5	36.0	67	594	10.1	25.2	8.21	0.0	0.0
July	22.9	33.0	77	553	7.0	20.4	5.82	89.5	71.6
August	22.8	33.4	75	542	8.2	21.7	6.16	0.0	0.0
September	20.0	34.0	73	454	10.0	22.8	6.32	0.0	0.0
October	16.1	31.5	65	221	9.2	19.2	4.88	0.0	0.0
November	9.7	27.2	51	151	8.6	16.1	3.67	0.0	0.0
December	7.6	21.3	71	163	7.8	14.1	2.46	0.0	0.0
Average	15.3	29.7	64	324	8.9	20.2	5.29	89.5	71.6

Table 7: Crop Water Requirements for Wheat

Month	Decade	No of days in decade	Stage	Kc (Coeff)	ETc (mm/day)	Etc (mm/dec)	Eff. Rain (mm/dec)	Irr. Req. (mm/dec)
Nov	1	1	Init	0.30	1.22	1.22	0.0	1.2
Nov	2	10	Init	0.30	1.10	11.00	0.0	11.0
Nov	3	10	Init	0.30	0.98	9.80	0.0	9.8
Dec	1	10	Dev	0.30	0.84	8.40	0.0	8.4
Dec	2	10	Dev	0.44	1.04	10.40	0.0	10.4
Dec	3	11	Dev	0.67	1.63	17.93	0.0	17.9
Jan	1	10	Dev	0.90	2.28	22.80	0.0	22.8
Jan	2	10	Mid	1.12	2.85	28.50	0.0	28.5
Jan	3	11	Mid	1.18	3.31	36.41	0.0	36.4
Feb	1	10	Mid	1.18	3.62	36.20	0.0	36.2
Feb	2	10	Mid	1.18	3.93	39.30	0.0	39.3
Feb	3	8	Late	1.17	4.46	35.68	0.0	35.7
Mar	1	10	Late	0.99	4.20	42.00	0.0	42.0
Mar	2	10	Late	0.70	3.28	32.80	0.0	32.8
Mar	3	9	Late	0.42	2.18	19.62	0.0	19.6
Total =						**352.1**	**0.0**	**352.1**

5. Conclusion and Recommendations

4.1 Conclusions

Based on the above results of crop water requirements and irrigation schedules computed by the software following conclusions can be made:

- The use of FAO CROPWAT model provided precise results pertaining to crop water requirements and irrigation schedules specific to the selected study area based on the seasonal and meteorological features of the area
- According to the model results 15%, 1.5%, 11.6% and 1.7% less water is required compared to those determined by Lysimeter method for Wheat, Sugarcane and Rice crops, respectively. Whereas 12% increase in water requirement for Rape-seed mustard crop only.
- Hence, better management strategies can be framed using precise results of the crop water requirements of the major crops under consideration
- Scientific technologies like CROPWAT can accurately measure CWRs and offer crop patterns and crop rotations that farmers can practice.

4.2 Recommendations

It is further recommended that:

- The results of this study may be utilized by water resource planners for long term planning, allowing them save some water while achieving CWRs, and by farmers when determining how much and how often to irrigate the crops under investigation.
- A strategy should be prepared to estimate the CWRs for the remaining crops cultivated all over Pakistan.
- A strategy like this might be used as the foundation for agricultural operations. Practical testing, on the other hand, are required to certify the usage of these software tools.

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ID 108: Reservoir Modelling by Using Hec-Ressim-A Case Study of Tarbela Reservoir

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A B S T R A C T

Reservoir modelling is the process of creating a three-dimensional representation of a given reservoir based on its petrophysical, geological and geophysical properties. Reservoirs storage capacity reduces significantly by sediment deposition, and it directly affects the releases from the reservoir and water availability at power intake. In this research, reservoir modelling has been carried out by using HEC-ResSim for Tarbela reservoir as case study. Tarbela reservoir is the backbone of Pakistan's agriculture sector and economy. The model was calibrated for year 2008 and validated for year 2010 in terms of outflow and power generation and model runs were made for different past flood events. The results show close comparison between simulated and observed outflow and power values for different scenarios. On the basis of 30-year histogram cycle, the future prediction of releases/outflows, power/energy generation in year 2035 has also been done. After 2035, Tarbela reservoir is expected to become the run-off the river type project due to decrease in the gross storage capacity. As per simulated results of the projected scenario (2035), the releases/outflows from reservoir and energy generation will increase in summer season by 7% and 36% respectively and decrease in winter season by 50% and 37% respectively. Further, the reduction in gross storage capacity due to sedimentation would result in the reduction of annual energy generation by 6.5% in year 2035. It is suggested to utilize HEC-ResSim model to estimate the impact of reservoir storage capacity on future outflows, power/energy generation for other reservoirs in the world.

K E Y W O R D S:

Reservoir Modelling, Hec-Ressim, Future Prediction, Tarbela Reservoir, Energy Generation, Flooding Scenarios

1. Introduction

Reservoir is an outside aggregating area (all around framed by block work or earthwork) where water is gathered and kept in total so it could be drawn off for use. Stores are a colossal part of many waters supply structures from one side of the world to the other. Changes in environmental circumstances cause the common development of endlessly streams to balance wonderfully with time. The development of reservoir helps the whole world to fulfil the need of food and fibre by providing water for agriculture and hydropower generation for swift monetary growth and controlling flood. At the same time the storage capacities of present reservoirs of the world are also decreasing which adversely affects the agriculture sector and hydropower production. Storage facility showing is the technique drawn in with making a three-layered portrayal of a given stock considering its petro physical, land and geophysical properties. These properties are portrayed during store portrayal where geoscientists and modellers gather all physical and compound information to extrapolate those attributes commonly through the storage facility [1].

A reservoir operation policy specifies the amount of water to be released from the storage at any time depending upon the state of the reservoir, level of demands and any information about the likely inflow in the reservoir. The operation problem for a single purpose reservoir is to decide about the releases to be made from the reservoir so that the benefits for that purpose are maximized. For a multipurpose reservoir, in addition to the above, it is also required to optimally allocate the release among several purposes [2]. All lakes and reservoirs created on natural rivers are subjected to reservoir sedimentation. There isa lack of accurate data regarding rates of reservoir sedimentation worldwide, all over the world, average annual reduction in reservoir storage capacity due to sedimentation varies from 0.1-2.3%, while the average annual world reservoir storage loss is about 1.0% [3].

The Tarbela Dam (Degree: 3405'23" N, Longitude: 7241'54" E) was proposed in 1976 on the Indus Stream as part of the Indus Waters Strategy (IWS) signed by Pakistan and India in 1960. The IWS wanted to construct three end supplies, especially Tarbela, Mangla, and Chashma, six effects, and eight affiliation channels to plan the influence of a water deficit on stream movement in Eastern Pakistan as shown in Figure 1. Aside from organizing the effect of water loss from eastern streams and establishing a strong foundation for the improvement of the water framework structure, one of the key goals of the hydropower age [2].

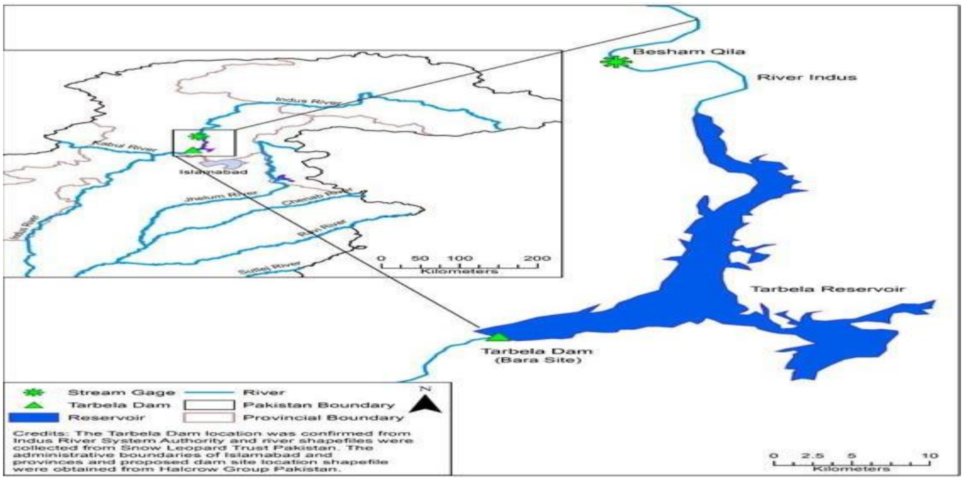

Fig. 1: Location map of Tarbela Dam and Reservoir [4]

The average advancement rate of sediment delta pivot point is 0.386 km/year by operating the reservoir according to current NESPAK operations. The location of Tarbela dam on Indus River and Tarbela powerhouse, respectively. Tarbela reservoir primarily holds the Indus River's waters, which carry high volume of sediment load in reservoir. The reduction in reservoir capacity due to sedimentation will reduce irrigation releases and their duration, gross power and power duration [5].

2. Literature Review

Worldwide reduction in reservoir storages due to problem of sedimentation is very significant. The maximum reservoir storage reduction in China is 2.3%, while the minimum storage loss in UK is 0.1% [6]. The International Commission on Large Dams has estimated that worldwide there are more than 42,000 large dams, and due to sedimentation problem, the resulting worldwide rate of storage loss and storage capacity are approximately 0.5% to 1% and 7,000 km^3 annually, respectively [7]. To compensate this loss rate, 50 km^3 of storage volume is added per year worldwide, with a replacement cost of approximately 13 billion dollars each year in 2003, or 18 billion dollars in 2015 [8]. A dependably expanding global population enhance this circumstance undoubtedly. Individuals rise, so does the fundamental for water limit, ignoring the contraction of overall storing volume [9]. A decrease in dam progression speed, combined with store sedimentation, resulted in a decrease in the overall net stock accumulation limit [10]. If the region allowed vaults putting away capacity decreases, the water need will eventually push toward the stock, causing a widespread water emergency [11]. Similarly, Tarbela reservoir supply in Pakistan captures an important volume of water from the Indus Stream. Its unique arranged storing volume was reduced by 20% over the first twenty years of development [8].

HEC-ResSim has been widely used for modelling of reservoirs all over the world. In this study HEC-ResSim has been used for modelling of Tarbela Reservoir in Pakistan. HEC-ResSim is a simulate design redirection model created by the Hydrologic Arranging Point of convergence of the US Prepared power Corps of Specialists to assist facilitators and specialists in anticipating how to deal with acting of vault frameworks in water and to help storage facility chief's transports primarily during crisis conditions and conventional endeavors [12].

The governing equation in HEC-ResSim is storage continuity equation [13].

$$S_t+1 = S_t + I_t - R_t - E_t – O_t \qquad \text{(eq. 1)}$$

Where $\mathbf{S_t}$ is the storage at the start of a time period **t**, $\mathbf{I_t}$ is the reservoir inflow during the period **t**, $\mathbf{R_t}$ is the release required for the specified power generation for the period **t**, $\mathbf{E_t}$ is the evaporation of a period **t** and $\mathbf{O_t}$ is the spillway release during the period **t** from the reservoir.

In Ethopia, HEC-ResSim model was applied for Omo Gibe River basin to simulate cascade dams on the river and reservoir operations to optimize water for hydropower energy generation, and flood management. The new reservoir operation rule selected by modelling of cascade dams from HEC-ResSim model increases energy generation of the Omo Gibe River basin 28-45 % [14]. HEC-ResSim was used to simulate reservoir releases and power generated from Mosul dam in Iraq[15]. HEC-ResSim model was employed to Tucuruí Dam´s reservoir's daily observed data from 2001 to 2006 of pool elevation, inflow and outflow discharge [16].

3. Research Methodology

3.1 Data Collection

Selection of an appropriate data and its collection from the relevant sources is an essential part of a research work. For modelling of the Tarbela reservoir operations, the data has been collected mainly from NESPAK as shown in Table 1. The data includes storage capacities of reservoir at different elevations, time series flow data, time series power generation pattern, area-elevation capacity tables, rule curves, and evaporation data of the reservoir for different years.

Table 1: Tarbela dam and reservoir data collection details

Data	Year	Source
Tarbela Reservoir Outflows and Power generation	2008, 2010, 2014 and 2020	TDP (NESPAK)
Tarbela Reservoir Area- Elevation-Capacity Tables, Rule Curves	2008, 2010, 2014 and 2020	hydrology and Survey TDP (NESPAK)
Tarbela Reservoir Levels	2008, 2010, 2014 and 2020	Hydrology and Survey TDP (NESPAK)
Evaporation Data	2008, 2010, 2014 and 2020	SWHP (NESPAK)
Future Reservoir Capacities	2035	NESPAK

3.2 Model Setup

Based on available data, the model setup in HEC-ResSim has been done by using its three modules i.e., Watershed Setup, Reservoir Network and Simulation Module. The flowchart for model setup and simulation has been presented in Figure 2.

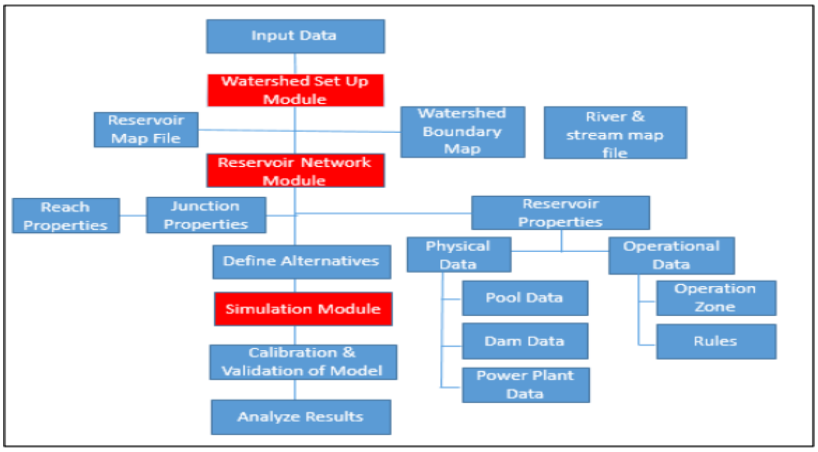

Fig. 2: Flow chart for HEC-ResSim Simulation

The Tarbela reservoir was modelled for the years 2008, 2010 and for the future year 2035.

4. Results and Discussion

4.1 Model Calibration

Based on the Input data HEC-ResSim Model was calibrated for the outflow and power generation for the year 2008 as shown in Figure 3.Results of the Model calibration are indicated in Figure, for outflow and power generation respectively. The initial runs of model suggested that the model results are sensitivefor power plant efficiency, which was also proved in the calibration process. The model results did not match the observed dam releases and power generation during the initial runs. After the trial run, the model generates the outflow and power generation from the Tarbela dam as that was approximately similar to the actual outflow and power generation recorded by NESPAK of the year 2008.

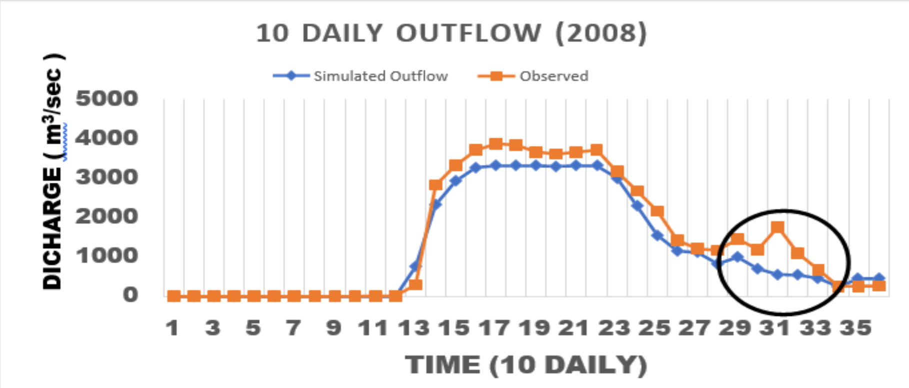

Fig. 3: Comparison of Observed and Simulated outflow (2008)

Observed and Simulated discharge values are close to each other throughout the year except a minor difference at the end of year. This may be due to some constant parameters in data entry in the model such as seepage or may be due to evaporation because evaporation although changes with respect to different months in year, but has been kept the same for all scenarios.

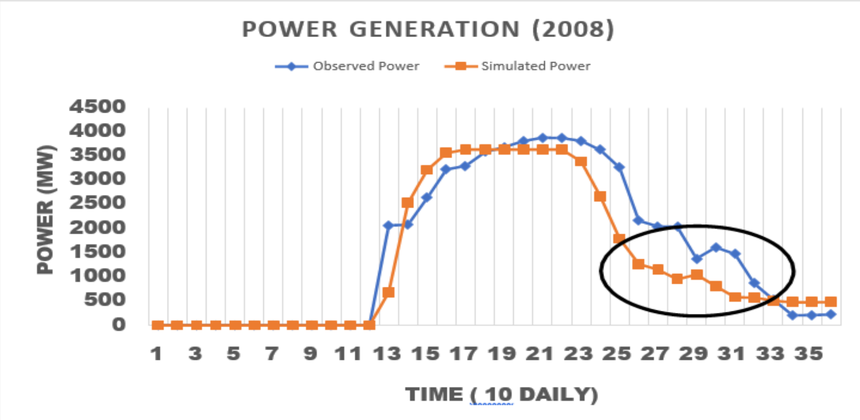

Fig. 4. Comparison of Observed and Simulated Power (2008)

The maximum power generating capacity of Tarbela reservoir for the year 2008 according to data taken from the relevant department (NESPAK) is 3890 MW, and the maximum power generated by model is slightly less then this and is equal to 3645 MW as shown in Figure 4.

4.2 Model Validation

The outflow and power results for the validation scenario have been shown in Figure 5 and 6 respectively.

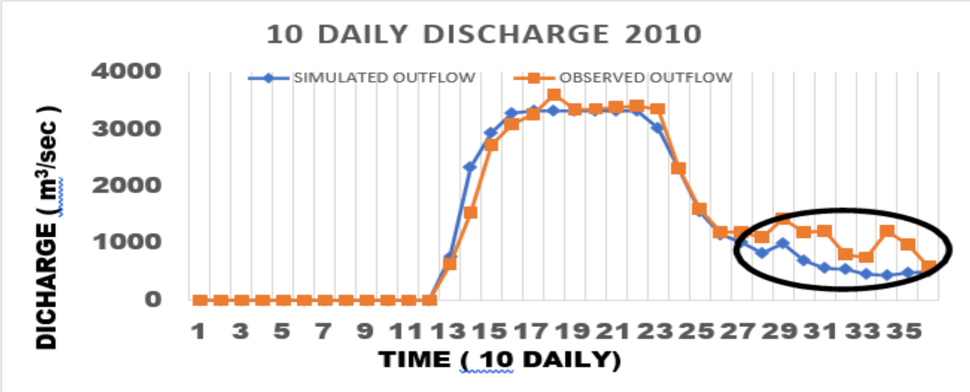

Fig. 5: Comparison of Observed and Simulated outflow (2010)

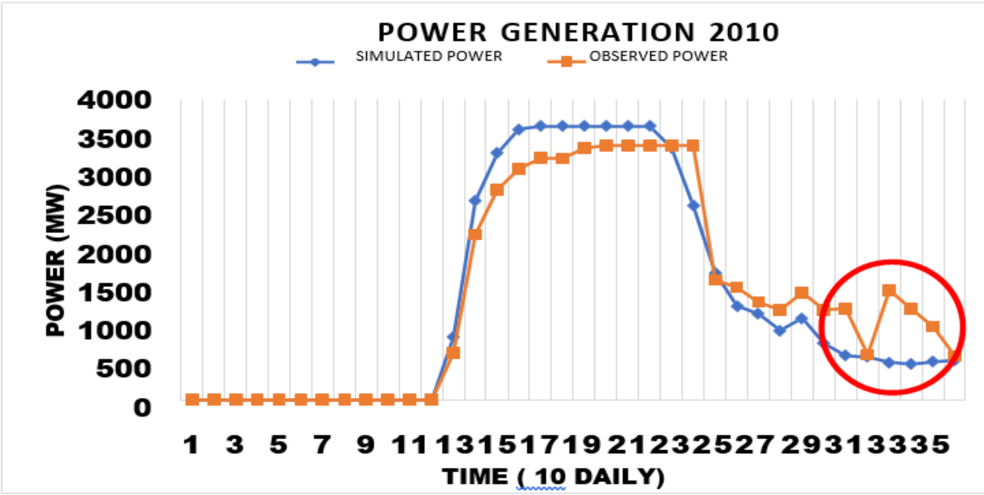

Fig. 6: Comparison of Observed and Simulated Power of the Model for Outflow (2010)

Observed and Simulated outflow and power almost remain the same throughout the year but have minor difference at the end of year.

4.3 Projected Scenario 2035

4.3.1 Inflow Hydrograph For 2035

The 30-years histogram cycle has been used for future prediction. Comparison of the inflow data of 1976 and 2005 has been done as shown in Figure 7 and the results show almost the similar trend. So, for future projection of year 2035, inflow hydrograph of year 2005 was used as input data.

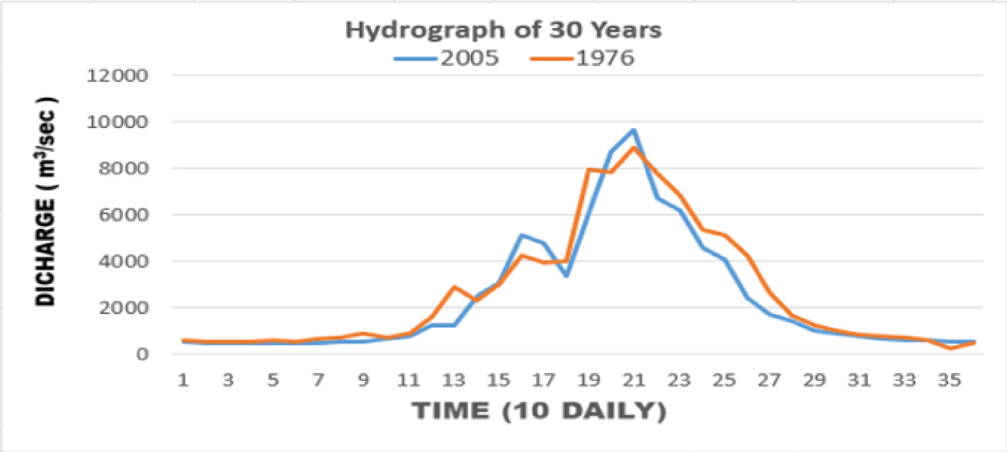

Fig. 7: Comparison between Hydrographs of 1976 and 2005

4.3.2 Future Prediction Results

It has been observed that power available in the months of May, June, July and August is higher than other months of the year. This is because the releases in these months are higher and cannot be stored in the reservoir due to lost storage in year 2035 which lead to inflows equal to outflows as shown in Figure 8. Further maximum power is most likely to be available in the month of August and minimum power will be available in the month of January.

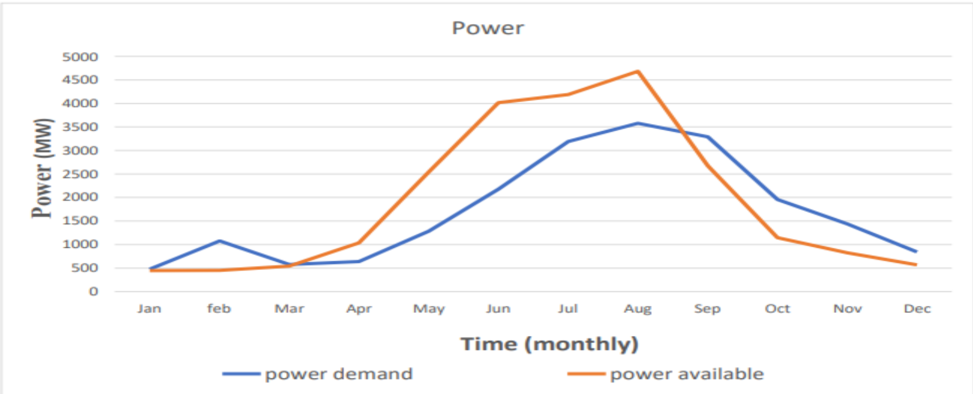

Fig. 8: Comparison of power demand and power available (2035)

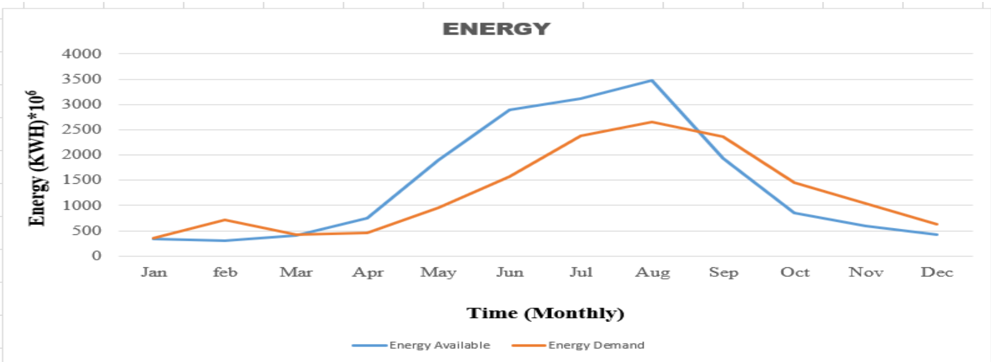

Fig. 9" Comparison of Energy available and Demand of energy (2035)

From Figure 9, it is observed that energy available in the months of April, May, June, July and August is higher than other months of the year. This is because the releases in these months are higher and cannot be stored in the reservoir due to lost storage in year 2035 which leads to inflows equal to outflows. In order to have detailed comparison, the predicted values of outflow and energy (as per predicted Power) for summer and winter season and annual energy for the year 2035 have been compared with the respective average base value of recent five years as given by Water Resource Division NESPAK, Lahore as shown in Table 2.

Table 2: Comparison of Outflow and Energy for year 2035

Parameters	Season*	Predicted value (2035)	Average Base Value** (NESPAK)	% Change
Outflow/Releases (m^3/s)	Summer	19142.43	17890.12	7%
	Winter	3974.236	7947.944	- 50%
Energy (KWh)	Summer	$14056.46*10^6$	$10310.63*10^6$	36%
	Winter	$2904.71*10^6$	$4617.03*10^6$	-37%
Annual Energy (KWh)	Per Annum	$16961.17*10^6$	$18146.55*10^6$	-6.5%

*Season includes ‘Summer’ from April to September and ‘Winter’ from October to March

** Average base value of recent five years given by NESPAK.

5. Conclusions

The results of all flooding scenarios show almost the same pattern of values for observed and simulated 10-daily outflow and power. After 2035, Tarbela reservoir is expected to become the run-off the river type project due to decrease in the gross storage capacity. As per simulated results of the projected scenario (2035), the releases/outflows from reservoir and energy generation will increase in summer season by 7% and 36% respectively and decrease in winter season by 50% and 37% respectively. Further, the reduction in gross storage capacity due to sedimentation would result in reduction of annual energy generation by 6.5 % in year 2035. It is suggested to utilize HEC-ResSim model to estimate the impact of reservoir storage capacity on future outflows, power and energy generation for other reservoirs in Pakistan as well as in other parts of the world.

6. Acknowledgment

The authors are thankful to the Water Resources Division, NESPAK Lahore for providing the valuable data and necessary guidance.

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Intelligent Systems in Highway and Traffic Engineering

International Conference on Sustainable Development in Civil Engineering,
16-18 February 2023 (ICSDC 2023)

ID 11: Exploring the Issue of Transportation within MUET, Jamshoro

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A B S T R A C T

This research explores the issue of lack of quality and climate friendly transportation service for students at Mehran UET Jamshoro. To investigate this research question, quantitative research approach was used, and a structured questionnaire was designed to collect data from 385 (Cochran, 1977) students enrolled in MUET Jamshoro through convenience sampling technique. In response 453 students from the university fill out the survey questionnaire. Simple Descriptive Graphical Representation was done by the help of SPSS. The study results reveal that students studying at MUET Jamshoro do face grave difficulties while commuting within the university premises. The existing hourly point service, provided to students by university, to travel to different departments within the university premises can only be availed at specific hours and is nor environment friendly neither cost effective. Pakistan, a country which is already facing an irreparable economic crisis and a climate change disaster are a daunting reality. Hence, the survey results emphasize the dire need of a sustainable, environment friendly and cost-effective transportation system in the university, which will eventually generate revenue and cut the fuel cost.

K E Y W O R D S:

Sustainability, Transportation, Environment.

1. Introduction

In Pakistan majority of the government universities are huge area wise and it is no less than a hassle for students and staff of universities to travel back and forth inside the campus. Mehran University of Engineering & Technology, Jamshoro is ranked as one of Pakistan's top ranked university, over 8507 students are currently enrolled in Mehran UET, Jamshoro. The university is spread over a large area in city of education Jamshoro. Despite having a large number of student's enrollment, there is absences of a cheap, reliable and sustainable transportation service inside the campus. The students at Mehran UET, Jamshoro have to travel from spot to spot inside the campus for different reasons like for the purpose of attending lectures schedule at any other department inside the campus, for reaching central library for having launch, Photostate of documents notes etc. As the university is huge area wise, it is not easy in any manner to travel inside the campus through walking to reach the desire location. Majority of the students enrolled in the university belong from middle class families and currently the only option of commuting available are point service available for specific time period only available inside university once a day, the other option is rickshaw rides which cost around 70 rupees per ride, this cost makes it unaffordable for majority of the students enrolled in university to opt this option and at the end students bear the brunt of the unavailability of a cheap and sustainable commuting system inside campus. Both these solutions are not environmentally friendly as they emit greenhouse gases which puts a bad impact on the overall environment and causes health related problems too. The current solutions of commuting provided by university is turning out to be a burden for the students of Mehran UET, Jamshoro rather than an easy, comfortable and cheap way of traveling inside the campus.

2. Literature Review

The last few years world has witnessed a huge growth in development of eco-friendly system. Researchers, entrepreneurs around the globe trying out different ways to solve the problem of transportation in a more sustainable way. These systems are economical as well as eco-friendly as it helps in reducing noise pollution, emissions of greenhouse gases, usage of gasoline, implementation of such systems ensures the harmful fluids that are usually required by other commuting vehicles to operate don't destroys the waterways and environment. In almost every government university of Pakistan the issue of transportation exists, non-seriousness and negligence of the university administration towards this issue is turning a huge burden on students. Majority of the students who opt for government universities in Pakistan belong from middle class families and they can't afford their own convince for the purpose of traveling. The principles of sustainable transportation also support the use of low-cost public transportation which is capable of working effectively [1]. The administrations of Pakistan government universities must find a solution by offering a sustainable transportation system inside the campus to make traveling more comfortable, affordable, and convenient. This would undoubtedly assist students in availing an affordable service to travel inside campus, which will also help them studying in peace rather than worrying or thinking about ways to pay amount to travel inside the campus as majority of the students belong from middle class families, with a low monthly household income, it is not easy to afford such expensive services of commuting. Universities can play a fundamental role in addressing the environmental challenges, we as human being are causing harm to our environment in some manner on a daily basis, when we are asked to live in a manner that doesn't put earth endanger, we find it a very challenging task to do, but we can change this thing, we can make the future generation to embrace change by teaching them the importance of sustainable development and by teaching them how we should move ahead as a society. Universities are considered as influential institutions; they can put a huge impact on global communities and environment [2]. In Pakistan universities like IoBM and NUST Islamabad have taken initiatives like bicycle sharing system to solve the problem of transportation within campus [6, 7]. Other universities can also think about adopting sustainable solutions for these issues and can spread awareness among the students.

3. Data Collection & Data Analysis

3.1 Study Area & Study Design

This research was carried out inside Mehran University of Engineering & Technology from 31st January 2022 till 15th August 2022. In this research quantitative research method, a quantitative survey questionnaire was designed to gathered responses from the participant on the issue of transportation they face inside Mehran UET, Jamshoro.

3.2 Study Population & Data Collection

The participants who were eligible for this study were the currently enrolled students of Mehran UET, Jamshoro in different programs, BS, BE, BBA, MBA, MS, and PhD etc. After permission was granted to collect data from the students of MUET, the qualitative survey questionnaire was spread among the students. Our target was to get 385 responses as the ideal sample size is 385 when the population size is unknown according to Cochran, 1977. In response we got 453 responses, in which 318 participants belong from bachelor's background, 132 participants were from master's background and only 3 participants were from PhD background.

3.3 Data Analysis

To prove the existence of this transportation problem inside Mehran UET Jamshoro we designed a quantitative research questionnaire, this questionnaire was consisting of 3 sections 1. Demographics, 2. Core Research Questions | Difficulty, Section 3 Students' Dissatisfaction and Preference. The first section, "Demographics the 3 Questions of this section," will provide background data on every participant who completes our form, the second section "Core Research Questions | Difficulty," will get an overview of the challenges students have when commuting throughout the campus and it will also help us find the reason that are causing these challenges. By looking at the questionnaire's last section, which is section 3, which asks about their participants preferences and level of discontent, we will be able to determine what students' level of satisfaction is for different transportation related factors and what are demands. Further data is shown in Figure 1 and 2.

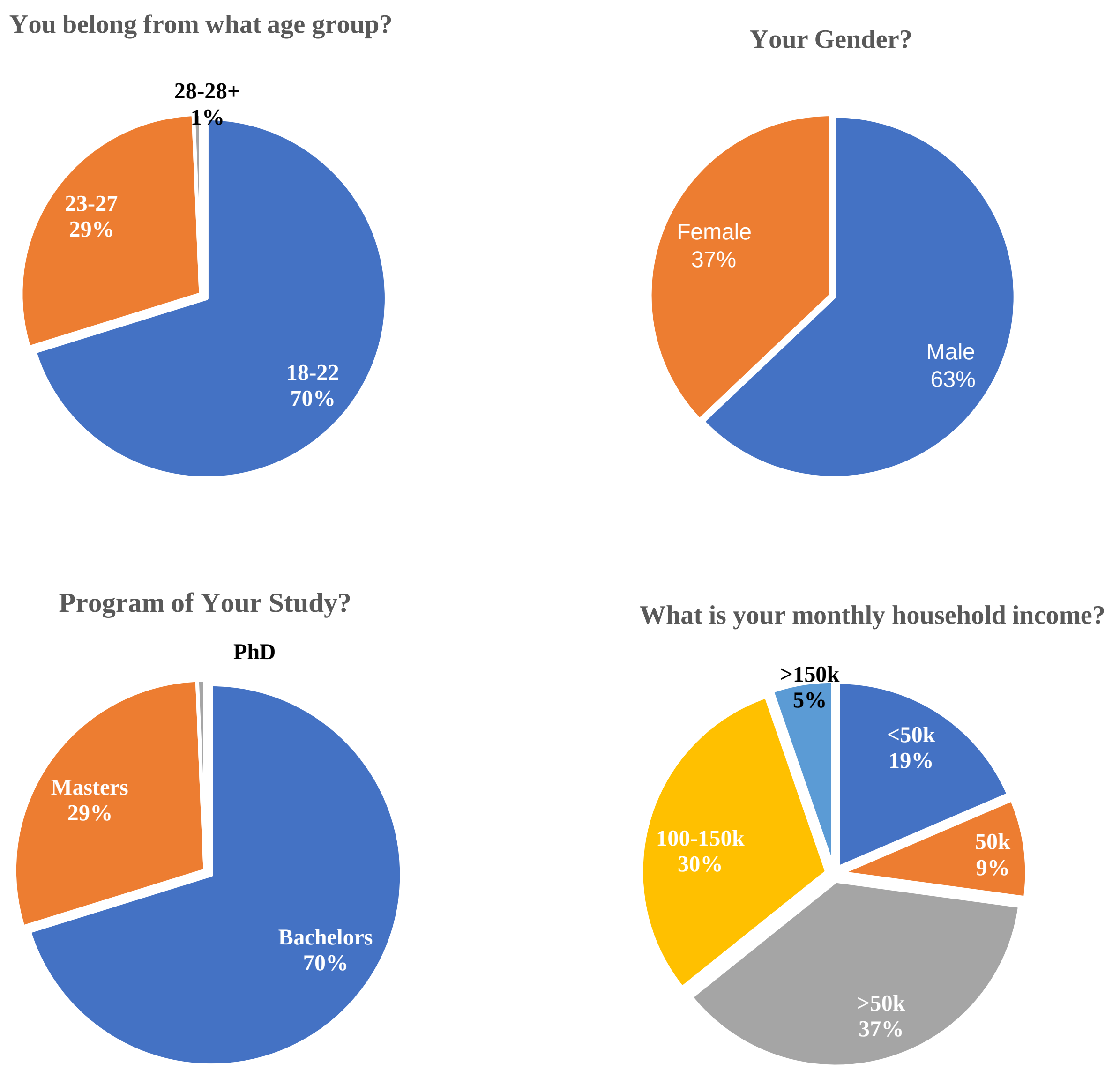

Fig 1: Demographic data of respondents

2. Results

The findings of this study manifest that there is dire need for a cheap and environmentally friendly commuting service inside Mehran UET, Jamsoro, (Column Chart: 4). Majority of the students currently enrolled in Mehran UET, Jamshoro belong from lower middle-class families with monthly household income of 50k PKR (Pie Chart: 4) and because of this vary reason, it is difficult for them to commute inside the campus, as there isn't any cheap transport option available for them. (Table1: Question 1). The result shows dissatisfaction of students with the handling of transportation issues inside campus, (Table1: Question 5,6). The students are in support of climate friendly and cheap option like bicycles inside the university. When the students were given the options of Buses, Rickshaw, Bicycles, Other, majority of them selected the option bicycle as their preference for commuting inside campus. (Table1: Question 2,3).

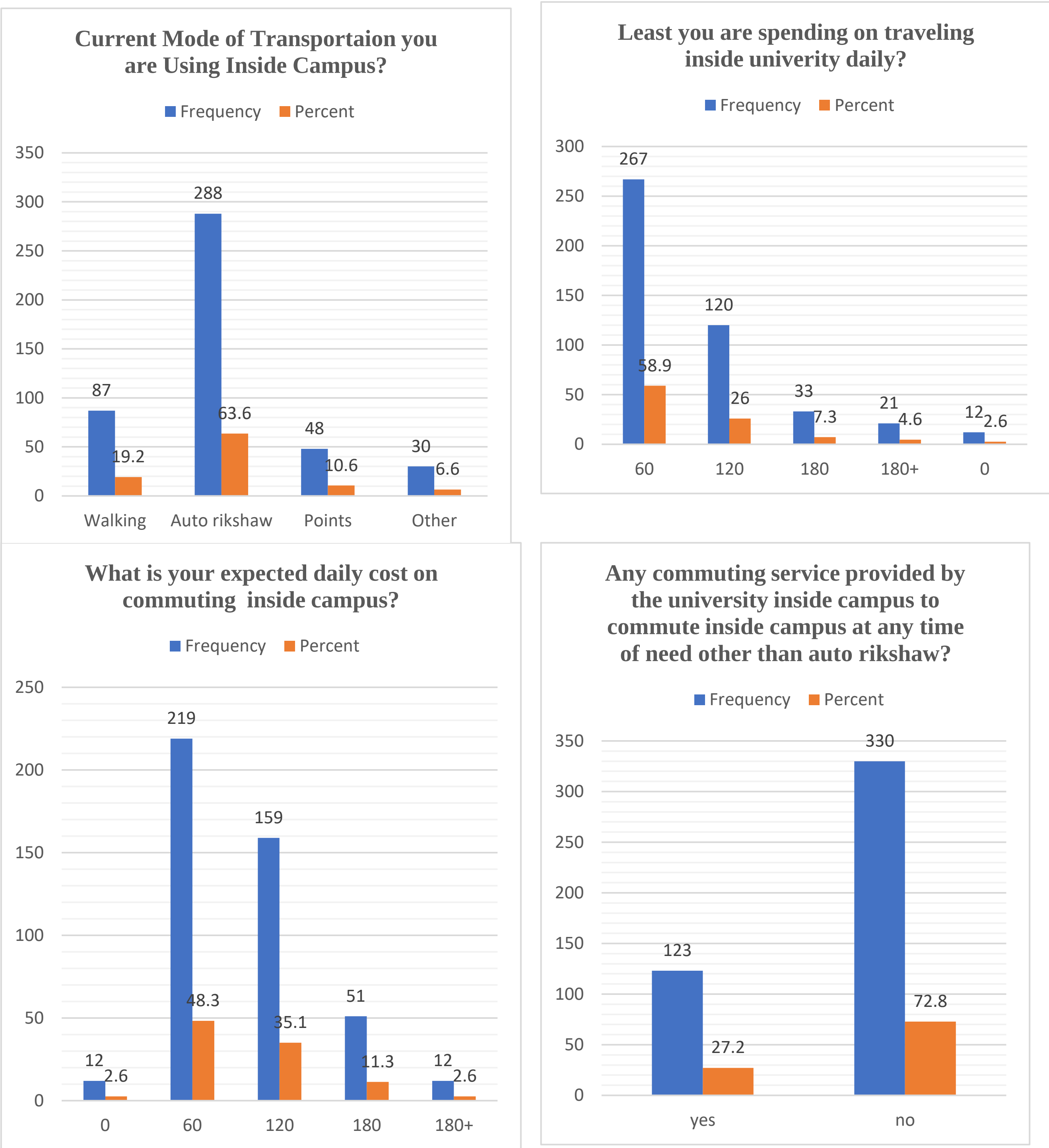

Fig 2: Section two data of questionnaire

Table 1: Section 3 Students Dissatisfaction and Preference

1. Do you think it's expensive to travel inside campus?		
Options	**Frequency**	**Percent**
Yes	405	89.4
No	48	10.6
2. Do you think there is need of a bicycle sharing system inside campus?		
Options	**Frequency**	**Percent**
Yes	435	96.0
No	18	4.0

3. Your preferred commuting option?		
Options	**Frequency**	**Percent**
Bicycle	372	82.1
Auto-Rikshaw	*30*	*6.6*
Points	51	11.3
4. Do you know how to ride a bicycle?		
Options	**Frequency**	**Percent**
Yes	393	86.8
No	60	13.2
5. Are you satisfied with the current transportation system?		
Options	**Frequency**	**Percent**
Yes	81	17.9
No	372	82.1
*6. **Rate your satisfaction level from scale 1-10***		
Options	**Frequency**	**Percent**
Strongly Dissatisfied	189	41.7
Dissatisfied	*180*	*39.7*
Satisfied	60	13.2
Strongly Satisfied	*24*	*5.3*

5. Discussion

According to our results the existence of this problem was proven. There are many ways through which this problem can be solved. The options that the university administration can think about while solving this problem are Buses availability inside the campus, the other option can be lowering down the charges of currently available commuting option Rickshaw rides. But going for both these options means compromising on the environment inside campus and health of students, as both these options are not climate friendly options. The result that we got by the help of (Question 3 of Section 3) indicates that students at the university are also in favor of bicycle sharing system inside the campus, and they preferred bicycles over the other options like bus, auto rikshaw (Section 3: Question 2). Buses and Rickshaw emits green-house gases which damages the climate and heats the surface of the planet [4]. Emission of such gases also puts a bad impact on the human health like respiratory diseases that are caused by air pollution, smog etc. [5]. A major contributor to global warming is the usage of personal automobiles, public transport options like Taxi, Rickshaw, Buses etc. Since the last several decades, climate change brought on by carbon dioxide and other greenhouse gases has become a significant concern that affects not just our health but also other fundamental human needs. Some effects, including as extreme flooding and sea level rise as well as record high temperatures, are already happening more often. Heat stroke, illnesses linked to air pollution, infectious diseases, illnesses spread by mosquitoes, and water and foodborne infections are only a few of the common illnesses linked to weather and climate adaptation. Extreme weather events, variable air pollution concentrations, and high temperatures are responsible for them. Additionally, heavy rains and flooding can provide habitats for several mosquito vector species, including Anopheles mosquitoes, which are linked to the development of malaria. Reducing the problems that risk the health of our children and generally have a negative influence on our environment will be made possible by adopting a less sustainable and more ecologically friendly approach. University should think about taking a sustainable initiative that can be good for our climate, students health and is capable enough to generate revenue for the university.

6. Conclusion

A problem well put is half solved, the data that we have gathered through quantitative survey questionnaire, through this data we came to know about the transportation problem existence inside the university. The research results also helped us in identifying the current need and desires solution of MUET, UET Jamshoro students, who are basically the potential customers, it also tells us about the scope for one of the sustainable transportation option, Bicycles. The data we have gathered in this study can help us in planning a sustainable business model inside the campus in future. We can think about taking initiative to make our university cleaner and greener one by taking initiative like bicycles sharing system. Many renown universities around the world have taken this initiative to solve the problem of transportation inside campus. like Oxford University, Stanford University and many other. In America there are programs like BFU (Bicycle Friendly Universities) this program basically promotes usage of bicycles inside campus of American universities. Its emphases on creating a safe and secure campus for bicycle riding, giving students the ability and skills to ride bicycle confidently and promoting the bicycle culture. This program also recognizes the efforts of institutes of higher education in America and rank them accordingly [8]. In Pakistan NUST, Islamabad also taken the same initiative of bicycle to make it easy for their students to commute inside the university. Government of Pakistan can also take initiatives like BFU in Pakistan to promote idea of bicycling among institutions of higher education in Pakistan. Taking such step can promote sustainable and climate friendly initiatives and can urge universities to take part in making the campuses greener.

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ID 28: Development of Guidelines for Road Safety Education – A Way Forward Approach in Motorizing Countries

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A B S T R A C T

As per the statistics of World Health Organization (WHO), every year approximately 1.24 million fatalities are observed due to traffic accidents. This is due to the increased number of vehicles on major cities particularly dependent on urban population. Traffic accidents as an outcome of this phase is one of the serious problem in densely populated cities which unfortunately are not giving proper considerations by decision makers. Hence, it is required to adopt a certain mechanism of road safety fulfilling the requirements of daily commuters. Road safety is basically the manmade problem hence its respective solutions should be manmade. The specific group in this context is in real need to critically synchronize the possible factors of road safety in lines with the effectiveness of road safety education. Amongst number of cities of Pakistan, Karachi city is exposed with significant number of road crashes. It is essential for the practitioners to brainstorm about the development of guidelines for road safety education as an initiation. The aim of the research is based with the focus on reduction of number of accidents in Karachi city. To enhance the less than 10% learning exposure, this could only be possible with an intellectual way of road safety education featuring qualitative assessments. This research is a way forward step to identify a model for the effective adoption of road safety education tool as an implicit requirement of Karachi. It may include strategic planning and improved guidelines for different phases of education.

K E Y W O R D S:

Accidents, Safety, Karachi, Roads

1. Introduction – Implicit to Traffic Management

In current scenario, traffic congestion is becoming a serious problem for large cities in the world. In-fact, the situation is critically different when comparison is drawn between motorized and motorizing countries. The reason behind this is existing metropolitan cities of developing countries are not provided with basic infrastructure requirements having low road network densities which in turn affects the direct interconnection between road users and transport modes [1]. Traffic congestion is primarily dependent on numerous factors. The directions may include economic productivity, environmental quality, poor traffic performance and above all traffic safety. In this connection, countries are expanding their stream of knowledge through smart applications like Advanced Traffic Management Systems, Intelligent Transportation Systems etc. [2].

By virtue of existing demand, transport sector should be given such considerations against the development and welfare of people. Improved transportation system may correspond to identify number of opportunities like accessibility to markets, proper employment levels and further investments [3]. Keeping in mind about various countries, Pakistan is one of them to inculcate with these features to be prepared and channelize remote regions of the country [4]. Karachi, the metropolitan city of Pakistan is generating signified economical revenues in this context but unfortunately, this particular city is not treated with the same. The city is not available with the basic road's requirements for daily travellers even after the huge share of import and export concerns. Not only that, due to increase in population and traffic demands, the users of the city is greatly affected with the serious road traffic accidents on its major routes. As far as, budget monitoring is concerned, measures are implemented to overcome the situation of road safety and in order to minimize traffic accidents but there is also a need to undertake the problem in terms to have organized mechanism for stakeholders. For the same, road safety education in broader canvas plays a vital role for such developing countries [5]. Existing traffic flow pattern of Karachi city is presented in Figure 1.

Fig. 1: Existing traffic flow pattern of Karachi, Pakistan

2. Traffic Accidents and Road Safety Education

Considering population and growth, Karachi comes within the seventh largest mega city in the world. As per the statistics, approximately 70% accidents are occurred due to lack of awareness about traffic and road safety rules as identified in Figure 2 [6]. The major contributory factors responsible for traffic accidents on important routes of Karachi include over-speeding, novice driving, pedestrians negligence, not wearing helmets and seatbelts, road encroachments, wrong way driving, improper implementation of road safety measures and inadequate legislations or enforcement actions [6]. Due to these factors, Karachi is classified as on 48th number worldwide in road accidents [7]. On the other hand, it is the basic requirement of any city to target the elementary countermeasure of accident safety which is actually road safety education. Road safety education has its valid importance in this context as the origin source of traffic safety and in order to specify relevant stakeholders. To educate the common class of road users about crash safety; it must be the prime agenda for controlling and reducing the graph of traffic accidents. For this, education sectors and enforcement agencies must join hands to contribute in it. The areas need to be addressed are safety schools, driving schools, licensing and training, policing, patterns of education at specified grades like primary, secondary and higher levels etc. [8].

Fig. 2: Traffic Accidents in Karachi, Pakistan (Location: Gharoo Interchange)

3. Aim and Objectives of the Study

The basic aim of the research is to reduce traffic accidents for metropolitan city Karachi, Pakistan through road safety education. Following are the objectives of said research:

1. To develop guidelines for road safety education considering the existing road network conditions of developing countries.
2. To predict the status of road safety education through curriculum development.
3. To develop the source model for finding out the solutions of traffic safety in terms of road safety education.
4. To connect the base parameters of traffic accidents and road safety with respect to road user requirements followed by particular recommendations to practitioners.

4. Road Safety Education in Pakistan – An Operational Tool

As a tool in school's education, whole-school approach is adopted in road safety education [9]. This approach is dependent on the effective coordination of schools, parents and communities working together for the implementation of road safety strategies in respective domain. This ensures the credibility of framework as health promoting activity. On standard note, this framework consists of three major areas as follows:

2. Curriculum
3. Environment
4. Guardians and Community

This framework may lead towards the contributions of health and learning outcomes with the interconnection of above parameters. Unfortunately, Pakistan and specifically, Karachi has very limited organizations who are channelizing the active participation of traffic safety through their contributions in road safety education. In this connection, an organization; Social Research and Development Organization (SRDO), Karachi, Pakistan is playing a vibrant role to control road traffic accidents within the perspective of road safety education [10]. This organization has showed serious concerns on major road accidents. Additionally, they have intimated the following preventive measures for the concerns of stakeholders in the longer run:

a. Applicability of Enforcement actions on Traffic Laws
b. Smooth Education and Training of Public Transport Drivers
c. Education of Safe Driving to Older Age Drivers
d. Sufficient Road Safety Trainings and Courses
e. Awareness of Traffic Rules among School going Children
f. Training of School Van Drivers
g. Awareness through Media
h. Inspection of Public Transport
i. Inspection of CNG Cylinders
j. Countermeasures for Pedestrians

5. Strategic Planning for Road Safety

Subsequent to strategic planning, a way forward National Road Safety Strategy (2018-2030) has been initiated in which the vision statement is based on minimization of road traffic accidents. The achieving targets shall ascertain the Pakistan's economy with the fulfilment of road safety standards through effective promotion of education and regulations in between drivers, passengers and pedestrians. The action plan includes entities like revision of current road safety practices, comparison of road safety education standards on international norms, analysis of crash data and involvement of key controlling organizations [11].

Furthermore, National Highways & Motorway Police also shared their contribution in promoting road safety education. This organization is striving hard to inculcate the basic understanding of road safety amongst common people with the advancements in education. Not only that, the organization shows their vigilant participation in executing road safety trainings and awareness sessions for all types of road users in addition to the publications of respective safety manuals. Motorway Police is also an important and active body on major routes of highway across the city of Karachi to provide the emergency services for the accidents occurring on highways. Therefore, the deputed staff of Highway and Motorway Police is always activated and functional by their smart monitoring mechanism [12].

Nevertheless, there are availability of organizations and driving schools who are imparting their skills to enhance road safety education but with limited constraints. It is required to synchronize all the pertinent responsible factors of traffic accidents that may be helpful to develop a sustainable mechanism of road safety education however; it must be viable and flexible to the choice of interest of any particular city. The said research is formally based on this thematic idea to which practitioners may opt their task fields as their direct or indirect assistance in the area of road safety education [13].

6. Research Methods - Approached Model for Road Safety Education in Karachi, Pakistan

As an outcome of research, certain methods are derived keeping in view of initiatives towards road safety education in Karachi, Pakistan. The idea is more elaborated in the upcoming headings of the research paper.

7. Balance of Matrix for 3 E's of Transportation

According to the research studies; there are three E's of transportation; Education, Engineering and Enforcement. All these three parameters are correlated with each other. In order to create balance in between prescribed entities, a matrix in Table 1 is produced in which similar directions are identified for explicit category of stakeholders:

Table 1: Fulfilment of 3 E's of transportation in standard matrix

Key Stakeholders	Education	Engineering	Enforcement
Institutions, Schools, Colleges & Universities	X	X	
Design, Consultant & Construction Firms		X	X
Public Sector Organizations	X	X	X
Vehicle Manufacturing Companies	X	X	
NGOs	X	X	

8. Curriculum Development for Different Phases of Education

Another major outcome of the research is the identification of road safety syllabi that may be incorporated and approved by authorities to bring positive awareness among the students. The classification for education phases is done in three ways; Primary (From Class I to Class V), Lower Secondary (From Class VI to Class VIII) and Upper Secondary (From Class IX to Class XII). The pre-defined road safety areas that are required to be addressed in curriculum against each phase of education is discussed in Table 2.

Table 2: Curriculum development and updating within the context of road safety education

Primary	Lower Secondary	Upper Secondary
Traffic Situations and Findings	Guidelines for Signaling Systems	Road Sense, Design Controls and Criteria

Primary	Lower Secondary	Upper Secondary
Concept of Pedestrians and Traffic Devices	Awareness about Vehicle Maneuvers and Precautions while Driving	Safe Driving Skills
Traffic Signs and Regulations	Accident Risk Factors	Helmet Protection
Advanced concept of Traffic Signs and Signals	Road Infrastructure Requirements	Road Safety concerns for different categories of Road users

9. Device Mechanism for Road Safety Education

Road safety education is a widespread field which requires the gradual and systematic acceptance from all concerns. Thereby, a designed structure below may be accessible to focus the targets of road safety education by highlighting the prime roles of statutory bodies. The idea is more expanded in Figure 3.

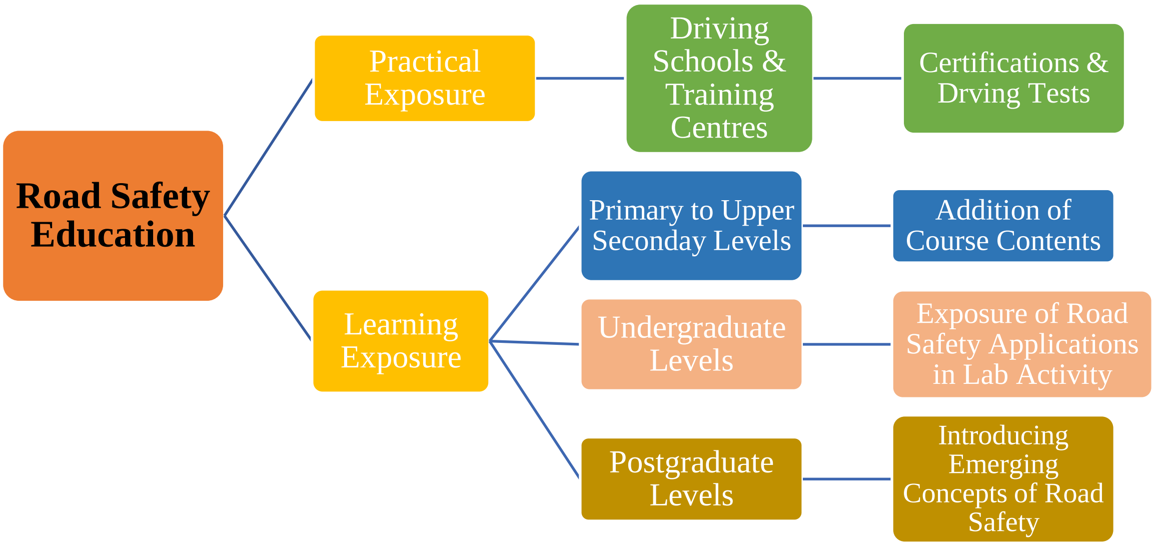

Fig. 3: Modelled approach for road safety education

As exhibited above, the way forward against road safety education is classified into two broader categories namely practical exposure and learning exposure. The existing driving schools and training centres are meant for providing driving skills by all means followed by proper certifications and tests. Learning phase is sub-divided into further modes to be addressed. As discussed above in detail, curriculum involvement in terms of road safety is required to be established in different grades of education from grade I to grade XII. This will ensure the capacity building of students to help develop the concepts of road safety. Likewise, education of smart road safety applications may be introduced at university level by means of sufficient laboratory activities. Furthermore, the researchers may extend their advanced knowledge and expertise of traffic accident and road safety engineering at post graduate levels.

10. Results and Discussions

Based on the literature and indigenous models, the study may be concluded in light of following future recommendations or discussion points:

- Within the domain of transportation; traffic accidents and road safety engineering should be given prior importance for the benefit of mankind.
- Specific guidelines and design standards should be available for vulnerable road users.
- Road infrastructure must be equipped with all necessary requirements of road users.
- The area of road safety education must be strengthened in terms to have effective coordination in between

public and private organizations.

- Guidelines should be developed in context to road safety education considering existing traffic conditions of a particular country.
- Driving schools and institutions must be given prime importance in similar context.
- The area of licensing and training should be re-formulized in order to focus road safety matters.
- It is needed to develop the strategies to overcome traffic accidents of Karachi city through proposing technical solutions by relevant group of stakeholders.
- Curriculum related to road safety should be familiarized at certain levels of education.
- To further rectification of solutions, a model is proposed in the research towards the promotion of road safety education; similar models may be generated and extended in lines with the execution of smart road safety applications. These include intelligent transportation system, smart Highways and Motorways and applicability of advanced traffic control devices.

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ID 29: Comparative Analysis for Base Materials of Flexible Pavement through Standard Combinations of Aggregates and Lab Procedures

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A B S T R A C T

Significant improvement in the construction of road infrastructures plays a vital role for the substantial growth in the economy of country. This factor is continuously taking into account by identifying the solutions within the context of flexible and rigid pavements. These types of pavements are presented with modifications in terms of their basic constituents which are aggregates, bitumen and concrete. Besides that, considerations for aggregates may be accumulated with different set of combinations ensuring the interlocking and durability between the layers. In addition to that, the findings may also reveal with the suitability of effective aggregate material focusing incurred cost. This paper presents the standard lab investigations on combinations like 100% fresh aggregates, 50% fresh aggregates + 50% Reclaimed Asphalt Pavement (RAP) material and 100% RAP against flexible pavements. The lab procedures are deployed to recommend the selection of material on the basis of quality and cost constraints idealizing an example of 1km road section. The standards are approached for ASTM and AASHTO guidelines while experimentations include sieve analysis, LOS Angeles abrasion test, aggregate impact value test, specific gravity, water absorption test and soundness measures. The outcomes of the research are carried out using trends of aggregate materials by graphical illustrations. Similarly, due to the limited use of recycled materials in developing countries like Pakistan, the said research may be taken as reference work for stakeholders. Further, the area is interlinked with decent work/ economic growth and climate action amongst prescribed sustainable development goals.

K E Y W O R D S:

Pavement, Flexible, Cost, Strength

1. Introduction

Construction industry is accompanied with the growth of economy and sustainable development. Pavement structures are generally based on the considerations and suitability of materials to be used within the assembly. However, the overall pavement design is dependent on material applicability, affectivity and sustainability [1]. Urban and rural road infrastructures are also associated with the traffic nature, its requirements and further traffic flow analysis of observed area [2]. Usually, three basis types including rigid, flexible and semi-rigid pavements are in practice for respective constructions depending upon the nature and load pattern. In the same way, they have their own characteristic properties in relation to bond mechanism with asphalt, concrete and primarily aggregate macadam [3]. In-fact, aggregates in any type of pavement play a significant role against the bond formation and in providing adequate strength to the structure [4]. Common types of pavements are accordingly characterized with respect to the features like durability, workability and compressive strength.

2. Advancements in Flexible Pavements

An emerging feature in this context is the involvement of cement treated layers for flexible pavements. This is more pronounced with the applicability as road base. It is generally prepared with the particular type of aggregates along with the percentage variations in cement and water [5]. Portland cement is used for this purpose under normal circumstances while sometimes it is also prepared with the addition of lean concrete and cement bound granular materials. It is also specified that mix design is entirely focused on the efficiency of batching plant with respect to its strength and uniformity modes for such cases [6]. Furthermore, the lay down procedures are carried out either by asphalt or cement or both. It may also be produced with the use of some recyclable materials [7]. According to the research, it can impact on unconfined compressive strength within the range of 50psi to 1500psi [8].

3. Contributions towards Reclaimed Asphalt Pavement

It is commonly used as aggregates in recycled asphalt paving in context to the adoption of proficient approach [9]. It may undergo with more efficient binding qualities as compare to virgin one therefore this material is more approachable on maintenance and rehabilitation works too [10]. In the similar way, Malaysia has contributed for the evolution of waste asphalt in road works in order to support high loading and maximum percentage of design mixture. The research is predominated with the evaluations of shock absorption and observed vibrations [11]. The measure of contact is the involvement of multiple steps for onward processing of RAP material to meet quality standards. Under normal circumstances, material is classified as coarse or fine or sometimes oversize considering certain scale. The performance of the pavement is based on experimentations like aggregate crushing, LA abrasion, impact test, water absorption and specific gravity [12].

4. Deployment of Recommended Lab Procedures

To verify the usability of aggregates in flexible pavements, it is needed to execute specific type of experimentations. These verification tests are actually dependent to frame the actual situation of the construction works not only in terms of quality assurance but to limit the construction with the identification of economic factors [13]. The relevant procedures may include sieve analysis against set of combinations of aggregates, abrasion test, crushing and impact value test, specific gravity, water absorption and soundness measures [14]. Above all, the recommended batch is to be processed for Marshall Test followed by its job mix formula (JMF) and achieved blend grading [15]. Later, stability and optimum bitumen content (OBC) are also enumerated for respective sample formation [16]. Verifications of lab experimentation may be carried out through technical empirical-mechanistic approach via smart KENPAVE software [17]. It is also important to identify the volume of roads in similar context in order to visualize the subsequent laboratory measures [18]. Marshall Mix Design procedure is variably dependent on numerous steps involved including aggregates selection, binder selection, sample preparation along with compaction, stability determinations, density and voids calculations and optimum asphalt binder content selection. It is quite evident that method selection is considerably based on the nature of sample followed by the recommended recycling actions [15].

5. Research Framework

The aim of the research is based on the sound analysis of RAP material and fresh aggregates focusing the sustainable infrastructure development under specified economic considerations. In this connection, laboratory results are computed governing the guidelines of ASTM and AASHTO against a single kilometre road section in Karachi city. The results are oriented with different sample combinations including 100% fresh aggregates, 50% fresh + 50% RAP and 100% RAP material however recommendations are drawn on the basis of incurred cost for similar road section. On the contrary, the procedures adopted are in lines with the guidelines of hot mix asphalt recycling. The research work is clearly defined on the limitations of 1km road section (7m wide and 150mm thickness) with the basic interpretations of density of aggregates and compacted volume. The overall research methodology may be easily understood with the schematic diagram as depicted in Figure 1.

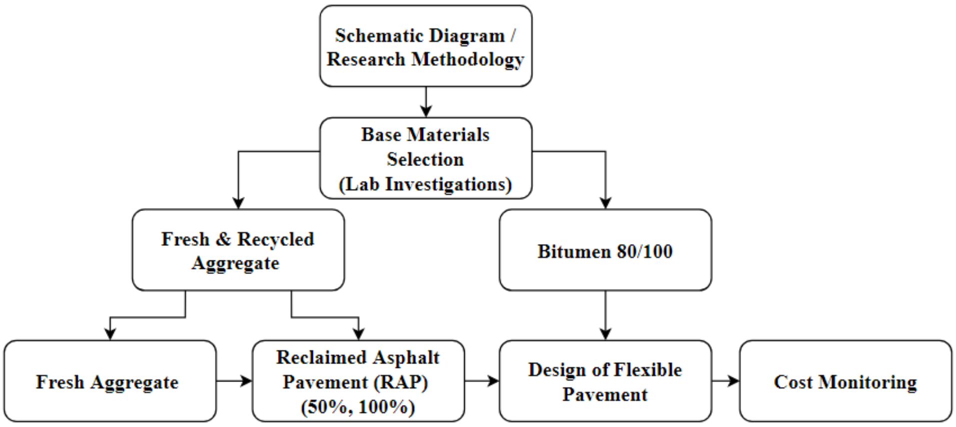

Fig. 1: Research framework

6. Analytical Facts and Findings

6.1 Sieve Analysis of Aggregates (ASTM C 136)

Procedure of sieve analysis is carried out on similar set of sample combination under the prescribed guidelines. Different sieve sizes are arranged accordingly to observe the percentage passing of the material in respective assembly. Graphical illustration of the accumulated results is presented below in Figure 2.

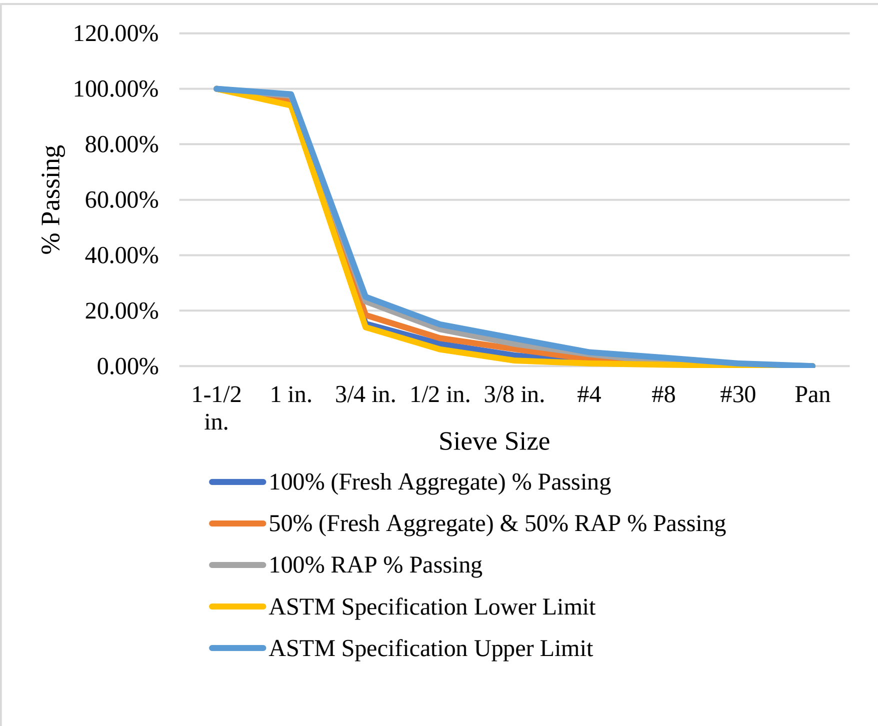

Fig. 2: Sieve analysis on sample combinations

It is quite evident from the above results that retained material is more significant in RAP case featuring the existence of already available granular material in the sample ensuring its specific use in base layers of flexible pavement.

6.2 Standard Experimentations on Base Materials (Flexible Pavement)

According to the standard test results exhibited below in Table 1, maximum limits are achieved for 100% RAP material in abrasion, crushing, impact, specific gravity and soundness however minimum percentage of water absorption is observed in similar scenario as RAP is based on different sizes of aggregates pre-loaded in deteriorated civil structures.

Table 1: Laboratory results of base materials (flexible pavement)

Sample Combination	Los Angeles Abrasion Test (ASTM C 131) Abrasion Value (W1 – W2) / W1 X 100	Crushing Value ASTM D 5821	Impact Value Test ASTM D5874-16	Specific Gravity	Water Absorption Test ASTM C127-12	Soundness of Aggregates by Use of Sodium Sulphate (Na_2 So_4) ASTM C88
100% (Fresh Aggregate)	12.58%	21.06%	8.23%	2.620	0.20%	5.86%
50% (Fresh Aggregate) & 50% RAP	17.38%	29.44%	12.55%	2.904	0.16%	11.86%
0% (Fresh Aggregate) & 100% RAP	21.88%	30.33%	18.28%	3.385	0.09%	20.52%

The above results are graphically illustrated below in Figure 3 in accordance with the permissible limits.

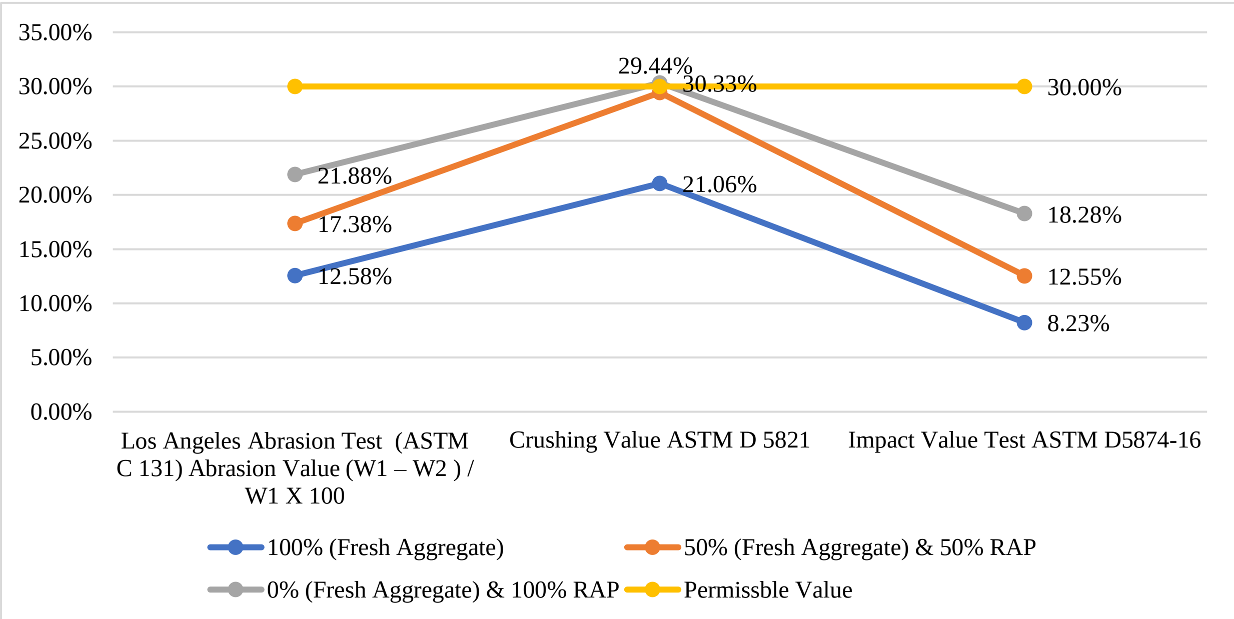

Fig. 3: Standard experimentations for flexible pavement

On the contrary, increasing trends are monitored against three sample combinations for specific gravity. This is actually due to the gradual reduction of fresh aggregates in the samples. Similarly, reverse situation is idealized in the case of water absorption. RAP material has got less sorptivity as the aggregates in the sample are already experienced with the entrapped water when previously used. Both tests are graphically represented below in Figure 4.

7. Job Mix Formula and Marshall Testing

After successful interpretation of suitable sample combination on the basis of base results, 100% RAP material sample is to be addressed for job mix formula and its adequate quantification of weight for Marshall testing. This step is important in order to achieve blend grading for 100% RAP. Achieved blend grading and sample weight quantifications are tabulated in Table 2 and Table 3 respectively. It is to be noted here that the findings are revealed in accordance with the preferred choice of recycling and developed within the prescribed practices of asphalt institute manual series (Asphalt Mix Design Methods; Manual Series No. 2; MS-2) [19].

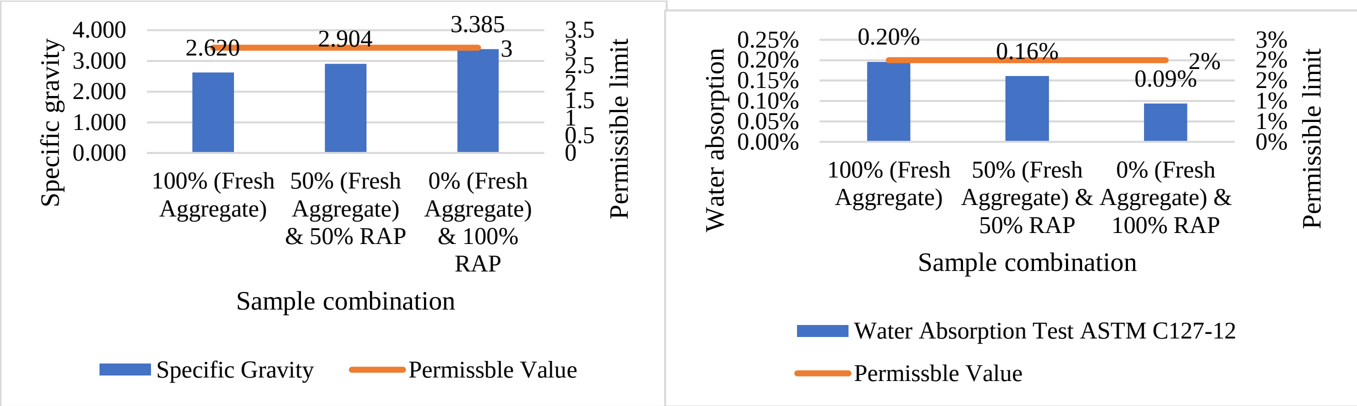

Fig. 4: Specific gravity and water absorption test results with permissible limits

Table 2: Job mix formula (JMF)

Sieve Size	100% RAP Achieved Blend Grading
1-1/2 in.	100
1 in.	100
3/4 in.	95.754
1/2 in.	71.17
3/8 in.	54.66
#4	31.524
#8	13.804
#30	8.377
Pan	1.114

Table 3: Weight quantification (Marshall test)

Description	100% RAP				
Quantity of Sample	3	3	3	3	3
Wt. of Sample (gm)	1200	1200	1200	1200	1200
Bitumen Content %	3.50%	4.00%	4.50%	5.00%	5.50%
Wt. of Bitumen (gm)	42	48	54	60	66
Total Material %	96.50%	96.00%	95.50%	95.00%	94.50%
Wt. of Total Aggregate (gm)	1158	1152	1146	1140	1134
Wt. of 19mm Aggregate (gm)	115.8	115.2	114.6	114	113.4
Wt. of 12.5mm Aggregate (gm)	405.3	403.2	401.1	399	396.9
Wt. of 9.5mm Aggregate (gm)	405.3	403.2	401.1	399	396.9
Wt. of (0-05) mm (gm)	231.6	230.4	229.2	228	226.8
Total Weight in gm	1200	1200	1200	1200	1200

8. Optimum Bitumen Content and Stability Measures

In addition to the standard tests, measures are also accounted for OBC, stability and flow for particular three combinations of aggregates. Again in this case, minimum percentage i.e. 3.85% is noted for 100% RAP material which is due to the existence of coated bitumen amongst the entire sample. The specific results are tabulated in Table 4 as under.

Table 4: Stability & flow results of conventional moulds

Sample Combination	Optimum Bitumen Content	Stability (kgf)	Flow (mm)
100% (Fresh Aggregate)	4.52%	1426	12
50% (Fresh Aggregate) & 50% RAP	4.20%	1382	11.16
100% RAP	3.85%	1303	11.26

9. Cost Considerations for 1km Road Section

In continuation to the recommended sample combination of 100% RAP with 0% fresh aggregates, the density of aggregates and compacted volume are set out as 2550kg/m^3 and 1050m^3 respectively. Focusing a 250m^3 dumper cost (market price), the overall material used and its estimated expenditure are exhibited below in Table 5.

Table 5: Material and cost analysis

Aggregate Compacted Volume (cum)	1050
Material 250m^3 dumper	4.2
Cost of 250m^3 dumper (aggregate) PKR	16,000/-
Total cost of material (aggregate) PKR	67,200/-

Here it is quite obvious from the above table that total cost incurred for aggregate material in terms of dumper is about 67,200 PKR for 4.2 dumpers approx. Hence, this amount could be easily saved if 100% RAP option is availed for only 1km road section. Besides that, further cost analysis may be carried out for multiple kilometres in normal road construction.

10. Conclusion and Recommendations

The entire research is useful in formulating the key challenges faced by the concerned stakeholders in terms of sustainable development and in lines with the decent way of construction or its further economic growth. Nevertheless, it also imparts on the area of climate action as the interest is also based on the effective use of RAP material in flexible pavements. The summary of the research may be accommodated in the light of following points:

- It should be the part of guidelines for any development works to propose environment friendly structures using recycled materials.
- Suitable combinations of RAP and fresh aggregates are required to check and process with the basic parametric tests followed by ASTM and AASHTO guidelines.
- Source of material is of great concern in this situation. It is essential to identify the accurate source of material for aggregates as the properties varies accordingly with the sources.
- Similarly, for the complete proposed working, bitumen grade 80/100 is opted to work simultaneously in the research.
- Considerations for JMF must be in accordance with the suitability of material and Marshall procedures keeping in view of achieved blend grading.
- 100% RAP material should be used in base layers against flexible pavements instead of providing the blanket of fresh aggregates (As the research is taken into account for 1km road section).
- The research is also providing the cost effective solution with the use of RAP material in flexible pavements because 67,200PKR is saving at all for only 1km road section however the particular cost constraints are preferably limited to the requirement of dumpers at this stage.
- The presented work is restricted to the use of RAP material in base layers of flexible pavements.
- This study is a way forward step for practitioners promoting the use of recycled materials in an effective manner by means of standard experimentations and protocols.

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ID 59: Effects of Waste Engine Oil and Crumb Rubber on Physical Properties of Bitumen

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A B S T R A C T

Bitumen is widely used road infrastructure material exhibiting black color and sticky consistency and is known for its versatile use and thermoplastic nature. In recent years, predicting road life has been an arduous work due to increasing traffic, global warming, and ever-changing stresses on pavements. Meanwhile, a large amount of waste engine oil (WEO) and vehicle tyres from a variety of automobiles is disposed of into the atmosphere as a hazardous waste. Relatedly, heavy metals and the huge capital involved in sustainable treatment of these materials has been challenging. Therefore, this study aims to analyze modified bitumen using (WEO) in combination with waste crumb tyre rubber (CTR) thus reducing bitumen use and making bitumen a sustainable material. During the characterization of modified bitumen, the following WEO concentrations were utilized: 3%, 5%, 7%, and 9%, as well as the following CTR concentrations: 5%, 7%, 9%, 12%, and 15%. The properties of modified and virgin bitumen were compared. It has been found that the blend of 5% CTR and 9% WEO exhibit the highest penetration value, and the lowest softening temperature of all the samples examined. As a result, this mixture can be used to reduce the excessive brittleness of bitumen to a greater extent. Moreover, after modification, the flash and fire point values have increased while the ductility and specific gravity values have decreased. In summary, the modified bitumen has shown promising results in terms of physical changes in bitumen.

K E Y W O R D S:

Modified Bitumen, Crumb Tire Rubber, Waste Engine Oil, Physical Properties, Sustainability.

1. Introduction

The economy of a country moves on the wheel; rather the wheel be industry or vehicle. Relatedly, the economic development of a region can be symbolized in the growth of the number of vehicles [1]. Since the 1900s, worldwide roads and highways have been rapidly expanding [2], the traffic pressure on roads has also increased. As a result, significant rise in tyre manufacturing has been observed. The growing number of automobiles on existing road infrastructures has led to discomfort and breakdowns, as well as in exacerbating pollution emissions and landfills [3]. Besides, waste oil is generated in a range of industries, including manufacturing, automotive, aviation, and marine sectors. Due to the growing number of vehicles on the road, the amount of waste engine oil that is disposed of has also increased. Further, the presence of metals and other pollutants in waste oil has an adverse effect on the environment and human health [4]. Pavement industry has been known for recycling waste materials into asphalt concrete and bitumen. Consequently, this research aims to utilize WEO and CTR to develop modified bitumen and to examine their impact on the physical properties of modified bitumen.

Bitumen is one of the earliest engineering materials [5]. It has been used as an adhesive, sealer, preservative, waterproofing agent, and pavement binder for thousands of years [6]. Bitumen's chemical composition, particularly the molecular structure, affects its physical, rheological, ageing, and adhesion-related characteristics [7]. Therefore, excellent bitumen qualities may be produced by choosing good crude oil or appropriate refining procedures. However, the absence of effective control measures during the refinery and limited oil resources for manufacturing high-quality bitumen, together with the need to maximize economic advantages, has led industries to pay greater attention to bitumen modification [8]. As a result, bitumen modification has gained popularity in the research world. It is true that commercially available modifiers, such as fillers, extenders, polymers, fibers, antioxidants, etc., are often added to bitumen in order to improve its performance; however, with their use, the cost-benefit ratio of these mixtures' declines [9]. To address this concern, this research incorporates WEO and CTR for bitumen modification considering their adverse impact on the environment, as well as the financial costs associated with their recycling.

2. Literature Survey

Bitumen modification has existed for a long time. People began changing natural bitumen before refined bitumen could be produced, and a few patents for natural rubber modification have already been granted [5]. There have been numerous studies on the rheology, mechanical properties, thermal behavior, morphology, storage stability, aging, and temperature sensitivity of a wide range of PMBs over the past few decades [10]. By polymerizing bitumen, enhanced properties can be achieved, such as improved stiffness at high temperatures, increased resistance to cracking at relatively low temperatures, improved resistance to moisture, and improved fatigue life [11]. The advantages and disadvantages of PMBs have both been investigated, and it has been found that polymer modification improves a number of bitumen properties, including improved high-temperature rutting resistance and lower low-temperature cracking resistance [12]. With the addition of plastic wastes to bitumen, the stability and longevity of the basic asphalt mixes has been found to improve, which then lowers the penetration values and increases the softening point temperature due to improvements in permanent deformation and fatigue resistance [13]. However, several drawbacks have been also identified, including thermal instability and phase separation issues in some PMBs [14].

Similar to this, adding crumb rubber affects properties of bitumen, including viscosity, penetration, and softening point, proportionate to the amount of rubber incorporated for modification [14]. Bitumen characteristics such as modulus of resilience, rutting resistance, and fatigue cracking resistance are all enhanced when rubber crumb is added to asphalt mixtures. The way rubber particles expanded after coming into contact with bitumen determines the changes in bitumen. Because of the absorption of bitumen's maltene element by rubber fragments, they can grow up to three to five times the size they were originally at the time of absorption [15]. Relatedly, the viscosity of the binder increases as the asphaltene content increases. Further, mixing factors such as temperature, time, and type, as well as bitumen type, particle size, the crumb tyre rubber quantity, and crumb tyre rubber type, all have a significant impact on the properties of crumb rubber modified bitumen (CRMB). Especially, crumb tyre rubber particle size is important in determining CRMB performance because the finer particle size results in the bitumen having higher softening temperatures, viscosity, and elasticity due to a larger surface area [16]. Bitumen dissolves into smaller, less thermodynamically stable particles (or become partially dissolved). Similarly, the finer grade has a reduced elastic response due to the stability of the particles in the swollen state, which further reduces the elasticity (elastic recovery) of the final CR mix [17]. Therefore, this study uses CTR with a coarser gradation (CR-30 mesh). On the other hand, for developing a modified bitumen that is resistant to rubber segregation and settling, coarse particles and high rubber content would require the increased temperatures of mixing [18]. During mixing, rubber depolymerizes and distributes throughout the mixture at excessively high temperatures and for an extended period [19]. Further, rubber depolymerization has been found to be influenced by the curing time, mixing rate, mesh size, and temperature [20]. In addition to these numerous variables, the bitumen properties used to produce crumb modified bitumen (CRMB) have a significant impact on the final product's quality [21]. Moreover, bituminous binders also degrade with age, altering their viscosity, softening point, loss modulus, and storage modulus [22].

The industry for auto engine oil (EO) is renowned for its high levels of production. Every year, 24×10^6 tonnes of WEO are dumped [23]. Due to the frequent use of motors, EO is frequently contaminated with debris made of metal, and its usable life changes with time and usage intensity [24]. Waste engine oil (WEO) contains elements that are hazardous to the environment and human health [25]; therefore, it is required to be drained and replenished frequently. Despite the environmental issues it causes, WEO can still be valued through refinement, cogeneration, and combustion [26]. Most of these methods are pricy, resource-intensive, and they also leave behind residues that are unpleasant for the environment. Therefore, research into the presence of WEO in bitumen has remained appealing [27]. As asphaltenes, which are heavy-weight fractions, give bitumen its viscoelastic properties at room temperature (10-40°C), whereas oils, which are light-weight fractions, act as a carrier for asphaltenes and resins, oils are frequently used for bitumen modification [28]. Additionally, WEO is used to improve the performance of damaged asphalt [29]. Furthermore, various studies have demonstrated that adding WEO to ageing asphalt pavements increases both the viscosity and softening point of the bitumen [30]. Moreover, the bitumen with a higher proportion of aromatic compounds has a higher viscosity and is more temperature sensitive [31]. Further, WEO has the potential to act as a regenerant, as evidenced by the effectiveness of recycled asphalt components that contained it [32]. However, the addition of WEO would lessen some of the other performance characteristics of the road surface. The balance of the internal network and the bond between asphalt molecules would also be negatively impacted by WEO as an additional material, significantly reducing the asphalt's macroscopic and micro-mechanical properties [33].

In addition, crumb rubber improves the quality and durability of asphalt mixtures. It has been found that crumb rubber modified asphalt requires lesser bitumen [34]. This results in the conservation of resources and paves the way for long-term growth and economic gains and helping in making the pavement industry sustainable. Low asphalt content, on the other hand, increases the amount of air in the mixture, thereby enhancing permeability while diminishing durability. Apart from the crude refinery, bitumen can be produced by using WEO, CTR, and coal tar [35]. When WEO is added in the presence of CTR in the bitumen, the WEO heats and melts the rubber crumb, causing it to depolymerize and disintegrates in order to produce modified bitumen. Although bitumen and rubber are fundamentally distinct, the rubber can be used to modify the properties of the bitumen. Moreover, when polymer-containing waste motor oil products are used to modify bitumen, the same penetration values and softening point temperatures are achieved as with commercially modified binders [36]. Nonetheless, the effects of waste oil on asphalt quality may result in abnormal ageing, which may contribute to the premature cracking of pavement [37]. Since incorporating oils into polymer-modified bitumen is an effective method for enhancing its low-temperature cracking resistance, WEO and CTR has been used to modify the bitumen in this study.

3. Research Methodology

3.1 Study Materials

In this study, 80/100 grade bitumen has been selected. In addition, waste engine oil is used without any pre-treatment. Furthermore, crumb tire rubber of size #30 mesh has been used in this study.

3.2 Mixing and Proportioning of Materials

In this study, 24 samples of bitumen have been proportioned by replacing waste engine oil and crumb tyre rubber in bitumen. The partial replacement has been mixed with the base bitumen (grade 80/100) using the shear mixer for 20 minutes at the base bitumen's production temperature (150°C). The composition of the WEO utilized in this phase ranged from 3% to 9%. Further, the WEO binder was subsequently replaced with crumb rubber in the shear mixer at 160°C-180°C for 45 minutes. The crumb tyre rubber concentrations varied from 5% to 15% throughout the mixing process.

3.3 Physical Tests

3.3.1 Penetration Test (AASHTO Designation: 49-74)

This test has been performed to assess the hardness of WEO-CTR-MB. The penetration value has been found by determining the vertical penetration depth of a standard needle in tenths of a millimetre under the required load, duration, and temperature conditions.

3.3.2 Softening Point Test (AASHTO Designation: T 53-4)

Bitumen's softening point is the temperature at which it softens to a predetermined degree under specified test conditions. This test is classified as a consistency test because it identifies the temperature at which a bituminous material attains a particular consistency. It is used in asphalt standards for crack filling, roofing point sealing, and other applications in which thick films are used to prevent materials from flowing during service.

3.3.3 Flash and Fire Point Test (AASHTO Designation: T 73-74 & D 93-72)

At higher temperatures, bitumen may leak volatiles. These combustible materials (volatiles) set fire to themselves. This is a very dangerous scenario; therefore, mixing and operating temperatures must be kept well below the safe limits. The test was conducted to determine the temperature threshold below which fire hazards must be avoided when applying the WEO-CTR-MB.

3.3.4 Ductility Test (AASHTO Designation: T 5-74)

When strain is applied to a material, it might stretch before breaking. Relatedly, all bitumen modification must fulfil ductility standards such that they deform instead of cracking. Furthermore, the binders from the ductile thin film around the aggregate are crucial when bituminous binders are used in flexible pavement construction. The ductility of WEO-CTR-MB has been measured in centimetres and is defined as the farthest a thread can be extended before breaking at a temperature of 25 + 0.5°C, and a rate of 1 cm per minute.

3.3.5 Specific Gravity Test

In order to determine the specific gravity of a substance, the weight of a certain volume of the material is divided by the weight of an equivalent volume of water at room temperature. This results in the substance's specific gravity. The unit weight of WEO-CTR-MB can be computed with the help of this test.

4. Results and Discussion

4.1 Penetration Test (AASHTO Designation: 49-74)

Penetration test determines the grade of bitumen. Figure 1 shows an illustration of penetration values for virgin and modified bitumen. It is evident that for virgin bitumen, penetration value (0.1 mm) is 82 while for 3% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding penetration values (0.1 mm) are 98.5, 94, 91.5, 89, 87, and 83.5 respectively. From the results, it can be interpreted that with increasing CTR content in the bitumen, its grade value decreases. It's since the addition of CTR makes bitumen harder to penetrate when compared to the virgin bitumen. Additionally, the penetration values (0.1 mm) for 5% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR are 116, 112, 109, 106.5, 102.5, and 101 respectively. Further, the penetration values (0.1 mm) for 7% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR \are 132, 127, 119, 117.5, 116.5, and 115 respectively. Similarly, the penetration values (0.1 mm) for 9% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR are 146, 141, 135, 132, 131.5, and 126 respectively. However, it is observed that at each concentration of CTR, with the increase of WEO content, the penetration values for the modified bitumen increase. This is because bitumen gets softer with the increase of WEO concentration in the mix. As a result, the deformation resistance and fatigue resistance of the asphalt mixture will increase, thereby enhancing the mixture's stability and durability [38]. Moreover, a higher aromatic content in bitumen can contribute to its higher viscosity and increased sensitivity to temperature compared to bitumen with a lower aromatic content. Aromatic oils can serve as lubricants for asphaltenes, resulting in bitumen with increased viscosity and temperature sensitivity [31].

4.2 Softening Point Test (AASHTO Designation: T 53-4)

Additionally, softening point determines the temperature at which bitumen gets soft and is a key indicator for operating temperature of HMA. Figure 2 depicts the softening point trend for WEO-CTR-MB, illustrating the temperatures at which the mixture will soften under various conditions. The results indicate that for virgin bitumen, the softening temperature is 46.5°C while for 3% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding temperatures for softening point are 49.5°C, 50.5°C, 51°C, 53°C, 55.5°C, and 56.5°C respectively. Additionally, for 5% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding temperatures for softening point are 48.5°C, 49.5°C, 51°C, 52.5°C, 54°C, and 55.5°C respectively. Further, when the WEO content was increased to 7% and 5%, 7%, 9%, 11%, 13%, & 15% CTR the corresponding temperatures for softening point for modified bitumen were observed as 46°C, 48.5°C, 49°C, 51.5°C, 52°C, and 54°C respectively. Finally, for 9% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding temperatures for softening point are 36°C, 37°C, 37.5°C, 38°C, 39°C, and

39.5°C respectively. From the laboratory results of softening point for modified bitumen, it can be established that when the proportion of waste engine oil in modified bitumen increases, the temperature at which the bitumen softens decreases. Meanwhile, it is evident from the results that as the amount of crumb rubber tyre in bitumen increases, softening point temperatures also increase. In conclusion, for a lower concentration of WEO and higher concentration of CTR, the bitumen is comparatively stiff; therefore, has higher softening point.

4.3 Flash and Fire Point Test (AASHTO Designation: T 73-74 & D 93-72)

In addition, there is a risk associated with a lower flash and fire point temperatures when working with bitumen. As a result, it is imperative to set the safe temperature limit as high as possible to reduce the likelihood of such risk occurring. The laboratory results indicate that for virgin bitumen, the flash and fire temperature are 282°C & 294°C while for 3% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, corresponding temperatures for flash and fire points are 310°C & 326°C, 312°C & 331°C, 315°C & 337°C, 316°C & 344°C, 318°C & 350°C, and 324°C & 353°C respectively. Additionally, for 5% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding temperatures for flash and fire points are 293°C & 316°C, 296°C & 323°C, 301°C & 331°C, 303°C & 336°C, 307°C & 344°C, and 314°C & 355°C respectively. Further, when the WEO content was increased to 7% and 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding values for flash and fire points for modified bitumen were observed as 281°C & 303°C, 285°C & 311°C, 287°C & 316°C, 288°C & 320°C, 291°C & 326°C, and 301°C & 340°C respectively. Lastly, for 9% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding values for flash and fire points are 272°C & 286°C, 277°C & 294°C, 279°C & 299°C, 282°C & 307°C, 285°C & 314°C, and 302°C & 329°C respectively. Further, WEO-CTR-MB has resulted in a significant improvement in the flash and fire point values as can be seen in Figures 3 and 4. Since the results for the flash and fire tests are within the safe limits, it can be concluded that the WEO-CTR-MB is a risk-free product for operation.

4.4 Ductility Test (AASHTO Designation: T 5-74)

Meanwhile, for the modified bitumen, the lab results suggest the ductility value has been negatively impacted by the addition of crumb tyre rubber and waste engine oil in virgin bitumen. The figure 5 exhibits an illustration of ductility values for virgin and modified bitumen. It is evident that for virgin bitumen ductility value (cm) is 102.7 while for 3% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding ductility values (cm) are 41.5, 40.8, 39.2, 39, 37.6, and 36 respectively. Additionally, for 5% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding values for ductility are 35.4, 34.7, 33.2, 30.1, 31, and 30 respectively. Further, when the WEO content was increased to 7% and 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding values for ductility (cm) for modified bitumen were observed as 28.9, 27.8, 26.9, 25.7, 24.6, and 24 respectively. Finally, for 9% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding values for ductility (cm) are 23.5, 21.4, 20.7, 19.3, 19, and 20.1 respectively. In figure 5, it is demonstrated that the ductility values drop when there is an increase in the proportion of WEO and CTR replacement. The lack of ductility, on the other hand, is not necessarily an indication of poor quality of bitumen [39].

4.5 Specific Gravity Test

Specific gravity of bitumen has been observed to decrease when it was mixed with waste materials (WEO and CTR). The figure 6 highlights an illustration of specific gravity values for virgin and modified bitumen. It is evident from the table 1 that for virgin bitumen the specific gravity is 1.016 while for 3% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR, the corresponding values for specific gravity are 0.996, 0.987, 0.984, 0.982, 0.977, and 0.973 respectively. Additionally, for 5% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR the corresponding values for specific gravity are 0.997, 0.989, 0.986, 0.981, 0.974, and 0.971 respectively. Further, when the WEO content was increased to 7% and 5%, 7%, 9%, 11%, 13%, & 15% CTR the corresponding values of specific gravity for modified bitumen were observed as 0.994, 0.983, 0.98, 0.978, 0.973, and 0.972 respectively. Finally, for 9% WEO & 5%, 7%, 9%, 11%, 13%, & 15% CTR the corresponding values of specific gravity are 0.992, 0.984, 0.981, 0.978, 0.973, and

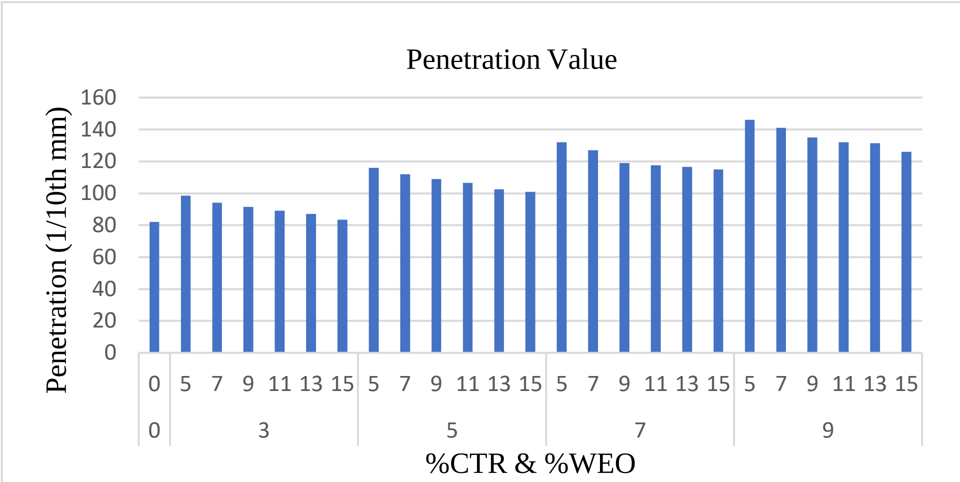
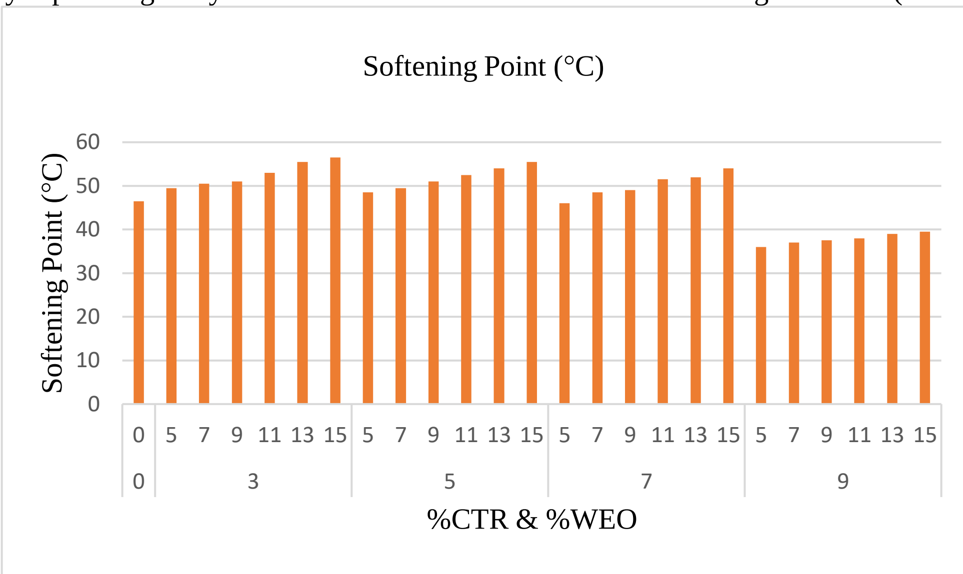


Fig. 1: Penetration

0.967 respectively. Specific gravity of bitumen has decreased because the mixing materials (WEO and CTR) has a



lower density compared to the virgin bitumen.

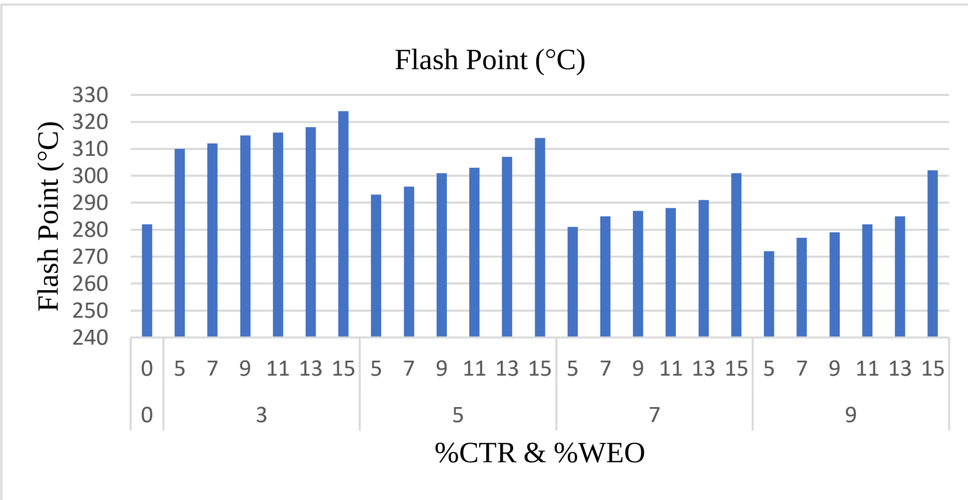


Fig. 3: Flash Point

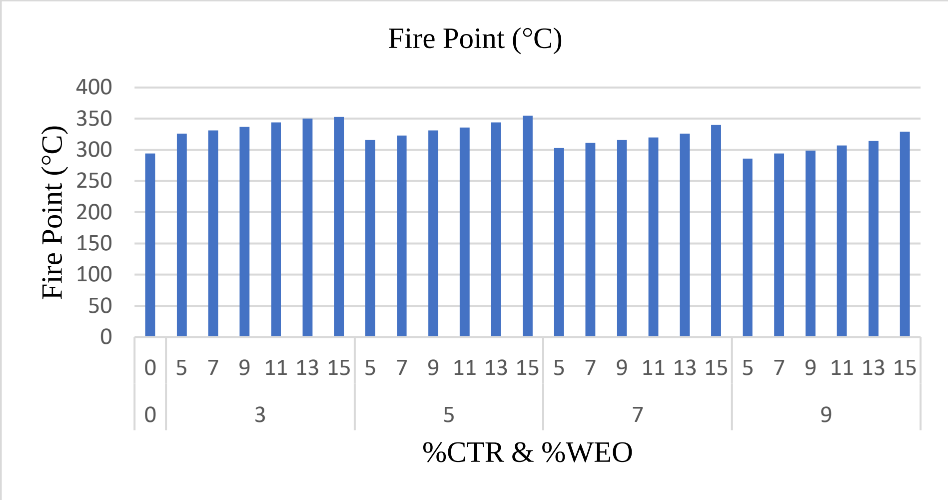


Fig. 4: Fire Point (°C)

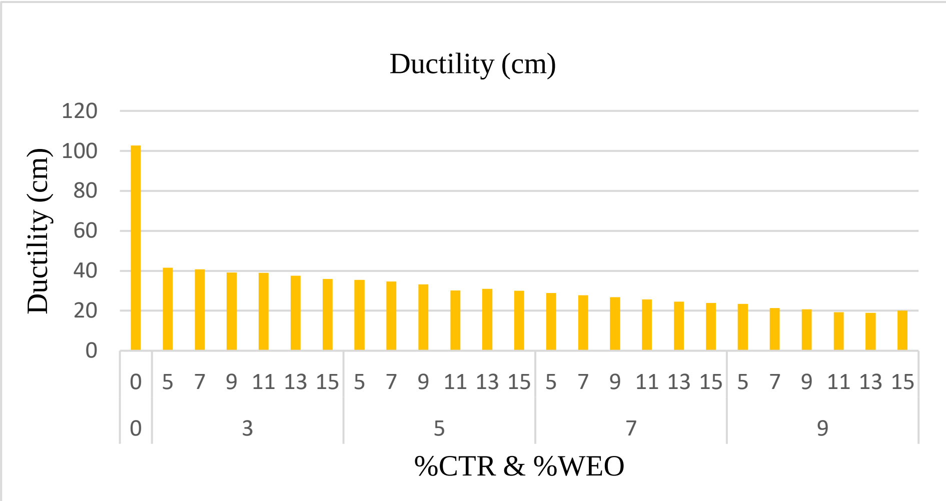


Fig. 5: Ductility

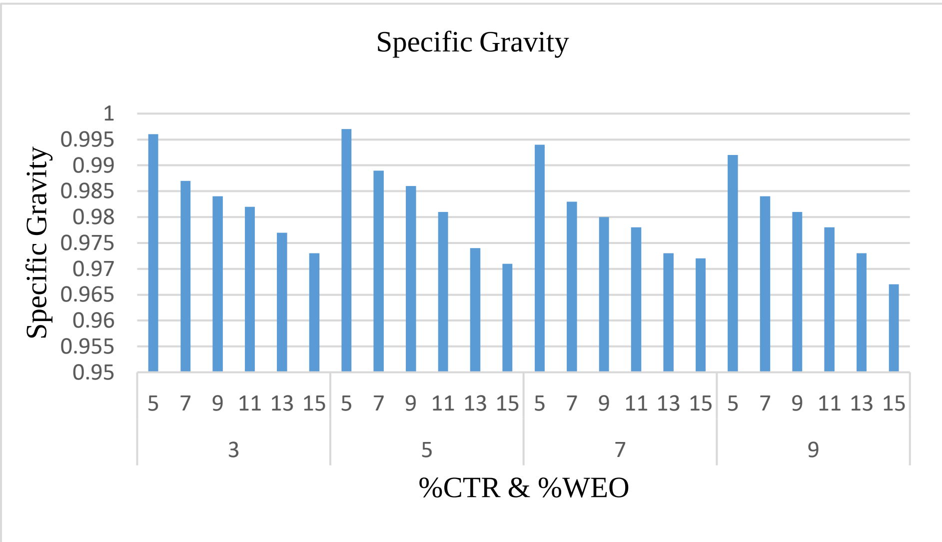


Fig. 6: Specific gravity

5. Conclusion

During this study, 3%, 5%, 7%, and 9% of WEO has each been correspondingly mixed with 5%, 7%, 9%,11%, 13%, and 15% of CTR to study the physical characteristic of virgin and modified bitumen. For this, the virgin and modified bitumen has been tested for penetration, softening point, flash and fire point, ductility, and specific gravity in the laboratory. After interpreting the penetration results, it can be concluded that with the increase of CTR concentration in the bitumen, the modified bitumen hardens; therefore, penetration value decrease. Moreover, the blend consisting of 5% CTR and 9% WEO has the highest penetration value of all the samples examined in this study. Therefore, this mixture can be used to reduce the excessive brittleness of bitumen to the greatest extent possible as it is more penetrated than virgin bitumen. Additionally, the softening point value has been observed to increase on the addition of CTR in the bitumen. Further, the mix prepared with 5% CTR and 9% WEO has the least softening temperature. While the highest softening temperature has been observed in 3% WEO and 15% CTR blend. Additionally, with the increase of WEO and CTR concentrations, the ductility value has been observed to decrease significantly. The blend having the highest value of ductility (41.5 cm) is 3% WEO and 5% CTR. Moreover, the flash and fire point value for all the mixes have also improved and all are within safe limits of operating with HMA, thereby ensuring the safe operation of WEO-CTR-CR modified bitumen. Lastly, it has also been observed that the specific gravity value for all the sample has decreased. In conclusion, the various mixes exhibit distinct behavior such as the 5% CTR and 9% WEO blend. This blend has the highest penetration value, and the least softening temperature of all the samples examined in this study. Since this blend has a lower softening point, it suggests that it may be used to reduce rutting, which further supports the economic benefits of the modified bitumen leading to the development of sustainable pavements. Similarly, various other sample could be used in the varying environment as the grade of bitumen has been varying throughout the study. On the final note, this modification, along with modifying bitumen, addresses the concerns of costly recycling of hazardous wastes (WEO and CTR), as a result addressing the economical and environmental aspects, which again is one more step towards sustainable development in pavement industry.

6. Recommendations

WEO-CTR-MB can be further tested in detail by investigating the rheological characteristics of bitumen, such as phase angle, shear modulus, and FTIR spectral analysis. Furthermore, it is recommended to examine the hot asphalt mixes and long-term performance of the WEO-CTR-MB asphalt pavements.

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ID 61: Empirical Analysis of Level of Service Based on Users Perception at Hyderabad Toll Plaza

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A B S T R A C T

Sustainable development requires a well-developed public transportation system. The relationship between efficient transportation systems and urban sustainability has been demonstrated in a variety of studies. Level of service is one of those important parameters that measures the operational performance of a transport system and ensures the smooth and safe movement of peoples and goods with minimum delay and discomfort. At the toll plazas, the traffic congestion occurs due to multiple factors which results in slower operating speed, prolonged travel time and delay, thereby affecting the fuel consumption on road, as a consequence, leading the environment to further deterioration. Therefore, this research seeks to establish the level of service perceived by the users at Hyderabad toll plaza, located on M9, Pakistan, and to identify the factors for the improvement of level of service for smooth and sustainable traffic movement. For that, a questionnaire is designed and a total of 150 responses are collected. Specifically, the data is collected only from the car vehicle users. By carrying out the Importance-Satisfaction (IS) Analysis, Delay and Percentage of trucks and buses were found out to be the most important variables rated by the users. Furthermore, the ordered probit model results were developed and validated and It was found that there are a number of factors that govern the perceived level of service at the toll plaza.

K E Y W O R D S:

Users Perception, Level of Service, Hyderabad Toll Plaza, Ordered Probit Model

1. Introduction

The transportation infrastructure of any country serves as the cornerstone of its economic prosperity. Most industrial sectors, regardless of the subject matter, consider the effectiveness of transportation operations vital for their growth. This is evident as the United States of America as well as several European countries have an advanced transportation framework which is a key indicator, among several others, of their economic potential. However, developing countries like Pakistan, India, and China, among others, continue to struggle to build an effective transportation infrastructure due to their ongoing population growth. In order to improve traffic infrastructure, the level of service at the road section is determined to assess how well the road will meet traffic demand [11]. Besides, in recent years, the levels of service and performance quality of roads have decreased due to the rise in the number of vehicles [12]. Traffic engineering is concerned with the improvement of the performance of road traffic, which a key aspect of the topic is presented [13-15]. Consequently, to improve traffic conditions, it is indispensable to improve service levels. An important aspect of the LOS is the quality of the transportation facilities, which is a measure of how well they have been designed.

Since rapid economic development of emerging countries has been accompanied by advancements in social development and economic growth, traffic on the road network has grown. The Pakistani government has therefore established an ambitious road development portfolio, as such, while the fiscal budget allocations alone would be able to satisfy nearly half of the established target demands, the remaining funds would need to be obtained through off-budget financing through public-private partnerships (PPP) [1]. When private organizations collaborate with the government to build infrastructure, both the public and private sectors profit [2]. Private partners oversee the construction of the necessary facilities and are the primary shareholders in these PPP projects. Users of the road must pay a toll for a reasonable amount of time in order to recoup the costs incurred by the private entities. As part of the built facility's toll collection system, the PPP plans call for toll plazas to be set up at each of the facility's entry points to keep track of the vehicles that use it. As part of this, all road users who pass through the toll areas plan to pay their toll fees as soon as possible to minimize their waiting time in line. If not regulated at a higher level of service, this leads to frequent mixed traffic at tollbooths, the situation gets even worse during peak hours. In this case, the poor management needs to be fixed as it hurts the capacity of the tollbooth and makes customers wait longer [3]. Additionally, this leads to increase in stress among users, surge in fuel consumption, and intensification in harmful emissions [11]. Furthermore, significant actions are required to mitigate the adverse environmental impact of transportation, in particular the emission of hazardous substances and noises into the atmosphere, in order to reduce their negative effects on the environment. Otherwise, this will be accounted for in external costs [16-20], limiting sustainable economic growth. Further, along with health constraints, this limits the sustainability of transportation systems. Since sustainability requires a transport system that is reliable, efficient, safe, and has a minimal impact on the environment [16]. Therefore, this study is one step towards the LOS determination at the Hyderabad M-9 toll plaza, which will serve as a premise for sustainable traffic mobilization at the toll section.

Further, while passing through the toll plaza, the drivers anticipate a higher level of service, such as a shorter wait time, better aesthetics, a better infrastructure facility, the attitude of the tollbooth attendant, etc. Moreover, the letters “A” through “F” stand for the facility’s operational states, with “A” denoting unrestricted flow and “F” representing the worst-case scenario. The aforementioned components are further divided into operational characteristics that directly relate to how practical and at ease a user feels when navigating various traffic situations. In contrast, the Highway Capacity Manual provides no information regarding the methodology to be used in evaluating LOS at toll plazas. Even though this is frequently the case, many studies in the literature [5-9] emphasize LOS and capacity at toll plazas by taking into account various measures of effectiveness (MOEs). This study includes the importance-satisfaction (IS) assessment, which is conducted in the early stages to learn more about customer perspectives on the factors that affect the LOS at the Hyderabad M-9 toll plaza. By employing this methodology, it is possible to assess the relevance of all identified criteria as well as the level of satisfaction of consumers [3]. Furthermore, it assists with identifying those components that are inefficient and contribute to customer dissatisfaction. This study has used a probit model technique to analyze how users perceive the level of service at the toll section. Various reasons can be attributed to the use of ordered probit models. Their primary purpose is to determine the relationship between a group of independent factors and a dependent variable. Therefore, this study has employed an ordered-probit model approach to study variables that control how users perceive LOS at Hyderabad’s M-9 toll plaza.

2. Literature Review

There exist several studies in the literature regarding the determination of the level of service at the toll plaza by analysing a variety of factors, among all the qualitative, empirical, and simulation-based research approaches are the most commonly adopted. Although the Highway Capacity Manual does not specify a method for assessing the perceived level of service at toll plazas. After careful survey of the literature, it has been found that many studies in the literature [15-19] emphasize LOS and capacity at toll plazas by taking into account various measures of effectiveness (MOEs). Further, it has been found that a variety of factors influence the quality of service at the toll plaza. Traffic congestion is always found to be adverse for the road operation. On the other side, traffic congestion increases during peak hours [20], which has a direct impact on the volume capacity ratio of the toll plaza. As a result, a lower level of service is achieved, denoted as Level of service F [20].

With this increase in congestion, there are high chances of the delay. Relatedly, the delay can be caused by a mix of different types of traffic at the toll plaza, which affects both the amount of time customers must wait in line and the length of service [6]. To quantify the effect of delay on the efficiency of the toll plaza [7] to be prepared for delays there exist models for achievement of both goals [21]. Not only that, but the composition of the traffic, vehicle characteristics, toll rates, and the behaviour of the individuals working the toll booths has been found to have a significant effect on the variation in service time and quality of service [22].

Level of service varies with change in time. One study [23] investigated the level of service and found that LOS experienced by users during the week was a D, while it dropped to a F on weekends. Furthermore, the impact of numerous other parameters on the quality of service at the toll plaza was also evaluated and it has been found that the method of payment, the number of toll booths, the type of vehicle, and the behaviour of toll booth operators are among the key variance factors which needs to be considered for LOS investigation [23]. Another study [24] assessed the perceived level of service at a manually managed toll plaza using the Ordered Probit Model technique. This study concluded that, according to the users, the most influential variable was discovered to be toll plaza delay.

Moreover, studies show that the users' perceptions of service quality depend upon a variety of factors [4,5,9]. These factors included the amount of time spent waiting in line, the condition of the infrastructure, the method of payment, and the behaviour of toll booth operators. According to the researchers, the average wait time at the toll plaza as well as the proportion of large vehicles passing through had a significant impact on customer satisfaction [19]. The same could be established for the manually operated tolls, one study [24] investigated worker productivity at manually operated toll booths. Furthermore, they established a method for assessing the efficiency of toll booth employees. The amount of service time, the number of tolls collected, and the types of vehicles were discovered to have the greatest impact on the capacity of the toll plaza.

3. Research Methodology

3.1 Identifying Influencing Variables

The variables influencing the perceived level of service at a toll plaza are filtered out from previous studies and are included in this research to further inspect the effect of these variables on the perceived level of service. The variables included are gender, age, humps, scenery, lanes followed by vehicles, instructional sign about fare value, experience, frequency of trip, purpose of trip, presence of trucks and buses, speed and method of payment, delay and number of toll booths.

3.2 Data Collection

The data collected in this research is ordered and discrete in nature for which the questionnaire survey is designed and is divided into two parts: (1) information regarding driver’s trip and socio-economic factors (2) drivers perception. The questionnaire survey is presented to the users that travel from the toll plaza and they are asked to fill. A total of 150 responses are collected. Out of of 150 responses, 80% (120 responses) are used for ordered probit model estimation results and 20% (30 samples) are used for model validation.

3.3 Data Analysis

The responses collected from the users are cross checked to see if there is any inaccurate or incomplete response before using it for ordered probit model estimation and validation. No missing data and outliers were detected using SPSS 22.0; moreover the summary and descriptive statistics were also generated using the software tool to get a whole idea of data collected, shown in Table 1.

3.4 Ordered Probit Model

The data collected is discrete and ordered in nature, Because of this, the ordered probit model approach is used and is given by the equation (1)

$$y_j * = \beta X_j + \epsilon_j \qquad (1)$$

Where, Xj is the term that for independent variable, β is the vector parameter and ϵj is the error term that follows the normal distribution. 120 responses are utilized for developing the ordered probit model results by firstly converting the level of service (LOS A to LOS F) into ordinal data from 0 to 5 respectively. The model results are developed into using STATA software. The user perceived level of service can be found from the model as shown below:

$$y_j = \begin{cases} 0, if\ y_j^* \leq 0 \\ 1, if\ 0 \leq y_j^* \leq \mu_1 \\ 2, if\ \mu_1 \leq y_j^* \leq \mu_2 \\ 3, if\ \mu_2 \leq y_j^* \leq \mu_3 \\ 4, if\ \mu_3 \leq y_j^* \leq \mu_4 \\ 5, if\ y_j^* \geq \mu_4 \end{cases} \tag{2}$$

3.5 Model Validation

By far the most important step of this research is validation of the model results to check the accuracy of the developed results and to know if the results obtained are accurate enough to be used in future planning, management and design of the toll plaza. The remaining 30 responses are utilized and are compared with the predicted perceived level of service obtained from the ordered probit model results.

4. Results and Discussion

4.1 Summary Statistics of Sample Data

Table 1. Summary Statistics of Survey Sample

Variables	Category	Percentage
Gender	Male	80.00
	Female	20.00
Age	18-30 years	77.33
	31-40 years	14.67
	41-50 years	3.33
	51-60 years	4.67
	60+ years	0.00
Driving Experience	upto 3 years	42.00
	4-6 years	30.67
	7-9 years	11.33
	10-12 years	8.67
	13 years and over	7.33
Purpose of Trip	Work	38.0
	Education	42.67
	Social	8.67
	Shopping	2.67
	Recreational Activities	4.00

	Personal Business	4.00
Frequency of Trip	Daily Occasionally	55.33 44.67
Waiting time in queue (Delay)	less than 60 seconds 60-120 seconds (2 minutes) 120-180 seconds (3 minutes) 180-240 seconds (4 minutes) 240-300 seconds (5 minutes) more than 300 seconds (over 5 minutes)	17.33 34.00 19.33 7.33 9.33 12.67
Number of tollbooths	Sufficient Insufficient	54.00 46.00
Dedicated lane followed by vehicles	Yes No	35.33 64.67
Percentage of Trucks and Buses	Low Medium High	2.00 36.67 61.33
Sign about Fare Value	Poor Moderate Good	34.00 55.33 10.67
Humps	Yes No	77.33 22.67
Speed of Payment Method	low medium high	32.67 54.00 13.33
Aesthetics	Poor Moderate Good	42.00 48.67 9.33
Perceived Level of Service	Level of service A	5.33

	Level of service B	10.00
	Level of service C	11.33
	Level of service D	19.33
	Level of service E	31.33
	Level of service F	22.67

4.2 Importance Satisfaction (IS) Analysis

The Importance Satisfaction (IS) is a one-of-a-kind tool that is used to increase the overall level of customer satisfaction with a given service. This is accomplished by locating, managing, and enhancing the aspects of the service that are regarded as being of the utmost significance by the users. The equation proposed by Iseki and Smart (2012), which is given here as an equation, can be used to make an estimate of the IS Rating (3).

$$\text{IS Rating} = \text{ImportanceRating}(100 - \text{SatisfactionRating}) \quad (3)$$

Table 2. Importance-Satisfaction Rating

Variables	Importance %	Importance Rank	Satisfaction %	Satisfaction Rank	IS Rating %	IS Rank
Delay	36.96	1	14.23	6	31.70	1
Number of tollbooths	24.87	3	13.45	7	21.52	3
Dedicated lane	21.87	5	20.88	2	17.30	5
Percentage of trucks and buses	29.64	2	10.72	8	26.46	2
Sign regarding Fare Value	20.87	6	19.54	3	16.79	6
Payment Method	24.77	4	15.95	5	20.81	4
Humps	18.61	7	17.47	4	15.35	7
Aesthetics	15.46	8	21.32	1	12.16	8

The ranking of the factors can be shown in Table 2, which is based on how important they are, how satisfied we are with them, and our IS Rating. The variable "Delay" is found to have the highest importance rating that means that the users perceive this factor to be the most influencing to them. Similarly, the highest satisfaction rank achieved is of the variable "Aesthetics" which shows that the users are highly satisfied with the aesthetics. The lowest satisfaction rank achieved is of the attribute "Percentage of Trucks and Buses" which indicates that users are highly dissatisfied with the percentage of heavy vehicles present at the toll plaza, this is due to the fact that mostly these vehicles do not follow their specified lane and hence the waiting time and traffic congestion occurs which ultimately affects the users perceived level of service. The IS Rank shows that the variable Delay followed by Percentage of trucks and buses are the most influencing factors that needs to be improved for achieving a better level of service.

4.3 Ordered Probit Model Results

In Table 3, you can see how several factors affected how satisfied customers felt with the quality of service they received at the toll plaza. The fact that the coefficient has a positive sign indicates that as the related factors are increased, the likelihood of customers evaluating the level of service as lower rises. Similarly, the fact that the coefficient has a negative sign indicates that the likelihood of experiencing an improved level of service increases when the corresponding characteristic is improved, either in terms of quantity or quality. According to the study's findings, the "gender" of the customer has no significant impact on the perceived quality of service. The fact that the Age and Delay coefficients have a positive sign indicates that increasing the magnitude of these variables will result in increased annoyance and pain, which will eventually lead to a lower perceived quality of service. The percentage of heavy vehicles, such as trucks and buses, and dedicated lanes have a positive correlation with the perceived level of service. As the proportion of heavy vehicles increases, so does the likelihood that those vehicles will abandon their designated lanes. This, in turn, causes an increase in traffic congestion, resulting in a decrease in perceived service level. The number of toll booths was discovered to be the most important variable, with a coefficient of +0.5025; this means that the users are dissatisfied by the number of tollbooths provided at the toll plaza as they are not sufficient; so if the magnitude of responses will increase, the likelihood of perceiving a lower level of service will also increase..Factors such as experience, purpose of trip, payment method, instructional sign about fare values, and aesthetics have a negative correlation with the perceived level of service, it can be deduced that as the magnitude of these factors increases, individuals have a tendency to perceive a higher level of service. The findings indicate that a variety of factors influence the perceived quality of service provided to customers at toll booths.

Table 3. Developed Ordered Probit Model Results

Variables	Co efficient	t-statistics
Age	0.3288	4.82
Experience	-0.0621	-2.76
Purpose	-0.0309	-4.68
Frequency	0.2193	4.22
Delay	0.2452	6.35
Number of Toll Booths	0.5025	3.56
Dedicated lane	0.4608	1.89
Percentage of Trucks and Buses	0.2839	4.54
Sign about Fare Value	-0.2086	-5.06
Payment Method	-0.0027	-1.46
Humps	0.0440	1.13
Aesthetics	-0.8628	-4.35
log likelihood function	-168.55832	-
Pseudo R-squared	0.2106	-
Number of samples	120	-

4.4 Marginal Effects for the Users Perceived Level of Service

In order to know how the variables individually affect the perception of the six levels of service, marginal effects are calculated for each one of the variables. Furthermore, it explains how the unit change in the independent variables will have an effect on the perceived level of service as a result of the unit change. With the variables being in the negative sign, we are indicating that an increase in the unit number of one of these variables will result in a decrease in the likelihood of perceiving the corresponding level of service and vice versa. Based on the marginal effects of the variable "Percentage of trucks and buses" it can be seen that for every unit increase in the ratio of heavy vehicles to light vehicles there is a decline in the probability of perceiving LOS A, B, C, D and by 0.0125, 0.0432, 0.0378 and 0.0195 units and increases the probability of perceiving LOS E and F by 0.0524 and 0.0607 units, keeping all other factors constant. According to the marginal effects, it can be seen that each unit increase in age, frequency of trip, delay, number of toll booths, dedicated lanes, and significantly decreasing the likelihood of recognising LOS A to D, while increasing the likelihood of perceiving LOS E and LOS F. Similarly, each unit increase in experience, trip purpose, and instructional sign concerning fare value, payment method, and aesthetics increases the likelihood of detecting LOS A to D and decreases the likelihood of perceiving LOS E and LOS F.

Table 4. Marginal Effects

Variable	LOS A	LOS B	LOS C	LOS D	LOS E	LOS F
Gender	0.0019	0.0067	0.0059	0.0030	-0.0081	-0.0094
Age	-0.0145	-0.0500	-0.0438	-0.0226	0.0608	0.0703
Experience	0.0027	0.0094	0.0082	0.0042	-0.1148	-0.0132
Purpose of trip	0.0013	0.0047	0.0041	0.0021	-0.0057	-0.0066
Frequency of trip	-0.0097	-0.0333	-0.0292	-0.0169	0.0453	0.0524
Delay	-0.0108	-0.0373	-0.0327	-0.0169	0.0453	0.0524
Number of toll booths	-0.0222	-0.0764	-0.0670	-0.0346	0.0929	0.1075
Dedicated lane	- 0.0203	-0.0701	-0.0614	-0.0317	0.0852	0.0986
Percentage of Trucks and Buses	-0.0125	-0.0432	-0.0378	-0.0195	0.0524	0.0607
Sign about Fare Value	0.0092	0.0317	0.02783	0.0143	-0.0385	-0.0446
Payment Method	0.0001	0.0004	0.0003	0.0001	-0.0005	-0.0005
Humps	-0.0018	-0.0066	-0.0058	-0.0030	0.0081	0.0094
Aesthetics	0.0381	0.1312	0.1151	0.0594	-0.1594	-0.1845

4.5 Model Validation

The model results were validated by utilizing the 20% sample that was initially kept aside. The results obtained from the model i-e model predicted level of service was compared with that of the observed level of service of 20% responses. The overall prediction-success of the model results developed was found out to be 83.68% accurate which shows that there is good understanding between the users perceived level of service and model predicted level of service.

5. Conclusion

This research was conducted to examine the influence of socioeconomic characteristics and users' perceptions on their perceptions of the level of service. A survey was conducted to determine the socioeconomic factors and users' perceptions. According to the results of the Importance Satisfaction Analysis, the variables Delay, Percentage of Trucks and Buses, and Number of Toll Booths are by far the most important factors according to the ratings of the respondents. Therefore, in order to increase the perceived quality of service at the toll plaza, these factors must be improved relative to the other variables. The results of the developed ordered probit model indicate that the variables age, frequency of trip, delay, number of toll booths, dedicated lanes followed by vehicles, humps, and percentage of trucks and buses have positive coefficients, indicating that an increase in these variables will result in a decrease in the perceived level of service. The findings also show that the potential of customers having a higher level of service improves if we raise the quantity or quality of the characteristics (gender, driving experience, purpose, instruction sign regarding pricing values, method speed, and aesthetics). In conclusion, the findings of the model are correct up to 83.16 percent of the time. This indicates that there is a significant correlation between the level of service experienced by users and the level of service anticipated by the model. To provide an improved impression of the level of service provided by toll plazas, this strategy might be implemented in the future design and building of such facilities so that sustainable and efficient transport could be delivered on the road resulting in better health and healthy planet life.

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ID 111: USPCAS-W Initiative of Bicycle and its Closure

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A B S T R A C T

The ultimate goal of this study was to discover the main reason behind the discontinuation of the USPCAS-W bicycle project at Mehran UET in Jamshoro. To address this research question a structured qualitative interview questionnaire based on the 9 components of the business model canvas was constructed, purposive sampling technique was used to decide the sample size two, as there were only two people associated with USPCAS-W initiative of bicycle, data was gathered through a qualitative research technique, interviews. Thematic analysis was used to analysis the data, results were generated through atlas.ti. The findings of the research indicate the main reason behind discontinuance of USPCAS-W Initiative of bicycle was the lack of funds because of this very reason they couldn't execute the program properly and decided to discontinue it.

K E Y W O R D S:

Sustainability, Transportation, System Failure

1. Introduction

Very recently in Mehran UET, Jamshoro we have seen huge increase in prices of Rikshaw rides, currently students are paying 70 rupees per ride for commuting inside the campus. These Rikshaw rides aren't a cheap and environmentally friendly option. In past Mehran UET, Jamshoro took initiative of bicycles, but after some time they shut down the whole program. Students want the same sort of initiative to be implemented inside the campus again as there isn't any low-priced, non-polluting, and environmentally friendly option available inside the campus. In Pakistan many universities took the same initiative of bicycles, to solve the on-campus day to day commuting problem. The students of NUST, Islamabad came up with similar idea of cycles to solve the commuting problem inside the premises of the university. [9]. Many other universities around the globe like Oxford University, Stanford University, Johns Hopkins University, Colorado State University and University of Pennsylvania adopted the same solution to solve the in-campus mobility problem and to encourage their students to choose this in-expensive, healthy, ecological option of commuting for reducing the pollution created by other vehicles.

2. Literature Review

An ever-increasing body of literature shows that in recent years there have been growing interest in bicycle sharing system all around the world. Countries like China, USA and other European countries are known for their bicycle sharing systems. These countries have taken all the necessary measures for the proper implementation of bicycle sharing to promote ecofriendly environment. Pakistan is one of the countries were the boom of bicycle sharing system is emerging. People are looking at it as a good investment option. Government of KPK inaugurated the first of its kind ZU bicycle sharing system in the province [5]. In Islamabad we have ez-bike which provides its customers a convenient and sustainable way to commute around the city [10]. Universities in Pakistan are huge area wise; many universities are solving the problem of transport inside campus premises through bicycle sharing systems, in Islamabad NUST launched Cykick which provide cycle service to its students to commute inside the campus [8]. In Karachi IoBM took the same initiative to make their campus cycling friendly campus [9]. Many bicycle sharing systems currently running all over the world, in china we have companies like ofo, mobike in USA we have citibike etc. Many of the bike sharing systems shut down their services in specific parts of the world due to several reasons like mismanagement of funds, bicycle dispatching, maintenance cost etc. Mehran UET, Jamshoro once executed same sort of bicycle sharing system inside the campus, the reason behind discontinuing this great initiative is still unknown. A questionnaire survey was conducted regarding this, the questions are mentioned in Table 1.

Table 1: Questionnaire survey template

What was the reason behind discontinuation of USPCAS-W bicycle program inside Mehran, UET Jamshoro?				
Theme	Descriptive Code	Participant A Frequency	Participant B Frequency	Total Frequency
Why The USPCAS-W Bicycle Program Discontinued	○ Freebie Service	2	2	4
	○ Absences of Hi-Technology	2	0	2
	○ No Administration Interest	1	1	2
	○ Unavailability of Cycle Lanes	0	3	3
	○ Unavailability of right number of Cycles	5	1	6
	○ Unavailability of Funds	12	3	15
	○ Unavailability of Stations	4	2	6
	○ Safety & Security of the Program	3	1	4
	○ Inadequacy of the Program	2	1	3
	Totals	32	15	47

3. Research Methodology

3.1 Study area and study design

This research was carried out inside Mehran UET, Jamshoro. In this research qualitative research method was used, a structured questionnaire was designed based on nine components of business model canvas to gathered responses from the participant on the issue of transportation they face inside Mehran UET, Jamshoro.

3.2 Study population and data collection

The participants who were eligible for this study were decided through purposive sampling technique, which refers to deliberate selection of particular individuals, who most likely possess the qualities your sample needs, later two individuals were selected for the interviews who were responsible for the handling of USPCAS-W program of bicycles. Interviews were conducted, later the data was filtered, transcripts were generated the data was analyzed through thematic analysis on atlas.ti. A research technique for assessing qualitative data is thematic analysis, usually it refers to a collection of texts, such an interview or a transcript, to find common themes, concepts, topics, and patterns of meaning. Atlast.ti is a software that helps in facilitating the analysis of qualitative data, it is used for coding & analyzation of transcripts, designing networking diagrams etc.

4. Data Analysis

Table 1 shows a theme, 9 descriptive codes, frequency of each participant and total frequency. Theme shows the main problem, descriptive code addresses the different causes behind the existence of the main problem. The two frequency columns show the number of times each participant used each code during the interview. Total frequency column shows the total of both participant frequencies combined for each descriptive code. The total row shows the total of each participant frequency separately as well as the total of total frequency column. The descriptive code with the highest frequency 15 was the unavailability of funds, due to the stoppage of funds from USAID, USPCAS-W BICYCLE SHARING SYSTEM program was discontinued (see Table 2). As without the funds, it was not possible to properly implement the initiative of bicycles inside the campus.

Table 2: Code explanation

Freebie Service	The service was free to use
Absences of Hi-Technology	There wasn't any usage of electronic locks, docks, RFID system, software.
No Administration Interest	After stoppage of funds from the USAID no one showed any interest in the program
Unavailability of Cycle Lanes	As there weren't any funds, the system was not implemented properly, and no work was done on infrastructure.
Unavailability of right number of Cycles	Due to lack of USAID funds, buying of more cycles wasn't possible.
Unavailability of Funds	Stoppage of funds from USAID.
Unavailability of Stations	Due to lack of USAID funds, building of station around the campus wasn't possible.
Safety & Security of the Program	the system wasn't a secure one as there weren't any management to manage the whole process of providing service of bicycle.
Inadequacy of the Program	The system wasn't a self-sustainable system it was unable to cover it cost and generate any revenue.

5. Results & Discussion

When analyzing the data, we applied thematic analysis technique to generate results, we created a theme and 9 descriptive codes from the words which were frequently used in the transcripts of both the participants. Our results demonstrated, at first university got funds from USAID to execute this program inside campus later the university stop getting fundings from the USAID, the lack of funds from the turn out to be the reason behind the closure of USPCAS-W program of bicycle, due to the lack of funds the whole system wasn't implemented properly as there weren't any funds to run the program.

To promote sustainable living inside the campus, university can reinitiate bicycle program on their own or by partnering with the big giants in market, nowadays customer prefer having sustainable products or services as they desire to play their part in improving the environment. Companies likes to associate themselves with such program to create a good impression in the market. The option of bicycle sharing system is also by far better than the two currently available modes of transportation inside the premises of the university (Buses and Rickshaws). Shifting from these two options to bicycles means moving towards a more organic, energy saving, fuel efficient, less populating environmentally friendly and healthy option.

6. Conclusion

Each problem that we face, it's an opportunity to grow. Implementation of USPCAS-W initiative of bicycles in past, shows the intent of the Mehran UET, Jamshoro towards sustainability. The university is eager to promote sustainable living inside the campus, but the lack of funds turns out to be the reason behind discontinuation of a great initiative. University must think about reinitiating the same program as implementation of bicycle program inside the campus will enable the students to choose an instant and healthier mode of transportation around the campus, without having to invest money on personal bikes. This option allows many people who are like linked with Mehran UET, Jamshoro, particularly the students, to easily access bicycles across the campus for purpose of commuting. The bicycle program is less expensive than renting a Rikshaw ride. Any student may immediately choose the bicycle ride whenever they are in need. Therefore, implementing bicycle program will help in reducing transit costs and saves money. Riding a bike, whether to commute inside any campus or as a major form of transportation, is far healthier than driving a car or motorbike. Cycling aids with muscle strengthening, calorie burning, decreasing stress levels and a variety of other benefits. Cycling is often regarded as the finest physical activity for its multiple health advantages. [11] Adopting this idea mean taking our students towards adopting a healthy way of commuting, which can also put a good impact on their results. People all around the world are becoming increasingly interested in incorporating cycling into their everyday routine as they become more aware of the health advantages of utilizing bicycles as a daily mode of transportation. This factor will increase the usage of bike-sharing systems in cities throughout developed and developing countries in the coming days. Mehran UET, Jamshoro must give the idea of bicycle a go, this can help them generate good revenue, can pleased the students, and help in creating a good impression all around.

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Sustainable Urban Planning and Architecture

ID 44: Bio-Climatic Architecture for Rural Area of Hyderabad- A Sustainable Approach

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A B S T R A C T

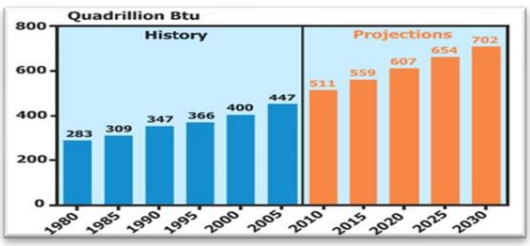
In the perspective on the developing requirement for energy utilization in Pakistan, the building construction sector consumes the largest amount of overall energy and destroys the ecosystem which can be reduced by using renewable energy resources. The proper adjustment of the architectural concepts to the climate is one of the basic characteristics of Bio-climatic architecture. Thus, it has a strong connection with nature. In this research, the rural area of Hyderabad, Sindh, has been selected as a case study of research. Hyderabad faces different problems such as energy crisis, solid waste management, non-availability of pure clean water and environmental deterioration. Design considerations for a bio-climatic house for agriculture-based people are studied in this research. The results suggest that renewable energy resources should be used to generate energy. In addition to this, passive design techniques and energy-efficient techniques should be used in the design (an idea of bioclimatic habitation). By adopting different architectural factors of bio-climatic buildings thermal comfort can be achieved in the house. This research encourages analyzing and taking benefit of environmental conditions around buildings to maintain perfect living conditions within the building through minimum consumption of energy.

K E Y W O R D S:

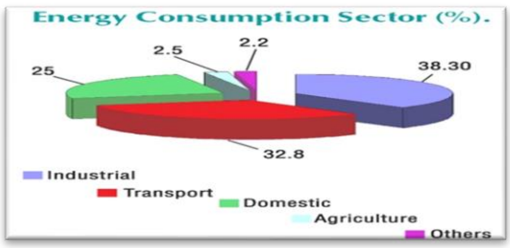
Bio-climatic Architecture, Renewable energy & Emerging Technologies, Passive Designs, Energy efficiency

1. Introduction

Pakistan is facing grave energy crisis. Pakistan's severe energy crisis is creating a severe dilemma for its weak economic system and instable national security situation. About 4% of Pakistan's GDP (gross domestic product) is invested on energy shortage over the last few years [1]. Determining Pakistan's energy crisis, need governmental decisions, more capital, and different power generation bases as renewable energy resources [1]. The building construction field has a big percentage of the world's total energy utilization. 30-40% energy is used in buildings. During the operational stage of the building about 90% of the energy is consumed. [1] Energy sector performs a crucial position in the financial development, mainly at the industrial area. World's main energy requirement will continue to increase at about approximately 2% yearly, for about the next twenty-five years, pushed through economic progress. Total energy consumption of world is expected to raise by 57% between 2004- 2030. Overall use of energy by world will increase from 447 quadrillion (Btu) in 2004 to 559 quadrillion Btu in 2015 and then to 702 quadrillion Btu till 2030 (as shown in Fig. 1a). In Pakistan now a days mainly energy consumption is for industrial, transport, domestic, agriculture and others (as shown in Fig. 1b). [2]



(a)



(b)

Fig. 1: Illustration of (a) Energy consumption (b) Energy consumption sector

Pakistan is an agricultural country. The building sector funds Pakistan's people and 26 percent of GDP. Pakistan's irrigation system, is one of the world's largest systems that contributes agricultural production. This production can also be expended without degrading an environment by the usage of renewable energy resources and waste management [3]. Renewable energy resources provide energy from sources that will never dissipate within a human's life time. Renewable energy is kind of energy produced from the natural resources such as: wind, water and natural light around the globe. The general examples include wind, solar, geothermal, biomass and hydropower. We can make and store some amount of energy with the help of special collectors, and utilize in our buildings. Green energy is a substitute of renewable energy, which boats low or zero emissions and less environmental impacts to systems such as land and water. By using renewable energy resources, we can control the degradation of environment. Environmental degradation is the destruction of the surrounding environment through depletion of various means such as earth, water and wind/Air. It causes the destruction of ecosystem, habitat, the extinction of wildlife and pollution. It can be decreased by using renewable energy recourses in buildings and the bioclimatic architectural concept is a key to its success

Keeping in view the aforementioned problem, this research aims to propose the strategies for the design of bio-climatic architecture for agriculture-based people of Hyderabad. The research envisages on various objectives such as observing the current situation of architecture of agriculture-based people of Hyderabad and their energy resources, exploring the sustainable architecture and renewable energy resources suitable for agriculture bossed people of Hyderabad, and suggesting techniques and methods of bioclimatic architecture for agriculture bossed people of Hyderabad.

2. Literature Review

Bio-climatic architecture discuss to the building designs and various spaces built completely under consideration of local climate, aims to provide visual and thermal comfort and by creating practice of solar energy and other green sources. Main factors of the bio-climatic architecture may include the consideration of building orientation according to sun and passive design techniques. Energy efficient building design features are installed into buildings to utilize natural energy sources (for example: air, soil, vegetation, wind, sun, water and sky etc.) for lighting, cooling, heating of the structures.

2.1 Climatic Design

Climate is the weather conditions of an area in general or over an extended period of time. The worldwide climate system and any changes that occur within it also influence local climate. The climatic design helps to reduce the energy demand of structures. Through ecologically sustainable means and energy consideration in design *one can improve* comfort inside the buildings and that increases the workability of occupants. Health of general public can be improved by climatic consideration and energy efficiency at every stage of building design.

Chris Reardon [4] describes that houses should be designed so that the occupants feel thermally comfortable with the climate where they are constructed. Design according to passive design techniques according to the climate is an important and provides energy efficient heating and cooling systems, and smart behaviour by the occupants. This research paper also tells that to achieve thermal comfort for occupants, about 40% of household energy is used for heating and cooling purposes. Through climate responsive design in new housing, strength of energy used for heating and cooling purpose may be reduce to about zero percent. The human body generates heat even while at rest. This human body temperature is about 37°C, no matter the fact that we work or sleep: we must gain heat at the same rate as we lose heat (as shown in Figure 2).

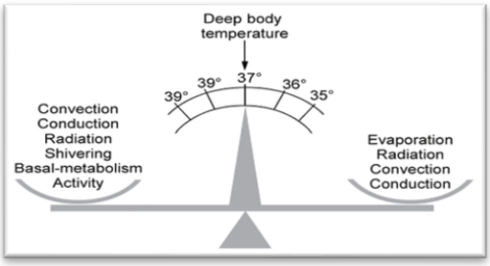


Fig. 2: Illustration of temperature scale showing human thermal comfort

2.2 Energy Efficiency

Energy efficiency defines the use of less energy to perform the same task. It simply reduces energy waste. It has so many advantages i.e. reducing greenhouse gas emissions, reduction in demand for energy consumptions, and lowering our costs on a household and economy on the extensive level. Tzikopoulos [5] in his research describes that on the application of bio-climatic principles is a critical factor in reducing energy consumption and carbon dioxide emissions of the building sector. This research paper develops a regression model of energy efficiency as a function of environmental conditions, characteristics of buildings and passive solar technologies. A sample of 77 bioclimatic buildings (including 45 houses) was collected, including Greece, other regions and the rest of the Europe. Average energy efficiency varied from 19.6 to 100% with an average of about 68%. Environmental conditions include the latitude, altitude, temperature, degree days and sun hours; building characteristics consisted in building area and volume. Passive solar technologies include solar water heaters, shading, natural ventilation, greenhouses and thermal storage walls.

Geoff Stapleton [6] found that renewable energy can also be used for domestic heating and cooling, hot water and even cooking. Renewable power systems use renewable energy resources to produce electricity with very low greenhouse gas emissions. These resources, such as the sun, wind and water, are replenished naturally but are not available continuously. In stand-alone systems, back-up electricity can be supplied from storage batteries or generators. For grid connected systems, the predominantly fossil fuel-based electricity (i.e. coal or gas generated) supplied through the grid act as back-up when renewable systems are not generating. If fossil fuel generators are used for back-up power generation sources, greenhouse gases are produced. Photovoltaic systems (as shown in the Figure 3) have become the dominant renewable energy technology established for domestic systems.

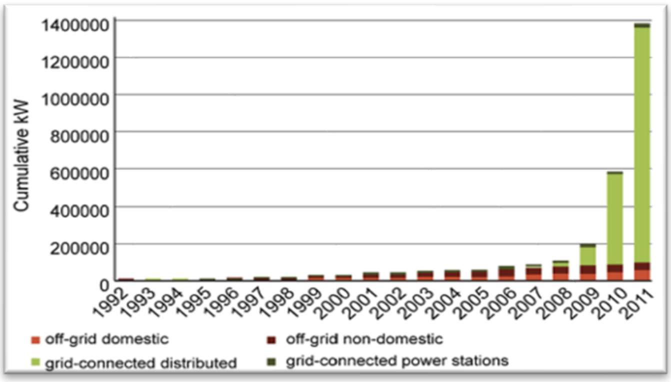


Fig. 3: Illustration of Photovoltaic or grid connected distributed system

2.3 Solar Energy

Solar Energy is the type of energy manufactured from the sun that can easily be converted into thermal or electrical energy as required. Solar technologies can harness this energy for a numerous use, which contain producing electricity, allow natural light, heating and cooling appliances, heating water for commercial, residential or industrial use and providing a comfortable indoor environment.

Shaikh [7] found that, since last ten years per watt cost of solar power energy devices is decreased. Due to the reduced amount of renewable energy devices and resources it becomes vital. It is absolutely set to appear as cheap in the future and developing as improved technology in relations of cost and usage. Energy from sun is a largest source of free available energy with no cost. Earth receives about approximately 1366W of energy from sun daily. The main advantage of energy generation from sun over other conventional power generation is that the sunlight can be directly transformed into solar energy with the help of photovoltaic cells or PV cells. Now a days many research activities are done to gain Sun's energy by improvement in solar panels or PV cells. When we compare solar energy production with other conventional energy resources, we found that energy produced by solar requires low man power and it is less expensive technology.

3. Research Methodology

Primary Data Collection

In this research both the primary and secondary data has been used in order to reach to conclusion. Literature review and case study were conducted in exploring the sustainable architecture and renewable energy resources. Surveys, questionnaires and interviews assist in observing the current situation of architecture of agriculture-based people and their energy resources and in suggesting the techniques and methods of bioclimatic architecture for agriculture-based people of Hyderabad.

Secondary Data Collection

2. Case study
3. Data collection

Hyderabad is second largest city of Sindh province and it is the district of Sindh, Pakistan. Hyderabad city is the capital of Hyderabad district. After Karachi, Hyderabad district is the second most populated district of Sindh province with about 80% urban and 20% rural population areas. Hyderabad district covers about 104,877 hectares of land with total estimated population of 2.199 million (estimated in 2017).Selected site of the project (area: 8 acres) is 7.22 km from Tando Jam hat is 18 kilometres away from Hyderabad city Pakistan, along Hyderabad and Mirpurkhas Road.

4. Case Study

4.1 Solar System

Solar systems generate clean and pure energy from the sun without degrading an environment. Large Scale Solar System is proposed in this study which should be installed in the house to reduce greenhouse gas emissions and decreases dependence on fossil fuels. The investigations is supported by a case study. Hyderabad is a semi-acid zone with high temperature during summer. This is worsened by electricity breakdown (load shedding) which is up to 10 to 12 hours maximum in Latifabad unit no. 06 Hyderabad and after getting awareness about the degradation of an environment through emission of greenhouse gasses, the users of the house decided to install a large-scale Solar power System (covering almost their complete house appliances) and play a role in saving an environment from degradation.

4.2 Proposed Type of Solar System

Hybrid solar power system need to be installed to generate electricity connected with battery backup (utility). Timings for solar are up to 21 hours and 6 to 7 hours backup (utility). The proposed solar system capacity is mentioned on Table 1.

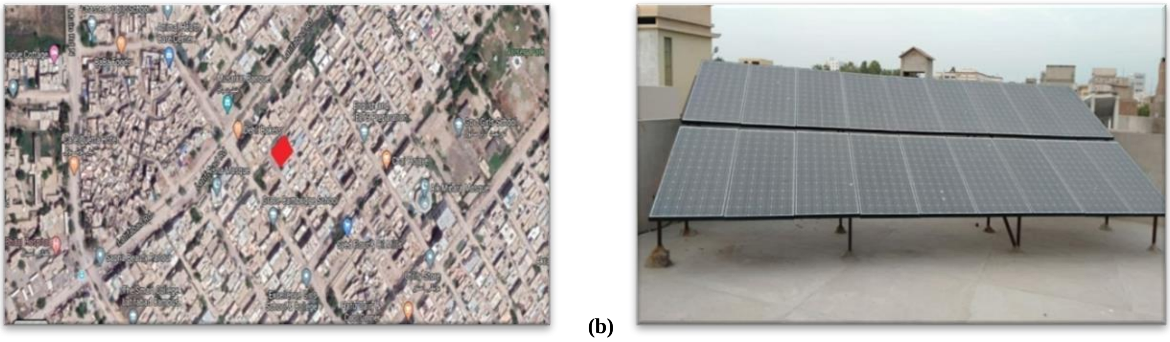
Table 1: Supported elements for the solar system

Elements	Quantity	Capacity
Panels	18	300 w
Inverter	01	3 kw
Battery	04	12 v 230 ah

Monocrystalline Solar Panels are recommended to install in the house which is best type of panel for residential building because are highly efficient and have a sleek design. The total cost of the system at the time of installation (installed in April 2020) was 600,000 or Six Lac Rupees (approx.), further see Table 2 and Figure 4.

Table 2: Appliances running on the system

Appliances	Quantity	Capacity
Fans	15	12 w
AC	04	01-ton DC inverter
Water Pump Motor	01	01 hp (746 w)
Oven	-	-
L.E.D TV	02	30 w
Iron	-	-
Refrigerator	-	-
LED Bulbs	20	12 w



(a) **(b)**

Fig. 4: Illustration of (a) Location Plan of House (b) Monocrystalline solar panels

4.3. Proposed Thermal Insulation

In hot regions, houses are built to make their inside environment cool for thermal comfort. As the heat transfer mechanism it transfers from hotter regions or places to colder areas and in result, heat loss happens in cool areas. To avoid heat loss in buildings, thermal insulation in building envelope or external surfaces is provided to keep the essential temperature inside the building. The purpose of providing insulation in walls, roofs and floor is to reduce the heat transfer between the exterior and interior of the structures. This research proposes a few major methods of thermal insulations such as used in the house are:

4.4. Thermal Insulation

When we compare the carbon footprint of the production of thermal insulation of different insulation methods, including western methods, such as fiberglass insulation then it is found that no or very less carbon footprint is generated by using straw as an insulation material on the roof of the house. It is very economical method used for thermal insulation and constructed through locally available materials such as wheat straw, straw, cotton seed hulls, etc. This method is usually used in the houses constructed in villages which is shown in Figure 5.

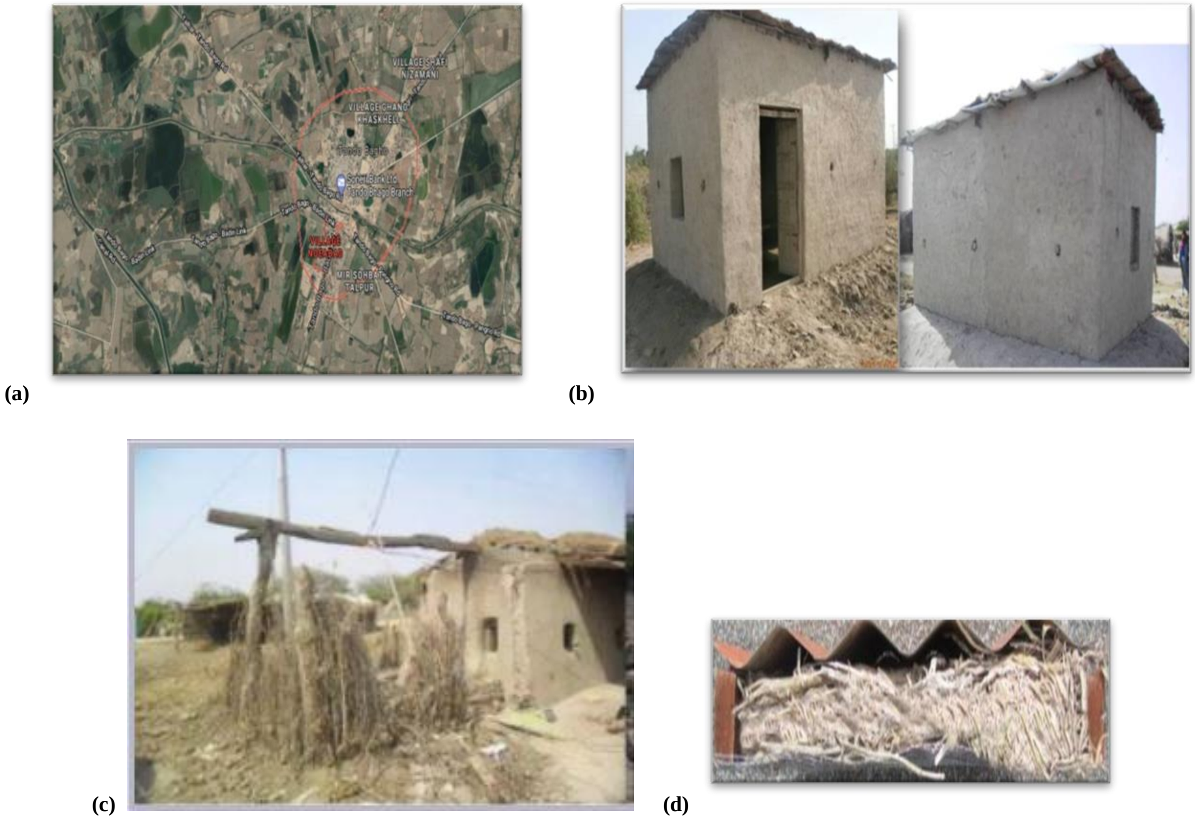


Fig. 5: Illustration of houses

4.5. Proposed Bio-Gas Plant

Methane and carbon dioxide gases are the main gases of biogas. Bio gas is formed naturally by chemical reaction of organic matter in the absence of oxygen. It is produced from industrially from raw materials such as animal and municipal waste, agricultural waste, plant material, fertilizers, sewage, food waste and green waste. The bio gas plant uses solid waste of the animals to generate gas. Biogas production depends on raw materials provided as feed, temperature and design of the biogas plant. A diverse range of solid animal waste from the cattle farm is collected.

1. The dung is collected and it is put with water in the dung and water feed starry. Which is also known as the inlet of the bio gas plant.
2. This inlet is further connected with the digester, circular underground pipe, it is also known as bio digester. In which the process of fermentation to break down organic matter from animals, to produce biogas.
3. Then, this digester is connected with the sludge, also known as the outlet of the bio gas plant. After the production of this gas in bio digester sludge or outlet of this plant pass out the collective waste.

5. Study Findings

In these research papers the researchers describe different aspects of bio-climatic architecture from which some of the important results are:

- About 40% of household energy is used in the buildings to acquire thermal comfort.

- Energy consumption in climatic design has importance in heating and cooling of buildings, Passive design and low energy techniques helps to take advantage of climate for energy efficiency and protects the building.
- Passive design techniques includes: Shading of windows for sun and wind, consideration of orientation, high thermal mass, evaporative cooling, cross ventilation and heating plus humidification etc.
- Consideration of orientation of building according to sun and wind, along with other energy efficient techniques, can decrease or remove the necessity for supplementary cooling, results in reduced energy bills and greenhouse gas productions.
- A building that has cross ventilation and passive design considerations, consumes less energy over the un-ventilated and without consideration of passive design techniques.
- The passive cooling is the economical method of cooling a building.
- Convective air movement improves cross ventilation or air flow and overcomes a number of the boundaries of unreliable breezes.
- Global warming and ozone layer depletion is the mainly result of growing usage of electrical energy.
- After adaptation of solar shading devices a clear reduction in room temperature as about six degree centigrade has been observed.
- The source of the construction materials and the way they are processed ultimately determines their environmental impact.
- Bio-climatic principles is a critical factor in reducing energy consumption and carbon dioxide emissions of the building sector.
- Renewable energy resources are used to produce electricity by technology and passive design techniques with very low greenhouse gas emissions.
- Hydraulic energy is a direct significance of solar energy.
- In cold season, up to 25% of heat loss is observed from a building and it is the greatest cost-effective way to provide insulation in a structure.
- Thermal insulation in roofs and walls not only reduces the use of air-conditioning system but it also reduces the annual energy rate.
- Solar energy is energy, which is available at low cost. It is cheap, so easily reachable to ordinary people and available in great amount naturally as compared to the other several resources and fossil fuels.
- Energy produced by solar energy uses small manpower expenditures as compared to other conventional energy construction technologies.
- Solar energy is one of the cheapest energy types that are currently used in world.
- Solar power is a 100% clean, renewable energy source.
- Solar energy is well known as one of the major renewable energy sources.
- Monocrystalline solar panels are best and more efficient for residential buildings because they are cheaper as compared to polycrystalline solar panels.
- Solar panels of 300-watt, Inverter of 2.2 kw and battery of 12 v 185ah is good enough to generate electricity for a small house.

- The approximate timings for solar system are up to 20 hours and 5 to 6 hours backup utility.
- Off-grid residential solar power system is best to generate electricity with battery backup.
- The solar system has more installation cost but less operational cost and gives life time comfort.
- Solar system works more efficiently in hot and dry climatic region than other climatic regions of the country.
- Installation of solar system in house reduces electricity bills.
- Solar system has low maintenance cost than other electricity generating systems.
- Solar system is the easiest way to reduce load shedding.
- Biogas production depends on the feed or raw materials, temperature and design of the biogas plant.
- Firstly, the dung is collected in the dung and water feed starry. Which is also known as the inlet of the bio gas plant. This inlet is further connected with the digester.
- Maximum space required for a bio gas plant is 16'-0" X 20'-0"
- Wheat straw, straw, cotton seed hulls are filled in constitute in the plastic flexible pipe, and prick film pipe two ends dead with anticorrosion rope can be used as the thermal insulator in the buildings.
- It is very economical method used for thermal insulation.
- It can be constructed through locally available materials such as wheat straw, straw, etc.
- Use of insulation in building has low or no environmental impact.

6. Conclusion

Bio-climatic Architecture, involves the design combining "biology", "climate" and landscape that is based on local climate. This architecture targets to protect the surroundings and natural resources. As Pakistan is facing energy crisis and environment is degrading day by day. Rural areas of Pakistan have proper facilities to overcome these issues. So, there should be an architecture that is based on local available materials and use of renewable energy resources to generate energy that do not deplete the environment. The purpose of this research is to provide awareness in agriculture-based people of Hyderabad regarding cost reduction by using renewable energy resources for energy generation and to provide comfort without degrading the environment. The site for Bio-climatic architecture is located in rural area of Hyderabad (between Tando Jam and Hyderabad city). It has an area of 8 acres (335865 square feet) and with irregular shape. It has a cattle and poultry farm and the entire area is surrounded by different fields. Many problems are found in the rural areas of Hyderabad such as burning of wood and leftover animal solid waste causes degradation of environment and non-availability of pure clean drinking water. Surveys, literature review, questionnaire, and case studies have done to find solutions for these problems that are available. Various design techniques and methods can be used such as: use of passive design techniques, solar energy, vegetation, bio gas plant, green roof, wind catchers, window glazing, different types of shading devices and rain water filtration system. If Bio-climatic architecture is introduced in Pakistan, energy crisis and environmental degradation can be reduced in an economical way. More research and innovation are needed to maintain this architecture which will improve our countries economy.

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ID 52: Analytical Assessment of Urban Stress in Public and Cooperative Housing Schemes with Perspective on NeuroUrbanism: Case Studies of Johar Town and WAPDA Town, Lahore City, Pakistan

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A B S T R A C T

Urbanization is accelerating at a meteoric pace around the globe. Over the last couple of decades, urban living has been evolving and going through several societal changes. Modern-day urban living and nurturing have conspicuously manifested stress and exposed them to several mental health-related problems. This research explores and compares the various factors leading to stress in two major planned housing schemes in Lahore; Johar Town & WAPDA Town. It focuses on figuring out the perception of stress among the residents of these areas; how 'stressed' they felt due to urban living. Various stress factors were identified by a comprehensive literature review and a structured questionnaire was designed to collect primary data. The data analysis finds that both the public and cooperative housing schemes, despite being planned and equipped with certain facilities, fail to contribute to healthy urban living. The findings suggest that major contributors to stress are related to travel patterns, insecure outdoor environments, traffic noise, and socioeconomic conditions of the residents. The study is unique in its scope and implementation as it emphasizes the need to pay special attention to this area of research and positively contribute to sustainable development goals (SDG) 11 and 16.

K E Y W O R D S:

Urban Stress, Planning, Peace and Justice, Sustainable Communities

1. Introduction

The global population living in cities today is more than fifty per cent and this rate, according to estimation is subject to reach almost seventy per cent by 2050 [1]. Modern-day urban living has manifested stress and exposure to several mental health-related problems [2]. The rapid pace of urbanization together with population growth has forced people to move and settle in urban areas for advanced education, health facilities and job opportunities. However, city dwellers are more subjected to stress disorders and mental illness [3]. Research studies proved that urban living can directly affect neural pathways and activate those regions of the brain that responds to stress, depression, anxiety and fear [4]. Being urban-born is associated with more vulnerability to stress [5]. The main health-relevant change we will be facing in coming years and even are facing in current times, and decades is Urbanization [6]. According to [7] psychiatric diseases come with a dose-response relationship for the time someone has grown up in a large city. It simply means that the more you have spent your childhood in cities, the higher your risk of developing stress disorders. Pakistanis are experiencing the fastest pace of urbanization in South Asia with a 3% annual rate of urbanization [8]. Among the adults of Pakistan, high prevalence rates of stress, depression, as well as mental and behavioural disorders have been found [9]. As the 5th most populous country in the world, Pakistan, by 2050 is projected to rank fourth most populated country on the globe [10]. As the population grows at this speed, it will have serious impacts on our physical as well as mental health, yet there is no clear agenda on mental health in Pakistan. The population is increasing so rapidly, and the pivotal contribution it is paying to current world events highlights a great need to develop future policies that address stress [11]. Lahore being the second most populated metropolitan city in Pakistan is experiencing an unprecedented pace of urbanization. Contemporary urban development practices have failed to contribute to sustainability. The present-day development is promoting urban sprawl with social segregation, car-oriented infrastructure, and self-enclosed housing schemes at fringes. Dynamic and structured institutions are needed along with technical, legal and regulatory support to manage the growing population. [12]

2. Literature Review

2.1 Urban Stress in Lahore

The rapid urbanization in Lahore has triggered problems related to social dimensions & ecosystem disruption. The increasing population of the city drastically now has increased to 10 million [13]. It has given rise to plenty of problems relating to social, economic, physical as well as environmental attributes [14]. According to another study rural-urban migration and increased development in infrastructure and the residential sector have affected urban vegetation to a great level and there is a significant decrease in green cover in just a few years [15]. The consequences come in the form of socio-environmental impacts on city dwellers. Most of the development is taking place on green agricultural land which is alarming [16]. Horizontal growth in the form of urban sprawl is taking place resulting in a shift of people on the outskirts which has increased the urban footprint of Lahore [17].

2.2 Neuro-urbanism

City living is inextricably linked to our psychological well-being. The interdependencies between mental well-being and city living are also evident found from a meta-analysis that if you are born in an urban environment, the risk of developing schizophrenia increases by 28-34.3% [18]. This web of inter-dependencies needs to be understood as health providers as well as urban planners have so far largely failed to develop strategies that coordinate the bidirectional interaction between cities and mental health [19]. In a research study by [7], the effects of urban living on human brain structure through functional magnetic resonance imaging have been identified. The study suggests that city living affects the stress associated with emotional settings and may cause further health impacts due to multiple risk factors associated with urban living. The stress and mental health-related diseases caused by urban life is a question that has to be answered with the concept of “Neuro-Urbanism”; a field of study and research that bring together neurologists and urban planners. Neuro-Urbanism is a new scientific approach that aims to examine the relationship between cities and the psyche of their inhabitants [19]. A novel approach consisting of strategies under the umbrella term of ‘urban remediation’ has been proposed to help patients recover from their psychotic episodes [20]

2.3 Built Environment and Brain

Social Pressure, isolation and poverty activate the brain structures that respond to stress [21]. Social stress processing in urban living underlies greater mental health risks as proposed by multiple authors [22-24]. It has been shown from a meta-analysis that current city dwellers have a substantially increased risk of developing disorders related to anxiety and mental stress. Despite [the fact] that its dwellers receive better facilities, nutrition, contraception and improved sanitation, they are more subjected to mental disorders [25]. The evidence comes in the form of a neuroimaging study that revealed the relationship between the brain and stress. From a study, it was revealed that brain functions are highly affected when an individual is faced with a stressful situation [26]. The human mental state is strongly linked to an urban environment with the increased risk of anxiety and depression as well as a higher rate of schizophrenia in people born and brought up in cities [23]. The brain and its regions that are associated with stress response have a direct relation to the nervous system. Certain physiological changes occur in our bodies when we become stressed [27].

2.4 Nature and Stress

Nature plays the role of an anti-stressor as has been proven through plenty of research studies. Frequent visits to parks and urban greenspaces ultimately reduce mental stress [28]. Another research study revealed that public housing residents who were surrounded by nearby trees and greenery coped better with daily life stressors. Moreover, parks contribute to more positive mental health [29]. According to [30], higher mental well-being is positively associated with neighbourhood aesthetic quality. The wellness of city dwellers can be enhanced with easy access to parks, views of trees and even spending more time in urban natural settings. Aesthetics and a simple view of nature can produce recovery benefits. Natural setting act as an antidote to stress since it offers a restorative function to the mind, providing experiences that ease and heal the mind and body [31].

3. Materials and Methods

3.1 Methodology

This study is carried out by using quantitative methods of data collection and analysis. The focus of the study was to identify the stress-causing factors in the built environment of two major planned residential areas such as Johar Town and WAPDA Town, see Figure 1.

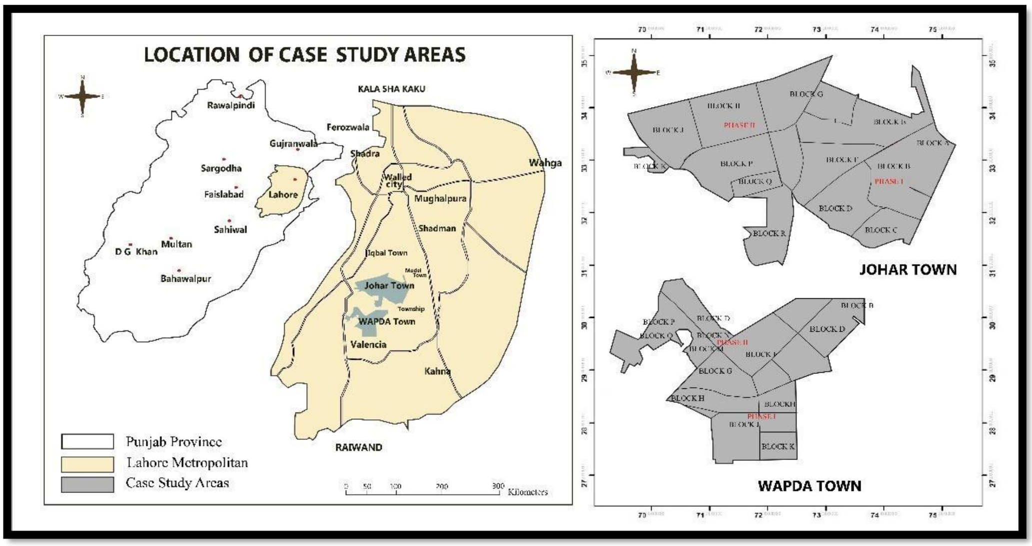

Fig 1: The map of Punjab province along with Lahore city and case study areas

Stress scale as designed keeping in view Perceived Stress Scale (PSS). This scale consists of direct questions and queries about levels of experienced stress. The respondents are inquired about how they feel about certain conditions [32]. The following Stress scale was developed (Table 1)

Table 1: Stress scale

5	4	3	2	1
Very High Stress	High Stress	Moderate Stress	Low Stress	No Stress

Articles from different research studies were reviewed & urban stress factors were identified. These factors were then further modified in the questionnaire to design various questions relating to urban stress. The following categories were made: Green Spaces & Recreational Facilities, Neighbourhood Environment & Residential Density, Transport & Accessibility, Socio-economic Status and Infrastructure & Community Facilities & Housing see Table 2.

Table 2: Urban Sectors and stress factors included in the questionnaire

Urban Sectors	Urban Stress Factors	Sources
Housing	Housing costs, Household income and Housing condition.	[33], [34], [35]

Urban Sectors	Urban Stress Factors	Sources
Green Space & Recreational Facilities	Daily visits to green spaces, Availability of green spaces, Access to green spaces, Lack of Exposure to nature, Lack of entertainment, Places to shop, Provision of parks in neighbourhoods.	[36], [37], [38],[39], [34]
Transport	Traffic and road safety, Physical threats such as accidents, Disturbed mood and frustration due to traffic congestion, Aggressiveness & stress due to long driving hours, Accessibility by public transport.	[40], [41], [34]
Neighborhood & Residential Density	Neighbourhood cohesion, Fear of crime &harassment, Insufficient Privacy, Neighbor Noise, Noise annoyance, Exposure to noise pollution, Noise from traffic or other homes, Disturbance by neighbours or youngsters, Litter in the streets, Air pollution built environment.	[35], [39], [42], [43], [44], [45], [46], [47], [48], [49]
Socio-economic Status	Financial strain, Work stress, Family environment & marital conflict, Minor daily stressors (workload etc), Social Exclusion, Family Income & wealth, Increased Social Isolation, Unemployment, Job insecurity.	[50], [51], [52], [39], [53],[35]
Infrastructure	Accessibility to services, Community facilities, Stagnant sewer water, Solid waste heaps, Poor quality of water supply.	[34], [54]

4. Results and Discussion

4.1 Correlation analysis

Pearson correlation was run to access the relationships between different variables of urban stress in 105 respondents of WAPDA Town & 100 Respondents of Johar Town. To figure out the strength of the relationship between variables and also to establish the possible connections between them, a correlation matrix was developed between variables of different urban sectors. Below is the matrix showing the Pearson correlation between variables relating to the urban transport sector. It is clear from Table 3; Travel Frequency shows a strong relation with long travel distance for WAPDA Town $r (99) = 0.485$ $p< 0.01$. It is observed that a higher rate of travelling is directly associated with higher stress due to long travel distances. Travel frequency also shows a relationship with other variables such as the threat of accident, crime and over-crowdedness for both towns. A significant correlation between modes of travel can be noticed with feeling insecure while travelling $r(99)=0.463, p< 0.01$ for Johar Town. The relation exists with other variables as well for both towns. Table 4 shows the correlation matrix of variables related to the Housing sector. House ownership has a significant relationship with certain stress-causing factors in both towns; house ownership with not having permanent residence ($R (95)=0.872$, $p<0.01$ & $R(99)=0.794, p<0.01$), Size of House is correlated with Stress due to poor housing condition ($R(95)=0.437$, $p<0.01$ & $R(99)=0.574, p<0.01$) and feeling unsafe at home ($R(95)=0.566$, $p<0.01$ & $R(99)=0.547, p<0.01$) for both towns. The house shifting frequency also shows a strong positive correlation with not having a permanent residence ($R (95)=0.810$, $p<0.05$ & $R(99)=0.598, p<0.01$). In other words, the stress among residents who shift houses frequently is predominantly due to not having permanent residence. In correlation table 3, we can clearly notice a strong correlation between the threat of crime with stress due to an insecure outdoor environment ($R (95) =0.851$, $p<0.01$ & $R(99) =0.683, p<0.01$). Stress due to traffic noise also shows a correlation with the presence of commercial activity near the residence in Johar Town ($R (99) =0.596$, $p<0.01$). The number of visits to the park also shows some positive correlation with a visit to parks for physical activity.

Table 3: Correlation analysis among various urban stress factors

Correlation Matrix		Stress due to: Inaccessibility of Public Transport		Lack of access to recreational places		Travel to Parks Frequency		Lack of Visit to Parks		Insecure while traveling		Traffic noise while traveling		Threat of Road Accident		Stress Level due to Over-crowdedness		Long Travel Distance		Threat of Crime		Travel Frequency	
		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Travel Frequency	Pearson Correlation	-0.083	0.043	-0.066	0.111	-0.107	0.03	0.02	0.195	-0.179	0.099	0.389**	0.21*	0.193*	0.222*	0.231*	0.126	0.485**	0.2158*	0.213*	0.198*	-	-
	Sig. (2-tailed)	0.401	0.672	0.502	0.273	0.279	0.767	0.843	0.052	0.68	0.328	0	0.027	0.048	0.026	0.018	0.752	0	0.031	0.029	0.048	-	-
	N	105	100	105	100	105	100	105	100	105	100	105	100	105	100	105	100	105	100	105	100	-	-
Modes of Traveling	Pearson Correlation	0.061	-0.053	0.09	0.005	-	-	-	-	-0.220*	0.463**	-0.242*	0.355**	-0.274**	0.382**	-	-	-	-	-	-	0.56	-0.97**
	Sig. (2-tailed)	0.534	0,597	0.924	0.962	-	-	-	-	0.024	0	0.013	0	0.005	0	-	-	-	-	-	-	0.572	0.003
	N	105	100			-	-	-	-			-	-	-	-	-	-	-	-	-	-	105	100
No. of Owned Vehicles	Pearson Correlation	-	-	0.199*	0.121	-	-	0.155	0.041	-	-	-	-	-	-	-	-	-	-	-	-	0.467**	0.297**
	Sig. (2-tailed)	-	-	0.142	0.230	-	-	0.166	0.688	-	-	-	-	-	-	-	-	-	-	-	-	0	0.003
	N	-	-	105	100	-	-	105	100	-	-	-	-	-	-	-	-	-	-	-	-	105	100

***Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed) 1= WAPDA Town, 2= Johar Town.**

Table 4: Correlation analysis among house ownership status and housing conditions

Correlation Matrix		Stress due to: Not having permanent residence		Poor Housing Condition		Feeling Unsafe at home		Family Type	
		1	2	1	2	1	2	1	2
House Ownership	Pearson Correlation	0.872**	0.794**	0.051	0.312**	0.288**	0.095	0.041	0.083
	Sig. (2-tailed)	0	0	0.880	0.001	0.003	0.347	0.679	0.525
	N	105	100	105	100	105	100	105	100
Size of House	Pearson Correlation	0.166	0.437**	0.574**	0.504**	0.566**	0.547**	-0.103	-0.035
	Sig. (2-tailed)	0.099	0	0	0	0	0	0.294	0.789
	N	105	100	105	100	105	100	105	100
Not having Permanent Residence	Pearson Correlation	-	-	0.375**	0.243*	0.329**	0.209*	-	-
	Sig. (2-tailed)	-	-	0	0.015	0.001	0.037	-	-
	N	-	-	105	100	105	100	-	-
House Shifting Frequency	Pearson Correlation	0.810**	0.598**	-	-	-	-	-	-
	Sig. (2-tailed)	0	0						
	N	105	100						

***Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed)** 1= WAPDA Town, 2= Johar Town

Table 5: Correlation analysis among factors of outdoor environment and crime

Correlation Matrix		Stress due to Not having permanent residence		Stress due to Poor Housing Condition		Stress due to Feeling Unsafe at home		Family Type	
		1	2	1	2	1	2	1	2
House Ownership	Pearson Correlation	**0.872****	**0.794****	0.051	**0.312****	**0.288****	0.095	0.041	0.083
	Sig. (2-tailed)	0	0	0.880	0.001	0.003	0.347	0.679	0.525
	N	105	100	105	100	105	100	105	100
Size of House	Pearson Correlation	0.166	**0.437****	**0.574****	**0.504****	**0.566****	**0.547****	-0.103	-0.035
	Sig. (2-tailed)	0.099	0	0	0	0	0	0.294	0.789
	N	105	100	105	100	105	100	105	100
Not having Permanent Residence	Pearson Correlation	-	-	0.375**	0.243*	0.329**	0.209*	-	-
	Sig. (2-tailed)	-	-	0	0.015	0.001	0.037	-	-
	N	-	-	105	100	105	100	-	-
House Shifting Frequency	Pearson Correlation	**0.810***	**0.598****	-	-	-	-	-	-
	Sig. (2-tailed)	0	0						
	N	105	100						

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed)

1= WAPDA Town, 2= Johar Town

5. Conclusion

This research has identified the major contributors to urban stress in public and cooperative housing schemes i.e., Johar Town and WAPDA Town. The common factors that play a major role in causing stress among residents of both Johar Town and WAPDA Town as well as those which differ are mainly related to travel, crime threats & insecure outdoor environments, long travel distances, and housing. The data analysis has portrayed that the residents of these towns mostly feel stressed due to an insecure outdoor environment and the threat of crime. Inhabitants' perception of being stressed is also associated with long travel distances. Furthermore, daily travelling, traffic noise and overcrowdedness directly affect the mental stress level of the residents of these areas. However, socioeconomic factors also play a significant role, especially in elderly age people and single-earning members, associated with relatively low monthly income & family conflicts. Considering the data analysis and findings of the research, it is recommended that urban safety should be considered a priority while designing or making future urban plans. Public parks and open spaces are under-used due to fear of crime or an insecure outdoor environment, urban designers should focus on various tools and strategies for crime prevention such as VPUU: Violence Prevention through Urban Upgrading (Matzopoulos., et al 2020) etc. As far as neighbourhood safety is concerned, the concept of sidewalks and corner shops in the context of safety (Jacobs, 1961) should be revoked in improvement plans. Moreover, ingredients of walkable communities should be introduced into traditional planning and design practices to promote physical activity inside the schemes resulting in a healthier living environment. It is also recommended that housing and socioeconomic factors must be taken into account on a priority basis. Furthermore, to solve the issue related to transport and daily travelling, the necessary paradigm shifts in needed: cars must not be the primary shift in designing transport networks instead, a multi-model network of city transport must be considered. This is possible by introducing mobility plans integrated with public safety, flow, walkability and accessibility.

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ID 118: Window Views in Urban Setting: Impact on Apartment Dwellers in Hyderabad

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A B S T R A C T

Pakistan has the highest rate of urbanization among South Asian countries. Apartment buildings have been recognized as a characteristic type of urban housing due to the increasing intensity of land use in urban areas. In Hyderabad, one of the neglected aspects of urban living is the neglect of window design, orientation, and view through the window in apartment buildings. Windows are the primary means of communication between the inside and outside of the building. This paper highlights the significance of window views in urban setting in relation to sustainable development. Furthermore, the purpose of this research is to investigate the impact of window views on apartment dwellers in Hyderabad and how it affects the sustainability of a building. The case studies were conducted on apartments in Qasimabad, along with a questionnaire survey based on the residents' preferences for window views and how the existing setting affects their behavior. After analyzing literature, conducting case studies, and completing a survey questionnaire, results suggest that window views promote pleasant emotions, productivity, health, and well-being, which contribute to a sustainable development.

K E Y W O R D S:

Urban Dwelling, Window Views, Urbanization, Visual Comfort, Well-being and Building Orientation.

1. Introduction

Our surroundings shape our personalities. Who we are relies upon where we are living [1]. According to United Nations Development Program, Pakistan has the highest rate of urbanization among countries in the South Asia [2]. With the increasing intensity of land use in urban areas, apartment buildings have been acknowledged as a typical type of urban housing [3]. Undeniably, home is a healing base to return to after engaging with the world, and it's a process to revive up your routine [1]. Living in an apartment has its own benefits such as affordability, security, maintenance etc., besides there can also be some downsides. One of the overlooked elements of urban dwelling is the lack of consideration for window design, orientation and view through the window in apartment buildings.

We have become indoor people by spending more than 90 percent of the time indoors [4]. Our lives are cooped up in buildings, with windows typically being our foremost connection to the outside world [5]. There have been very few studies on window views in urban settings. In Hyderabad, window design is the most overlooked aspect of apartment building architecture. Looking out the window often undervalued in practice, despite several research demonstrating that it improves observers' well-being and health and increases their behavioral and visual comfort [6]. People who spend an extended period of time in a closed environment with no windows may face difficulties concentrating, a lack of stimulation, unpleasant emotions, and other forms of psychological distress discontent, and they may even suffer from severe symptoms such as depression, sleeplessness, and a loss of sense of reality [6, 7]. In designing an apartment, minimum consideration is given to window size, window shape, view through the windows, and orientation of the windows. Though, windows are our primary means of communication with the outside world. They play the part of bringing the outside world inside by being the source of information (weather, season, etc.), daylight, air, ventilation, nature, and aesthetics. When windows are designed carefully they help in enhancing the building's sustainability.

1.1. Aim of the Research

The aim of the research is to study the effect of window views on apartment dwellers in Hyderabad to benefit architects and designers reconsider the existing window orientation in terms of views through windows of apartment buildings for future designs and sustainable development.

1.2. Objectives of the Research

- To study the impact of window views.
- To study the window view preference of apartment dwellers.
- To study the role of view window in sustainable development.

2. Impact of Window Views

To study the impact of windows views, the existing literature is reviewed and then classified into six broad categories: effect of view through windows on behavior, window view and sustainable development, view preference, view quality, view and emotions, and view accessibility.

2.1. Effect of View through Windows on Behavior

A window serves as a channel for bringing the outside in. Additionally, functions as a source of information, daylight, ventilation and enhanced aesthetics. Windows that provide external views have been shown to have several positive effects on residents [8, 9]. The effects comprise but not limited to improved health, physical and psychological well-being, controlled emotions, cognitive performance, environmental satisfaction, reduced discomfort and stress reduction [9]. Furthermore, there are a number of positive benefits when observers are exposed to nature [10, 11]. Natural environments have been shown to influence chronological perception, exposure to nature gives the sensation that time goes more slowly [11-13]. According to some researchers, the nature view seen through the windows has the same effect on individuals as if one was actually in nature [6].

Alongside the occurrence of light and views, the window views also have an indirect effect on the efficiency and psychological well-being of occupants [12]. The window views conveying outdoors inside, causes a person to experience visual stimuli and influences his mood [6, 13].

2.2. Window View and Sustainable development

The Sustainable Development Goal No. 11 states that cities and human settlements should be inclusive, safe, resilient, and sustainable [14]. Connecting indoors with the outdoors in an urban setting plays a vital role in achieving the goal of sustainable development. A window with a view is the main source of visual connection with the outside world. The amount of daylight that enters a room depends on the size of the window, but the placement and shape of the window determines how much light enters the room and which portion of the outside world (ground of sky) may be seen [12]. Furthermore, selecting an adequate view window would improve sustainability by designing the proper size of the opening, resulting in a lower amount of construction cost, reducing material waste, and saving energy.

2.3. View Preference

Window view preferences are subjective and vary from person to person. According to [12, 15] window view preference is based on the following elements:

i. Function of the space
ii. Task of an individual
iii. Requirement for ventilation
iv. Requirement for light
v. Visual connection with nature and outside world
vi. Acoustics preferences

vii. Psychological and health benefits

In dense urban areas, apartment dwellers prefer a high-rise, open view [3]. However, if the views have restricted vision then it may affect psychological stress, for this reason views have a direct impact on resident health and quality of life. The distance of view from the window also influence the preference of residents in urban settings. When view characteristics are distant, people are more satisfied. According to the findings of [11] building occupants preferred window views with nature to be nearby and urban features to be seen from a distance. Natural environments are often preferred over urban settings [11, 16]. Moreover, dynamic views engage us and are frequently chosen over static views [17]. Brief movements in the view give building residents the awareness of their surroundings as well as connectivity to the outside world [9].

2.4. View Quality

The view from the window has a direct impact on the health and well-being of the residents. The quality of the view should not be overlooked in order to provide a pleasant impression. The characteristics of window views determine the quality of view. Chang theorized the seven attributes as the characters that determine the view quality, i.e., Proportion of greenery, number of visual layers, view elements, balance, diversity, Openness, Depth of view [18].

In urban settings most of the view consists of neighboring structures. Minimum consideration for the landscape is made. The landscape of an apartment building not only promotes stress mitigation for occupants, but it also serves as a healing environment [3, 19]. Nonetheless, due to the existing economic crisis, the increase in land prices has led to a question about the provision of landscape. However, in congested urban settings when only the adjoining building is visible through the window, visual comfort is influenced by the architectural components that shape the façade and determine the aesthetic quality of what is viewed [20].

2.5. View and Emotions

Donald Hebb stated that among all creatures on Earth, man is the most emotional [21]. Experiments in psychology have shown how emotion can alter our perception, attention, and memory by focusing them on crucial components of our surroundings [22]. Different people may react differently to the same views, and the same person may react differently each time they are exposed to similar views [22, 23]. Response to the view are merely based on emotions of individuals. Window Views influence the intensity of emotions inside individuals. Emotional contentment is higher in people in a room with window views close to nature in contrast with the windowless condition [11, 24].

2.6. View Accessibility

The quantity of view an occupant sees through the window from the viewing position determines view accessibility. It precisely relies on window design and location of dweller. Many green-building certification schemes employ the percentage of occupied space with a window view [9]. Day Lighting standards [25, 26] [26] additionally prescribe that visual information viewed in the view be distant from the occupants' viewing position at minimum thresholds of 6 m, 20 m, and 50 m, respectively [11].

4. Research Methodology

The research was carried out using a review of the literature, a questionnaire survey, case studies, and an analytical study based on the opinions of the residents of an apartment in Qasimabad.

3.1. Case Study - 1

A case study of an apartment in a building named Asad Paradise in Qasimabad was conducted. The building consists of ground plus four stories, with five apartments of two types on each floor. A study was conducted on the general category of apartment on the second floor that consists of two bedrooms with an attached bathroom, a balcony facing South, a kitchen, a lounge, and a drawing room. The two bedrooms were studied for comparative analysis between rooms with and without windows. As shown in fig 1, only one bedroom has a window with a view of the balcony. The second bedroom, on the other hand, lacked windows and instead had a door that led to the balcony, as shown in Figure 1 and 2.

The room with a window leading to the balcony has a window measuring 3'-0"x4'-0" with a sill height of 3'-6". Due to the high height of the window sill, the view cannot be seen from the bed or even while sitting on a study chair, as shown in Figure 1. The window, however, lets in adequate natural light for the size of the room because it faces south. On the other hand, bedroom 2 lacked a window and had a door leading to a balcony instead. The bedroom had a wire-mesh door along with the wooden door, which provided a view of the balcony but also worked as an agent of noise pollution. However, the room cannot have a connection with the outside world without noise.

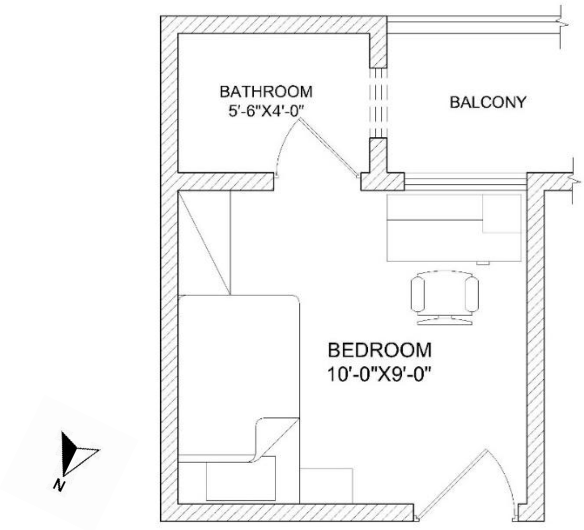

Fig 1: Plan of Bed Room - 1

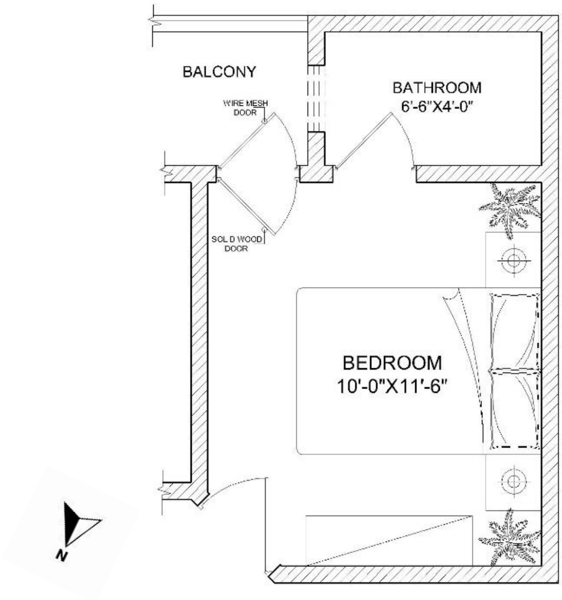

Fig 2: Plan of Bed Room - 2

3.2. Case Study - 2

A case study of an apartment in a building named Abdullah Sports Tower was conducted. The structure is eleven stories tall, with a commercial and residential plaza. The residential plaza is categorized into three apartment types: A1, A, and B. The case study took place in a B-category apartment on the third floor, which had two bedrooms with attached baths and balconies, a drawing room, a powder room, a lounge with a balcony attached, and a kitchen.

The lounge, consisting of a window leading to the balcony, provides a view of the outside without any obstructions, as seen in Figure 3. The floor-length window allows viewers to enjoy the view from any angle, but the view is limited to the neighbouring building, violating the privacy of both residents. The window lets in daylight, natural air, and weather information, but it fails to provide an aesthetic view and thus cannot be considered a view window. The bedroom-1 window also leads to the balcony and provides a distant view of the neighbouring building, as shown in Figure 4. The bedroom-2 has a window with a view, as seen in Figure 6, but the view cannot be enjoyed from all angles of the room because of the height of the window, as seen in Figure 5. All the windows provide a visual connection with the outside world, bring natural light and air, but do not provide comfortable or aesthetic views of nature or the outside world.

Fig 3: Lounge window

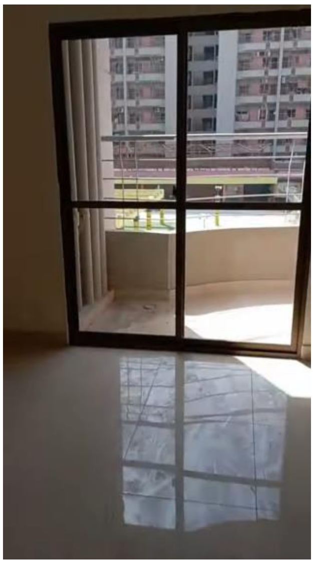

Fig 4: Bedroom-1 window

Fig 5: Bedroom-2 window

Fig 6: Bedroom-2 window view

3.3. Questionnaire Survey

The questionnaire survey was conducted based on the apartment dwellers' preferences regarding view windows and how their emotions are affected by the current setting. In the survey, both males and females participated equally. Furthermore, the survey was divided into two sections: dwellers' emotional reactions to current window view settings and their preferences. In the first section of the survey, data was recorded using a closed-ended questionnaire to analyse the viewing preferences of the apartment dwellers. In the second section of the survey, the data was recorded using a 5-point Likert scale to analyse the emotional behaviour of apartment dwellers toward window views. The questionnaire data was analyzed statistically based on the most common answers and response variability. The results are shown in Table 1.

Table 1: Results of survey analysis

View Preference			**Emotional Behavior**		
Interrogation	Results		Interrogation	Results	
choose sitting near window	yes 80%	no 20%	Level of pleasantness towards urban landscape	3	On the scale of 1-5
Chooses watching out: • Natural landscape view • Sky • Birds and animals • Neighboring buildings, road and people	 70% 35% 40% 15%		Level of pleasantness towards natural landscape	5	
			Level of satisfaction towards natural light	4-5	
			Level of satisfaction with window	4-5	
			Level of satisfaction without window	1-2	
Natural light	95%		Level of positive emotions with view	4	
Shading devices	55%		Level of positive negative with view	2	
Natural air over air conditioner	75%		Increase in productivity level with view	4	

Acoustic preference:			Emotional well-being with view	4	
• Birds and animal	55%				
• No sound	35%				
• People existence	10%				
Privacy concern	high	moderate			
	65%	35%			

4. Discussion

This research aims to find the solution to how a view window affects the residents of apartments in Hyderabad. Window design is an important element of building construction. This is essential not only for day-lighting, but also for sustainable development, because it covers a wide range of areas, from health and well-being to environmental effect and efficiency. The literature review suggests that the view window affects the behaviour of dwellers, sustainable development, emotions, quality of view, preference of view, and accessibility of view. Case studies prove the absence of view windows and questionnaire survey verifies the importance of window view design in the current setting.

The overall findings of the study suggest that people prefer to spend time in a room with windows rather than a room without windows. The windows with views of nature have a positive impact on a person's emotional and physical health. The window view does not only improve overall life quality but also enhances the sustainable development of a building. However, in urban areas where the view of nature is limited, the quality of the view is controlled by nearby faces and their design elements. Moreover, the results suggest that the preference for views was independent of the gender and age of the dwellers, but the need for views varies from person to person depending on which part of the residence they spend the most time in.

Further points of the study are discussed below:

- Productivity in the active zones such as kitchen is compromised due to the absence of a view window.
- View window affect the emotional state of a person therefore, people such as students and researchers are less likely to concentrate on their studies because of the lack of emotional peace.
- Windows are the primary means of daylight in an urban setting, and due to poor window design, children lack vitamin D because of the insufficient sunlight in the apartments.
- People are part of nature, and connection with nature increases health and well-being. Dwellers like to spend less time in their homes due to their disconnection from nature.

Considering the current state of urbanisation in Hyderabad, views of nature are difficult to achieve. However, linking the floor-length windows of each room to balconies and installing plants on the balcony can create view of nature and privacy from adjacent buildings.

5. Conclusion

Hyderabad is rapidly moving toward vertical living due to rural-urban migration. But the city lacks consideration for urban dwelling. One of the most neglected issue is emotional well-being caused by less consideration given to window design. The study investigates the importance of window views and their impact on dwellers' emotional well-being. The research was concluded after reviewing literature and conducting a survey and case studies of apartments in Qasimabad. The study proves the negative impact of current settings regarding window design considerations. The research also concludes that the window views increase positive emotions, productivity, health and well-being and sustainability. According to the findings of the study, there is a serious need for efficient window view design considerations for apartment buildings in Hyderabad. The study suggests that architects, designers, and urban planners should reevaluate the present window view design considerations in this regard. Redesigning corridors and implementing courtyard designs in apartment buildings can help achieve window views in all rooms of an apartment.

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All the praise is due to Almighty Allah, the ever-graceful and merciful to us, who made us able to achieve all this.

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ID 125: Estimation of the Non-Biodegradable Waste Through Empirical Model

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A B S T R A C T

The accurate prediction for the quantity of the non-biodegradable waste is important for the successful management of the municipal solid waste. The modelling methods are found applicable for the accurate prediction of MSW generation rate. In this study one model is developed for the prediction of non-biodegradable waste that formed the relationships between generation rate of non-biodegradable waste and socio-economic factors such as Household income, Number of kids, Number of residents, Garden (present at home) and Restaurant visit per month. The multiple linear regression technique applied in this model for the prediction of the non-biodegradable waste in two colonies of jamshoro. The result of the model showed that coefficient of determination is 0.743 for non-biodegradable waste. The accuracy of the model showed that the predicted values is very near to actual values of waste.

K E Y W O R D S:

Multiple Linear Regression, Non-biodegradable waste, Socio-economic Factors

1. Introduction

Pakistan is struggling a significant challenge in controlling the increasing quantity of waste. This issue is caused by industrialization, increasing household size, and population growth; people are now more focused on improving their lifestyles. This affects the increasing quantity of municipal waste. It is considered Pakistan is currently facing a high generation rate of 2.49% [1]. It is perceived that non-biodegradable waste is unbreakable; it does not dispose of properly and spreads population. This research work was performed on non-biodegradable waste. Collected non-biodegradable waste from houses, schools and universities is directly disposed of by open bumping. It causes health problems in humans and animals. In the waste hierarchy, the last option is landfill, however, it releases methane in massive amounts which contribute to climate change and also Detroit's quality of soil and water. To overcome this problem scientists believe that accurate waste determination is essential to build the proper landfill size. This paper aims to determine the accurate quantity of non-biodegradable waste so that in the future accurate landfill sizes will be used to bury the waste. One of the main issues in Pakistan is the lack of reliable generation data furthermore, the estimation of waste is inaccurate because of the effective characteristics of the MSW generation process. It has been noticed that forecasting waste generation is not a simple task, and Speedy change in socioeconomic factors makes it more difficult [2]. However, some models developed to predict waste, are performing inaccurately again due to the absence of important information about the influencing factors which is answering for waste generation.[3] The regression model is the solution to the waste generation rate but is also helpful for researchers in examining the variable of MSW. Regression models have been extensively used for the prediction of MSW .The present study considered five variables such as the number of kids, the number of residents, family income, and garden and restaurant visits per month as an independent variable.

2. Literature Review

I.garcia et al (2015) used site visit method for the waste quantification and it causes many solid waste related issues for humans. However to overcome solid waste related problem this paper generates regression models to estimate the house waste generation rate per capita and also several municipality factors that contribute to waste generation. This methodology is used in the province of Biscay and province consists of 1.1 million residents. In this study nature of the dependent variable (house waste per capita) is used. Biscay province has high heterogeneity between municipalities. The author used four models, the first model was used for the complete group without irregular municipalities (PM MODEL) and the second model was used for each cluster. As a result of these models' tourism activity, schooling level, economic dynamism and resources of the population have effect on different models Author also high spot on the significance of having error-free data about both dependent and independent to get a strong model for the estimation of household waste generation [4].

A. Kumar et al (2017) developed two models one for the forecast of biodegradable and the second for the non-biodegradable waste generation rate. Some common variables affect the Municipal solid waste generation rate in previous studies such as the income of residents, schooling, and household size but some other variables such as the occupation of residents and fuel used in the kitchen were never used for the forecast models. The existing studies examine all the above five parameters for the development of the model and the two variables occupation and kitchen fuel affects the forecast of non-biodegradable waste. The R2 values for biodegradable waste is 0.782 and for non-biodegradable waste generation rates is 0.676 [5]. Kolekar et al (2016) investigated that municipal solid waste plan is a difficult process, and estimation of municipal solid waste is not easy because it depends on many factors. A number of researchers have been estimated the solid waste generation using various modelling methods. The goal of this paper is to analysis such models related to municipal solid waste generation rate. This study revealed that entire published paper are multiple in nature for application from whole country to households. The strong modelling depends on the selection of waste stream. The majority of the models depends on the correlation and regression analysis. Limited attempts have been made on the artificial intelligent system like fuzzy logic [6]

3. Study area

The research is conducted in two colonies of Jamshoro which is Sindh university employee colony Fig 1 and second is Mehran University Employee colony Fig 2. The basic aim of the selection of two societies is highly large in size and different socio-economic people are residing here. Different socio-economic peoples from different communities describe the different ways of living .This impacts the waste generation rate.

Fig. 1: Sindh university Employee society

Fig. 7: Mehran university Employee colony

4. Research methodology

The research methodology of flow chart and description is given in Figure 3. In data collection the first step is to collect the data from the houses, after selecting the houses conducing the interviews from the houses then collect the waste from the houses and do the sample analysis in the laboratory. In model development first step is the selection of the five independent variable and dependent variable, because the data is quantitative and cannot fit in the statistical software, do the assumption of data in the software, after that using the multiple linear regression analysis in the software between dependent and independent variable and generate the regression equation which tells the value of coefficient of independent variable.

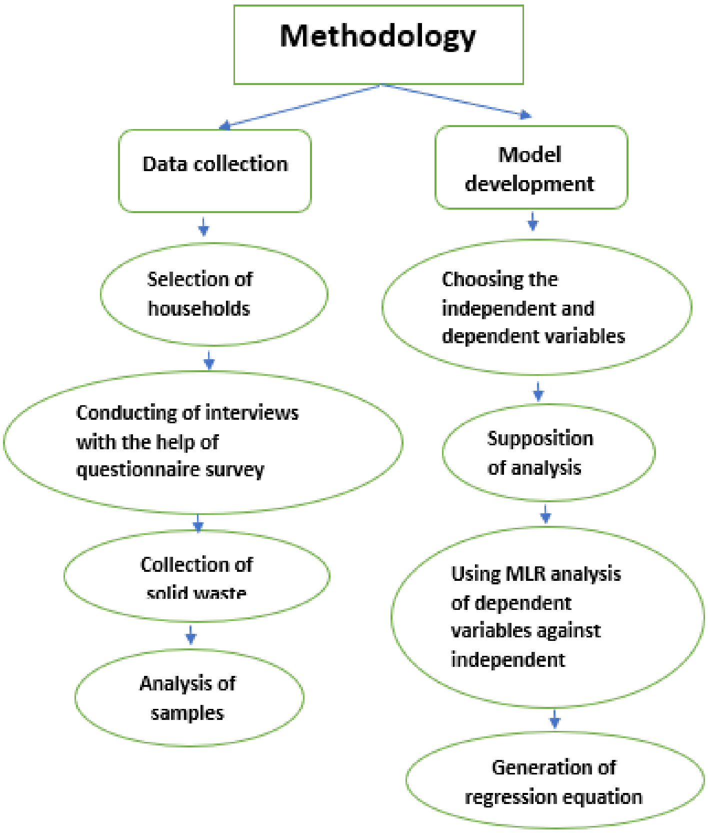

Fig. 3: Research methodology

The research methodology has been divided into two parts

- Data collection
- Model development

4.1 Data collection:

The collection of data started with the physical survey. In a Physical survey, houses of an individual society was selected. The Interview was conducted with selected households and asked questions regarding the factors which contribute to non-biodegradable waste generation rate in the house such as income of the head of the member, how many kids are living in house, number of residents, how many times residents visited restaurant in a month, and garden (present at home) Waste was collected from the houses in the individual society. For the determination of the composition of waste, one polyethene bag was given to each house and told to place all their non-biodegradable waste in the bag. The next day bags were taken from households, weighted, noted, segregated and supplied another bags to household members.

4.2 Model development

The developed model needs independent variables for the analysis of non-biodegradable waste. The principle to find out the independent variable depends on the situation. It was observed some of the reasons influence the estimation of the generation of waste and makes it difficult to estimate the Waste.

- Open dumping of waste
- Lack of sorting of waste.

Throughout the interviews and sample analysis of waste. The five variables were selected as the independent variables and statistics of non-biodegradable waste were considered as the predictor variable. Five variables were considered in this study

- Income of a household
- Garden (In house)
- Restaurant visit (Per month)
- Number of residents in a house
- Number of kids (In house)

The number of residents helps in describing the variations of waste. The second independent variable is the number of kids because it is verified that kids generate more waste. The third independent variable is total family income because it describes the family purchasing power and resources consumption power consecutively affects the waste generation rate. The fourth independent variable is restaurant visits per month, the money they spend on outdoor activities lesser the waste generated in houses and affects the waste generation rate. The fifth variable is the garden, it also affects the waste generation rate.

4.3 Model assumption analysis

Some independent variables of this study are assumed by SPSS such as income and garden. This assumption was used for the regression analysis between dependent and independent variables. The variables were assigned as a weighted numbers. Income has been divided into 3 weighted numbers. Income of more than 50,000 is assigned number 1, 31000-50,000 is assigned number 2 and 10,000-30,000 is assigned number 3. The garden variables are assigned by 2 weighted numbers. If the garden is present in the house weighted number is 1 and if it the not present weighted number is 2.The model accuracy can be checked by two error

Mean bias percentage error

Mean absolute percentage error

5. Results and Discussion

Model equation generated from SPSS software is

$$\mathbf{Y_{NON-BIO}} = -\mathbf{0.189} + \mathbf{0.040Resident} + \mathbf{0.010Resturtant} + \mathbf{0.100kids} + \mathbf{0.021Income} + \mathbf{0.006Gardens} \quad \text{(Eq: 1)}$$

From the above Eq: 1 the SPSS software generates coefficients of independent variables, all the coefficients of the independent variable is positive except intercept. It means all positive coefficient has an influence on the generation rate of non-biodegradable waste. Fig 4 is the collected data from houses placed into the SPSS Software and Fig 5 is the regression analysis of collected data from the houses. All the coefficients of independent variables and coefficient of determination can be seen in Fig 5.

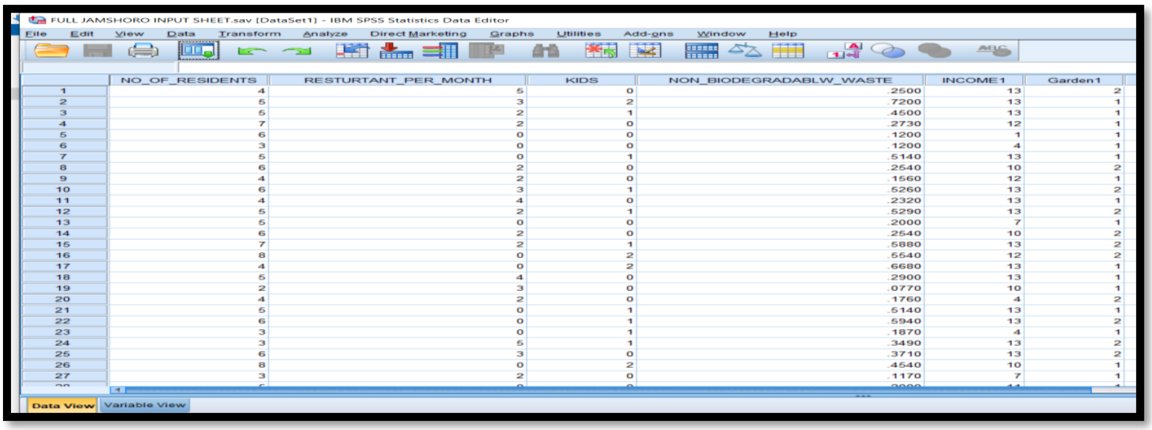

Fig 4: Data input

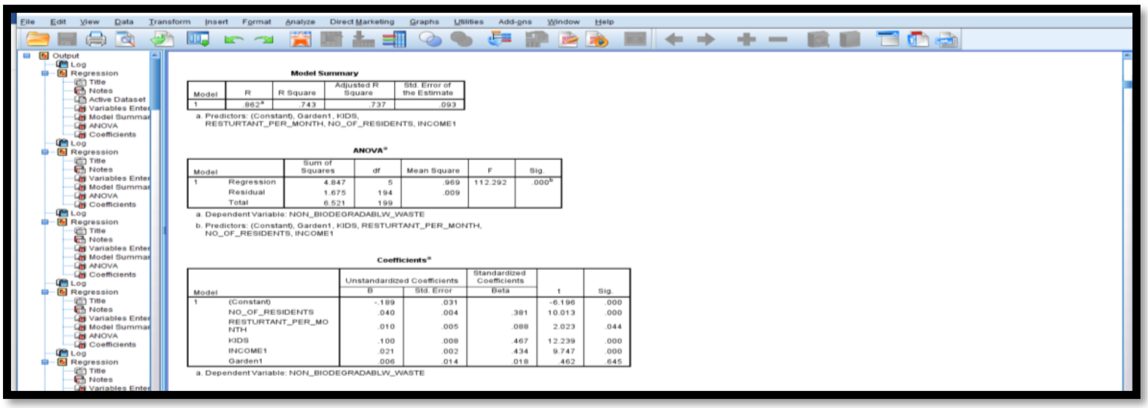

Fig 5: After regression analysis

The coefficient of determination is 0.743, it means 74% all the above independent variable has an influence on the waste generation rate of non-biodegradable waste. .The coefficient of determination is 0.743 it can be improved by adding more independent variable that has a high influence on the generation rate of non-biodegradable waste. The accuracy of the model can be checked by mean absolute percentage error and mean bias percentage error which is 26.699% and -0.907%. The model accuracy can be more improved by adding colonies, more collected data of colonies can improved the accuracy of the model.

6. Conclusion

This study is helpful to determine the estimation of non-biodegradable waste, five variables were used as the independent variable and non-biodegradable waste is considered as dependent variable. The R2 for the non-biodegradable waste is 0.743.The five independent variables is used in this study, household income, Number of family members, Number of kids, Restaurant visit per month and garden. The developed model will be used by the decision maker for the estimation of municipal waste generation.

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ID 126: Development of the Model to Estimate the Biodegradable Solid Waste Generation Rate

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A B S T R A C T

As we know the population increases day by day so the generation of the solid waste is also increases. It deteriorate the media of the environment such as land, air and water so in order to reduce the effects of solid waste. The efficient way of municipal solid waste is a difficult process. For the proper handling of solid waste it depends on the accurate estimation of the generation rate of municipal solid waste. The prediction of generation rate of solid waste effective management is needed. Due to insufficient of data different models are used for prediction the generation rate of solid waste different independent variables selected in the prediction models such as: occupation, income of family members, household size and education Previously many researchers using different modeling methods for identify the generation rate of solid waste. In the prediction of models regression analysis were used for due to its well-developed theory and simple algorithm .The prediction of municipal solid waste management depends on many factors. It has been seen that the total generation of municipal solid waste depends on total population while the chemical and physical components of Municipal solid waste depends upon a various factors such as living standards, commercial activities, food, seasonal variations, habits. The aim of this research is to develop the model to estimate the biodegradable solid waste generation rate.

K E Y W O R D S:

Solid Waste Management, Jamshoro, Biodegradable Solid Waste

1. Introduction

Now a days the solid waste is the major problem in Pakistan due to the increasing population [1]. Solid waste create the many issues on the human health as well as on the environment. Municipal Solid Waste comes from the human activities such as Domestic activities, Commercial and Operational activities. [2]. the composition of municipal solid waste is classified in to two groups first is Biodegradable and Non- Biodegradable Solid Waste [3]. In Pakistan there is no proper disposal sites of the solid waste and energy crises issues are increasing day by day so to overcome these difficulties biodegradable solid waste used as a source of energy**.** Inefficient management of solid waste create the pollution and produce greenhouse gases emissions [4]. No model developed in Jamshoro regarding the generation rate of solid waste. The developed model are less effective because they used smaller sample size and the value of R^2 reduce these impacts develop the model to estimate the biodegradable solid waste generation rate and its energy potential is needed. The modelling are necessary for develop the model for prediction of the solid waste. There are three objectives of this research first is Collection and segregation of solid waste second is Questionnaire survey to know the parameters of socio economic factors and then to develop the empirical model to estimate the biodegradable solid waste.

2. Literature Review

Kumar et al [5] developed two models using modelling, one model for the estimation of biodegradable and the second model for estimation of non-biodegradable waste generation rate. In this study the socioeconomic variables were used such as education, family income and family status factors were used for develop the models the value of R^2 was average Kolekar et al [6] asserted that the prediction of solid waste plays major role for the management of solid waste and the generation of solid waste rely on the socioeconomic factors such as income of household, and family members [7] developed three models for prediction the energy content of solid waste by finding their high heating value. Moisture Content, Fixed carbon, volatile matter, nitrogen, sulfur carbon, and the hydrogen. The three developed models used for the prediction of energy content and this energy will be used for the generation of electricity. [8] found that multiple linear regression equation was the accurate tool for prediction the generation rate of solid waste it's also help for the Solid waste management. The different socioeconomic parameters were selected according to the research area the model gives the best results. Thanh et al. [9] created mathematical models showing correlations between the rates of waste creation for the major physical categories and pertinent variables, such as household size and family income. To forecast the production of household solid waste, including food waste and plastic garbage, linear models with three variables were put out. The findings indicated that there was a relationship between the variables and that these correlations were weak. Liu et al [10] used multiple regression analysis to establish a predictive models of the energy content of municipal solid waste. The energy content was correlated with factors derived from physical composition and final analysis using two Reg ression models that were created. These models' predictions for this specific trash produced results that were highly comparable to those of equations created by other researchers (such Dulong and Steuer) to estimate energy content

Ghinea et al [11] examined and forecasted the generation of solid waste in Iasi, Romania, using Prognostic Tool and Minitab software. Compared to Waste Prognostic Tool, a software programme designed specifically for waste forecasting with variables already replanned, Minitab is more suitable for prediction, and more multiplex, and also displays the data and plots in a much better view and correlation. Regression analysis can also be strongly applied to control the changes of the response variable when a predictor variable changes the variables. Truong, et al [12] studied, a linear regression model is put forth to estimate the rates at which households produce food waste, home solid trash, and household plastic bags. According to statistical statistics, the generation rates of home solid waste, food waste, and plastic bags are directly proportional to household income and inversely proportionate to the size of a family [12]. Bureecam, et al [13] identified and quantified the factors that affect the costs of producing and collecting municipal solid waste (MSW) in Thai municipalities. Based on data collected from a survey of 570 towns nationwide, the empirical analysis was performed. The population density, household size, and size of municipality are the key determinants of trash creation, according to the conclusions of the MSW generation model [13].

Bandara, et al [14] employed nine empirical models to calculate the energy value in terms of heat from MSW (Organic Fractions of Municipal Solid Waste), of which two were based on physical composition, four on its proximate analysis, and the final three on its ultimate analysis. A comparison of all energy models reveals that some empirical models based on proximate analysis have the highest potential for energy recovery. In Pakistan there is no proper solid waste management. Due to improper of handling and collection of solid waste produce the harmful effects on human health and also negative impact on environment [15].

3. Study Area

The research is conducted from the two areas of Jamshoro. The first research area is MUET Employee Colony Fig 1. And second is Sindh Employee Colony which is Fig 2. These two societies have larger population and different socioeconomic people living in these societies. The different socioeconomic factors impact on the generation rate of solid waste.

Fig. 1: MUET employee colony

Fig. 2: Sindh University Employee Colony

4. Research Methodology

The research methodology is illustrated in Figure 3.

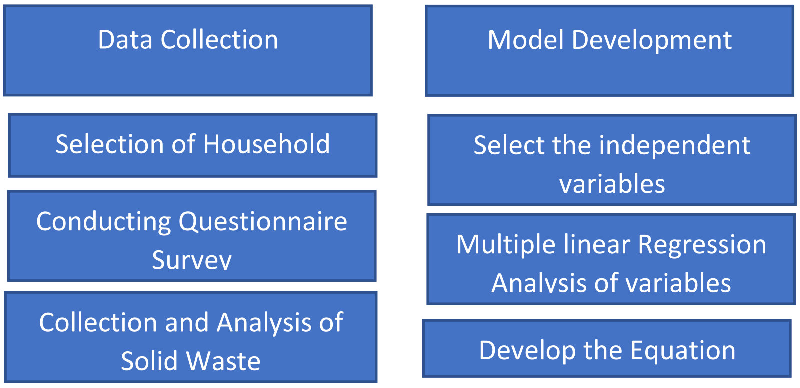

Fig. 3: Flow chart of Methodology

3.1 Data Collection

The data was collected from the two societies of Jamshoro. Personal interviews and a questionnaire survey was conducted of the selected households to collect the data such as socioeconomic factors income of household, household size, age, gender, number of family members etc. In this research, socioeconomic factors were considered as independent and the biodegradable solid waste was considered as a dependent variables.

3.2 Conducting Questionnaire Survey

The questionnaire survey was provide the data of dependent and independent variables for develop the empirical model. The survey was conducted from the two residential colonies of Jamshoro. The questionnaire survey were conducted 200 houses from the two societies of Jamshoro. For find the quantity and composition of solid waste from the selected houses Sampling was done for 2 months November and December 2022. 25 samples were collected in each day.

3.3 Analysis of Solid waste

For sample collection, one poly bags were given to each house to collect the generated biodegradable solid waste. This procedure was repeated for 8 weeks. The segregated waste was use for the physical analysis. The percentage distributions of biodegradable waste (kitchen and yard waste, paper/cardboard). The results are used for developing the Model.

3.4 Model development

After collecting the data then find the correlation between the each socioeconomic parameters and biodegradable solid waste in SPSS .If the correlation is strong then the parameter was selected as an independent variable for develop the model.

3.5 Select the Independent variables

The socioeconomic parameters were selected as independent variables because it has a direct effect on the generation rate of solid waste. In this research 5 independent variables were selected for develop the equation to estimate the generation rate of biodegradable solid waste. The Equation 1 shows the general regression equation.

Multiple linear Regression Analysis of variables:

$$Y = \gamma_o + \gamma_1 Z_1 + \gamma_2 Z_2 + \gamma_3 Z_3 + \cdots + \gamma_n Z_n \text{ Eq.1}$$

- $Y =$ Dependent variable **(Biodegradable Solid waste)**
- $\gamma_o =$ Y intercept
- $\gamma_1 =$ Coefficient of regression of the **No: of Residents** variable.
- $\gamma_2 =$ Coefficient of regression of the **Income** variable.
- $\gamma_3 =$ Coefficient of regression of the **No: of kids less than 7 months** variable.
- $\gamma_n =$ Coefficient of regression of the n^{th} independent variable.
- Z_1, Z_2 *and* $Z_3 =$ Are the socioeconomic independent variables such as **Residents, Income, Kids, Restaurant and Garden.**

3.6 Develop the Equation

For developing the MLR equation all the collected data put in the SPSS Software and then find the coefficient of the independent variables. Multiple Linear Regression analysis was used to develop a model for forecasting the biodegradable waste generation rate in kg/c/d. SPSS software was used to develop the equations the developed equation was used to find the biodegradable solid waste.

3.7 Accuracy of the model and validation

After developed the model find the MAE, MBE error to measure the accuracy of developed model the lower the error that means model gives best value.

4. Results and Conclusion

SPSS Software was used to developed the multiple linear regression equation and also find coefficients of independent variables. Figure 4 shows the results given by SPSS. The MLR equation is given by the value of R^2 was 0.814. The model gives the best fit line. The accuracy of model were checked by finding the error. The developed models will find the generation rate of biodegradable MSW and also it helps the planning and management of solid waste. The developed model will also use for the recovery of energy from the organic waste.

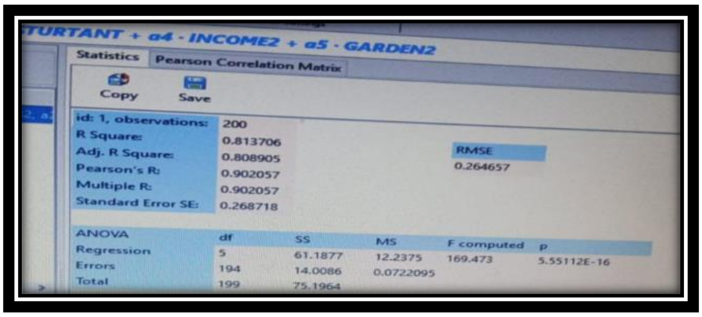

Fig 4. Results of SPSS Software

The equation No: 2 of developed by SPSS Software is given below:

$$Y_{\text{Biodegradable Solid Waste}} = -0.322+0.249\ (\text{RESIDENTS})$$

$$+ (-\ 0.195)\ (\text{KIDS}) + 0.009\ (\text{RESTURTANT}) + 0.019(\text{INCOME}) + 0.098\ (\text{GARDEN}) \quad \text{Eq. 2}$$

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ID 128: An Empirical Study on the Cost of Collection of the MSW - A Case Study of Hyderabad

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A B S T R A C T

Municipal solid waste (MSW) collection and transport are important operations in the MSW management system. Up to 70% of the MSW system costs are of these operations. This paper estimates the cost of collection of municipal solid waste in seven residential colonies of Hyderabad. The empirical analysis is based on the input data conducted through a survey, which are independent variables that affect the cost of collection. The cost of collection is separated into two costs i.e. the initial cost of collection and the operating cost of collection. Which gives two dependent variables i.e. Y1 and Y2, variables affecting the initial cost of collection of MSW are analyzed, such as the number of vehicles, hand trolleys, bins, houses, and collection points and operating costs of the collection of MSW are analyzed, such as waste generation rate, whole trip distance, frequency of collection, No: of workers, fuel and maintenance cost, and collection service charges. Through regression analysis, the coefficient of determination R^2 is estimated using excel, the R^2 for the initial cost of collection (ICOC) i.e. Y1 is $R^2 = 0.96$, and the operating cost of collection (OCOC) i.e. Y2 is $R^2 = 0.99$.

K E Y W O R D S:

Municipal Solid Waste Management, Cost of Collection, Hyderabad City, Initial Cost of Collection, and Operational Cost of Collection

1. Introduction

Solid waste management is a comprehensive system that controls the generation, storage, collection, transport or transfer, processing, and disposal of solid waste materials in a way that addresses a range of issues from public health, conservation, economic, aesthetic, and engineering, to other environmental considerations. Solid waste management of residential and commercial areas is commonly known as municipal solid waste management. The world generates 2.01 billion tons of municipal solid waste annually. Global waste generation is expected to grow to 3.40 billion tonnes by 2050, two times the population growth over the same period. Up to 70% of the MSW system costs are of these operations. The waste collection system depends on appropriate estimation and monitoring of the waste collection costs [1].

Pakistan lacks proper and sufficient infrastructure, institutional frameworks, policies, and resources for solid waste management. Even in big metropolitan cities, there are systems designed and developed but they are not sufficient, about 60-70 waste is collected from cities. Waste collection is the primary function of municipal solid waste management, if planned, designed, and implemented properly it can reduce the system cost and lower solid waste pollution [2]. In developed countries, a lot of research is carried out on the determination of the cost of collection of MSW and identifies tools and methods for its cost analysis. The whole MSW management system from 'cradle' to 'grave' includes three categories of costs, the up-front cost is an initial investment in the necessary equipment for waste collection and transport. Operating cost includes expenditures of managing MSW on a daily basis, and back-end cost involves proper disposal into landfills at the end [3].

2. Literature Review

According to the study conducted in municipalities of Thailand, a general multivariate empirical model was developed for the MSW generation and cost of collection. The cost of collection is based on fixed and variable costs.

The study takes the volume of MSW, distance, frequency of collection, and population density as the independent variables. Data was acquired through questionnaires and survey interviews. The method used in the study was based on ordinary least square regression technique. Results of the study show that predictability of MSW generation model was average and collection cost model was highly predictive [4]. Moreover, another study developed a mathematical model to use it as a tool in the management of waste collection costs. The model estimated the number of vehicles, no: of collection points, and time of the collection process. Excel worksheets used to calculate the predicted time and cost of collection [5]. In another relevant study, a mathematical model was developed to design an optimal solid waste management system by minimizing its total cost. It estimated the sum of the cost of collection at all collection points and transport costs from all in-between routes. The study estimates the different costs of collecting wastes at their sources i.e. collection cost for mixed waste, recyclable material, and yard waste. Each type of waste has a different unit and fixed cost of collection, the fixed cost depends on this area ($/km2). The total cost of mixed waste collection at time calculated by the model [6]. Furthermore, a comprehensive model was developed in the other study to predict waste generation for different collection streams by integrating the development of the collection and transportation cost model. The model was used as a predictive tool. This study focused on three areas 1) the simulation of generation, diversion and specific collection cost; 2) the effect of the addition of a new collection route; 3) the impact of the citizen participation (public awareness) on a specific collection system. The Predicted results of the study enables decision-makers to have access to very useful information [7]. In the other relevant research study, the cost of collection of plastic packaging waste was collected for recycling in two ways i.e source separation and post-separation. These have a direct influence on the cost of collection. The model is developed to identify the difference between the costs of municipal solid waste collection operations. Independent variables were vehicle cost both fixed and variable, crew cost, waste storage bins cost, as well as on emission costs (by assuming imaginary carbon taxes). The model was adopted by the Netherlands to calculate the cost of collection for all municipalities [8].

3. Research Materials and Methods

3.1 Data Collection

The seven residential colonies of Hyderabad are selected, namely: Amynabad, Mubarak, Aliabad, Al-Rahim, Karim, Fatimi, and Gulistan-e-Fatima Housing colonies. The selection of the study area is based on the preliminary survey conducted on the basis of the availability of a proper waste collection system, in order to calculate the actual waste collection cost. The study area is comprised of seven residential colonies of Hyderabad for the data collection. Which have a total of 1036 Households and 4992 populates. One individual from the management of each colony was interviewed to get the required data. Similarly, one of the crew members of the waste collection vehicle for each colony was interviewed. So, overall 14 questionnaires were conducted; Total 7 colonies, 1 management person from each colony i.e. (7 questionnaires from colony management) and 1 person of waste collection service for each colony i.e. (7 people from service).

After the selection of the study area, the survey interviews were conducted. For the survey, two questionnaires were designed. One for the colony management and the other one for the waste collection service i.e. responsible for waste collection and final disposal. Survey interviews were conducted from the colony management and waste collection service crew (private/government) of each colony as Figure 1 depicts interviews during data collection.

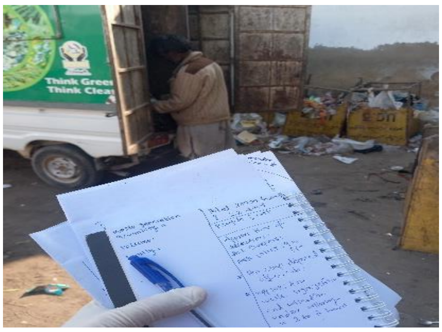

Fig. 1: Conducting survey interviews

3.2 Methodology

In the majority of the colonies, the primary collection of waste is done by the management of the colony. That is a door-to-door waste collection by sweepers from the whole colony as Figure 2 (a) shows door-to-door waste collection by sweepers. The garbage trolleys are used to collect waste from households. The sweepers then unload the trolleys onto the specified collection point, from that point the waste collection service (private/government) vehicle collects the waste i.e. the secondary collection as Figure 2 (b) depicts the unloading of waste from trolleys onto the collection point. This study also estimates the waste generation rate of each residential colony. The waste generation rate was estimated as:

$$\frac{Waste\ Quantity\ (kg)}{Population} \qquad \text{eq. 1}$$

Thus, the quantity of waste generated was calculated from each colony per day and divided it by the population of that colony and get the waste generation rate in kg/c/d as shown in eq. 1.

Fig. 2 (a): Primary collection of waste i.e. (Door-to-Door)

Fig. 2 (b): Secondary collection of waste by collection service vehicle

The empirical analysis is carried out of the input data (independent variables) with respect to the dependent variables i.e. cost of the waste collection. The total cost of the collection is separated into two costs that are: Initial cost of collection (ICOC) and Operational cost of collection (OCOC) which give two dependent variables Y1 and Y2.

4. Results and Discussion

4.1 Data Analysis

The waste generation rate is calculated by weighing the amount of waste collected in the hand trolley by the sweepers of the colony. The plastic bags were given to the sweepers to unload the waste into the bag and weigh it with help of a weighing scale as can be seen in Figure 3 (a) where a sweeper is emptying the contents of a trolley into a bag. Each trolley was weighed in this way, by adding the waste quantities of all trolleys the total quantity of waste generated was calculated as depicted in Figure 3 (b) waste bag is weighed by a weighing scale. This weight was divided by the population of the colony and we get the waste generation rate.

Fig. 3 (a): Sweeper is emptying the contents of a trolley into a bag

Fig. 3 (b): Waste bag is weighed by a weighing scale

The initial cost of the collection of MSW is the one-time investment cost. This is the cost that is invested in the purchase of the required equipment based on the number of houses in the colony. The ICOC is the Y1 first dependent variable. The operating cost of collection (OCOC) of MSW is the cost which is charged per month to run the operations of the municipal solid waste collection system. The operating cost of collection is Y2.

The initial cost of collection (ICOC) of the MSW has independent variables such as the number of collection vehicles, hand trolleys, bins, houses, and collection points. Whereas, the operating cost of the collection of MSW has independent variables such as waste generation rate, whole trip distance, frequency of collection, No: of workers, fuel and maintenance cost, and collection service charges.

4.2 Determination of Coefficients of Correlation

The coefficients of correlation are estimated to find the relation between the dependent variable with each independent variable. The correlation between Y1 and no: of hand trolleys, bins, houses, and collection points is

0.63, 0.64, 0.69, and 0.72. The correlation between Y2 and waste generation rate, whole trip distance, frequency of collection, No: of workers, fuel and maintenance cost, and collection service charges is *-0.91, -0.03, 0.83, 0.85, 0.49, and 0.35.*

4.3 Multiple Linear Regression Analysis:

Through multiple regression analysis, the coefficient of determination R^2 is estimated in Excel, and empirical equations are developed. The R^2 for the initial cost of collection (ICOC) i.e. Y1 is $R^2 = 0.96$, whereas the operating cost of collection (OCOC) i.e. Y2 is $R^2 = 0.99$.

The Empirical Model Equation of the Initial Cost of Collection Y1 of MSW developed:

$$ICOC = 76552.28\,Collection\,Vehicles + 88057.39\,Hand\,Trolleys - 15241\,No;of\,Bins - 2955.14\,Houses + 294633.4\,collection\,points$$

eq. 2

The Empirical Model equation of Operating cost of collection (OCOC) Y2 developed:

$$OCOC = -51801\,generation\,rate - 405.08\,distance + 3986.51\,Frequency\,of\,collection + 8006.08\,workers + 2.12641\,fuel\,\&\,maintenance\,cost + 0.83189\,Collection\,service\,charges$$

eq. 3

To compare the initial and operational costs of the collection of the MSW predicted by the developed models to the actual or calculated cost of collection graphs are created in excel as shown in the Figure 4 and Figure 5.

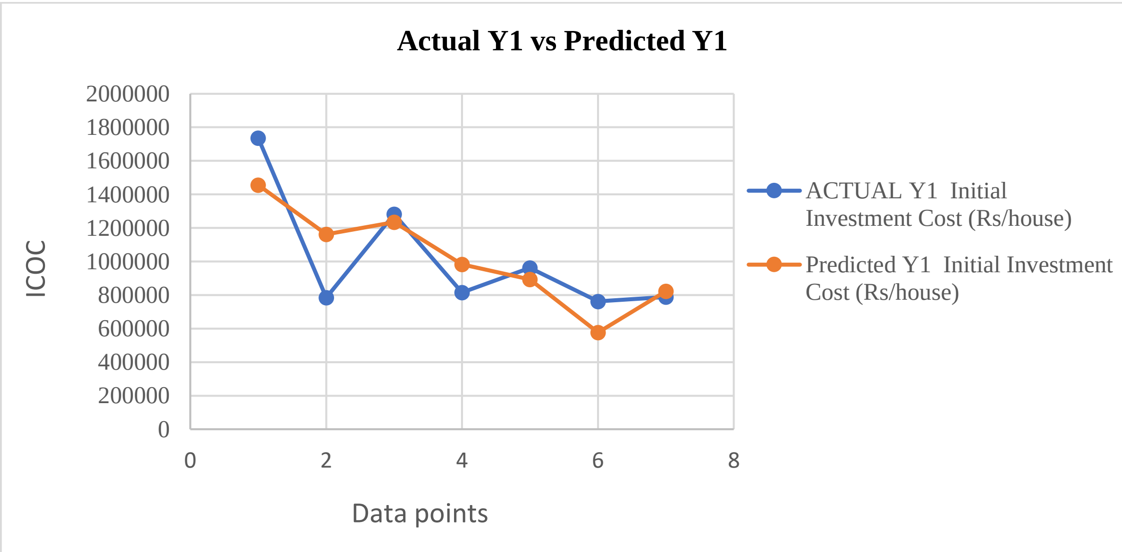

Fig. 4: Graph between the predicted Y1 and Actual Y1

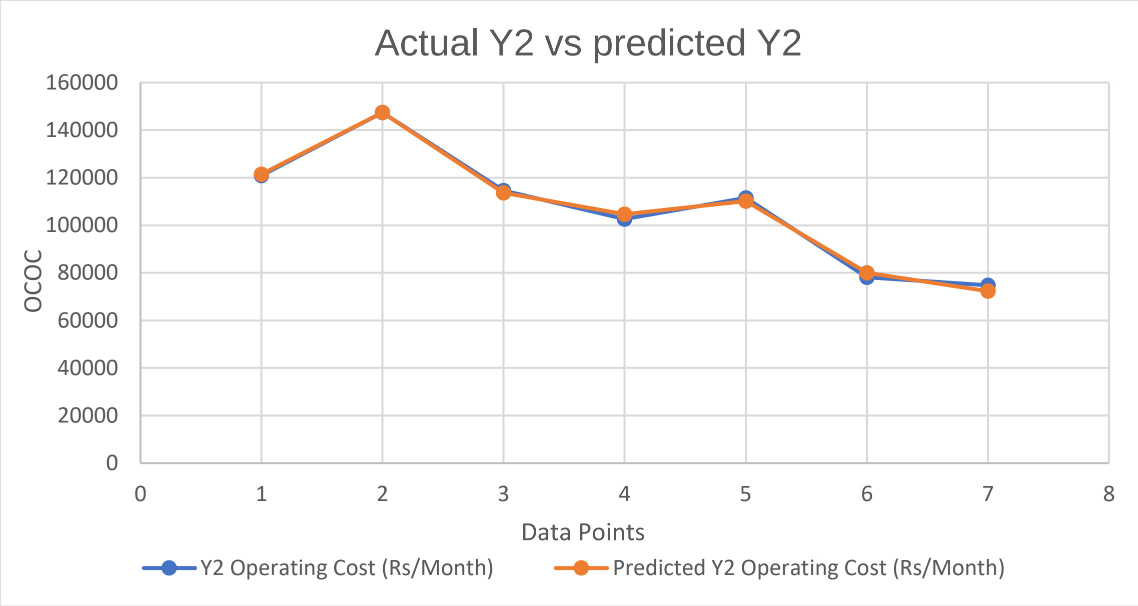

Fig. 5: Graph between predicted Y2 and Actual Y2

4.4 Discussion

By the correlation coefficients of the independent variables with their respective dependent variables. It is found that the Initial cost of collection Y1 shows a strong correlation with its all independent variables. Whereas, Operating cost of collection Y2 shows a very strong negative correlation with WGR and a very strong negative correlation with Frequency (days/week) and No: of workers. It has a negative weak correlation with distance, and a positive weak correlation with F&M cost, and collection service charges. Furthermore, it is observed that the Y1 and Y2 show good R^2 values. However, Y2 has an accurately predicted cost hence, has a mean absolute percentage error (MAPE) of 1.450 % and a mean bias percentage error (MBPE) of 0.065%. Whereas as compared, Y1 has a fine prediction and has a mean absolute percentage error (MAPE) of 17.803% and a mean bias percentage error (MBPE) of 17.803%.

Thus the models developed can be utilized to estimate the initial investment cost and operational cost of the collection of MSW in the pre-designing and post-designing phases of the waste collection system of any residential colony. The models can be useful for municipal solid waste management companies since it allows benchmarking and variance analysis.

5. Conclusion

Increased population has led to rapid urbanization that turned in a huge generation of municipal solid waste quantities. There is the utmost need for effective waste collection system operations, with easy techniques, environmentally effective, and economically sustainable approaches [9]. In Pakistan unfortunately, People opt for open dumping instead of a proper waste collection system. It is said that in the MSW management 70% of the cost is of collection and transportation. The whole system from collection to its safer disposal requires special attention. Moreover, public awareness can also help the system more. Public awareness campaigns should be started to make people realize how they can benefit from a sophisticated waste collection system. These programs would definitely aware the public, which is an important stakeholder in the reduction and proper management of municipal solid waste. The local government lacks an appropriate municipal solid waste collection and disposal system. This can be because of a lack of resources, accountability, and planning and maintenance. The present study estimates the cost of collection of municipal solid waste in seven residential colonies of Hyderabad. An empirical analysis is carried out based on the input data conducted through a survey, which are independent variables that affect the cost of collection. The cost of collection is separated into two costs i.e. the initial cost of collection and the operating cost of collection. Which gives two dependent variables i.e. Y1 and Y2, variables affecting the initial cost of collection of MSW are analyzed. The results show that the coefficient of determination R^2 is estimated using excel, the R^2 for the initial cost of collection (ICOC) i.e. Y1 is $R^2 = 0.96$, and the operating cost of collection (OCOC) i.e. Y2 is $R^2 = 0.99$. This gives the estimates of the cost of collection of MSW of any residential area by considering the respective independent variables. Thus an empirical analysis can be used to estimate the influencing factors and propose the cost of collection of an MSW. Thus the models developed can be utilized to estimate the initial investment cost and operational cost of the collection of MSW in the pre-designing and post-designing phases of the waste collection system of any residential colony.

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