

Causes of Heat and the Consequences on Construction Project in Extreme Hot Weather: A Case Study of Sindh

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Abstract: Highly concerned issue of global warming is affecting the workers of several outdoor industries including construction. Health and safety parameters of such industries are extremely important to be assessed and tackled. Current research work presents a crucial aspect of the regions having hot weather i.e., causes and consequences of stress generated due to heat, affecting the construction projects. Case-based analysis was conducted within the planned scope. Numerous causes of heat stress are categorized in four group i.e., metrological, personal, working practices, protective equipment. The analysis also revealed that ‘Productivity losses’, ‘Bad quality work’ and ‘Delay in project completion’ are the top-most critical consequences of heat stress.

Keywords: Heat Stress, Consequences, Construction Manpower, Health & Safety, Extreme Hot Weather, Sindh

I. INTRODUCTION

Construction manpower can face several conditions in their routine activities that can cause heat stress, hence different consequences occur. Heat stress is a hazard for manpower. It is generated inside human body through several causes while working in extreme hot weather at construction sites. Few of the factors that can cause heat stress at site are sun radiations, high air temperature, air stagnant, and high humidity [1], being older than 60, severe obesity, use of certain medications, previous heat-related illness, presence of certain concurrent diseases [2], shades/hats/caps not provided to labor for preventing direct sunlight during working, unavailability of rest tent at site, unavailability of potable water, prohibition of job rotation, utilizing manpower continuously without rest [3], lack of safety supervision, unavailability of emergency treatment services, untrained/unaware worker’s regarding heat stress[4], and wearing of PPEs can also cause of heat stress at a construction site [5], [6]. Extreme hot weather can result in harms and losses for construction sector laborers. The consequences appear in the shape of plentiful losses such as, Heat stress hazard for labor health and safety, Project time and cost overruns, penalties, Construction firm losses instead of benefits, Collapse of overall reputation of the firm etc. [7], [8]. Though the developed countries have discovered some remedies to minimize the impact of this hazard, whereas developing countries like Pakistan still lag to solve it [9].

II. LITERATURE REVIEW

A. Causes and consequences of heat stress

The heat stress factors raise the internal temperature of human body and when internal temperature crosses its maximum sustainable limit, heat stress is occurred [10]. Internal body temperature of human transfer to the surrounding environment through radiation, convection, and conduction, when the ambient temperature of the surrounding air is raised to 32°C or higher, then the process of radiation, convection, and conduction stops working and sweating takes place to cool down the internal body temperature [11]. Physical movement of human generates metabolic heat inside the body known as core body temperature, whereas outer environment temperature also plays an important role to increase or decrease human internal temperature [12]. The comfort temperature for labor working in which optimal productivity can be achieved is 10°C to 21°C [13]. However, labor can work easily during summer season if the temperature is lying between 21°C to 31°C, when relative humidity less than 30% [14], [15]. However, when temperature and relative humidity or one of them cross the mentioned limits, then it converts into a silent hazard [16]. The maximum sustainable temperature limit of human’s internal body is 37°C and above 38°C may result in short-term illness, long-term illness or even death in extreme cases [17]. In this situation, if labor continuously works without rest then the chances of death are increased [18], [19]. Surrounding air temperature plays a main role to generate the heat stress during execution phase. The second law of thermodynamics explains that, heat always transfer from hot region or cold region towards normal region of temperature [20]. When outdoor temperature is less than that of body temperature, then the internal body temperature easily transfers from body to surroundings through radiation process. Whereas, if outdoor temperature higher than body temperature, then surrounding temperature transfers inside the body. Therefore, heat stress is continuously raised due to outdoor temperature and human physical activity [21]. However, there are several other reasons which are involve increasing the heat stress of manpower during working in extreme hot weather [22].

When outdoor temperature reaches at 32 °C then internal body temperature becomes 37 °C, if the outdoor temperature increases from 32 °C then the internal temperature of human body will also increase from 37 °C which is known as basic effective temperature [23]. However, in this scenario if human doing physical activity then internal body temperature frequently boost up which is known as extreme hazardous temperature [1]. The significant drop occurs in human mental and physical performance at 38 °C [24], whereas at 39 °C or above heat stroke taken place which can be morbid or mortal [18]. The inside body temperature must be maintained below 37 °C limit, if temperature increase from the specified limit then there will be higher chances of mental disorder or physical disorder [21].

Extreme snow, extreme precipitation, and extreme wind creates physical barriers for the construction manpower, whereas extreme hot weather makes a different hazard profile like a silent killer [25]. In the entire 20th century, average increase in temperature was 0.76 °C, whereas in the starting decade of 21st century the average increase in temperature is 0.60 °C [26]. In addition, personal protective equipment (PPE) also play an important role to increase the chances of heat stress accidents [5], [6]. During 1985 to 1990 in America, when labor death toll increased due to heat exhaustion or heat stroke, then American conference of governmental industrial hygienists declare the law that labor should not be allowed to work when their internal body temperature reaches 38°C [27]. In the Gulf countries, outdoor manpower is not permitted to work at site during noon hot hours of the day (from 12:30 to 15:30) during three hottest months of the summer season which are May, June, and July [28], [29]. U.A.E summer temperature reaches at extremes level up to 50 °C or above, whereas the U.A.E construction industry is one of the successful industry of the region because government strictly implements the precautions as a rule and law for construction sector regarding manpower utilization in extreme hot weather [30]. Also, in the Hong Kong government implements work pattern/ work schedule for operations of construction sector during summer season [3].

Heat stress is a gigantic problem for outdoor manpower because it is hazard for health and safety, particularly in extreme hot weather during summer season it becomes active [11]. Heat exhaustion and heat stroke as a result of heat stress, directly affect labor health and indirectly affects their performance. Therefore, labor productivity losses happen which is verified by mathematical models through the relationship between extreme hot weather and labor productivity at a construction site [8]. Forecasting the losses in labor productivity, it is clear evidence that extreme hot weather negatively effects the labor performance [31], [32]. Construction Workers Productivity (CWP) losses also calculated and proved it through thermal comfort index i.e. Predict Mean Vote (PMV) [33]. Hence, it is clearly proved that extreme hot weather is a serious hazard for construction manpower which is mounting day by day due to the increase of global temperature continuously since past few decades. Global warming creates difficulties especially for the outdoor working industries as well as construction industry [34]. It is a very serious issue which is frequently discussed on the world level forum because global warming negatively affects all the industries either indoor or outdoor [35]. However, few measures are invented for the indoor industries to sustain manpower performance but outdoor industries like construction industry still lag in this regard [36].

B. Pakistan's construction sector

As per BBC News, June 2015 in Karachi (capital of Sindh) more than 1300 people were died due to heat stroke among them 60 % of mortalities belongs to construction sector [37]. There are several other heat stress accidents which were reported from different regions of the world [38]. ISO-7933:2004 and ISO-9886:2004 introduced the safe limits of human internal body temperature i.e. 37 °C, also recommended by [39-41]. Pakistan's construction sector faces the heat threats especially south region (Sindh province) more vulnerable. Extreme hot weather occasion of region begins from the month of May up to the month of July, in these months' temperature can rise up to 50 °C or above [37]. According to 47 years record since 1960 to 2007 during the months of May to July at different locations in the country, the permanent increment in temperature was 3° C [42]. Pakistan climate projection (PCP) indicates that there will be 5° C permanent increment in temperature by the end of 21st century due to global warming [34]. According to Pakistan Metrological Department (PMD), the air temperature of Sindh province become very hot in every summer season [34], [43]. Several accidents of injuries and deaths of outdoor manpower were reported in every summer season especially in the capital of Sindh [9]. This research paper aims to identify the causes of heat stress and their consequences on manpower at a construction site in extreme hot weather during the summer season at Sindh province of Pakistan.

III. METHODOLOGY

The objective mentioned in this research work, is accomplished by the questionnaire survey. In this survey, the factors identified from literature were further investigated and ranked by using Likert Scale. There are five options against every factor i.e. Never Happen, Rarely Happen, Sometime Happen, Mostly Happen, and Always Happen. Respondents must tick only one option against every factor. Total one hundred and twenty (120) hard copies of questionnaire were distributed among the respondents, from which one hundred and three (103) hard copies of questionnaire were received. The factors were analyzed with the help of SPSS software and MS Excel, the results are mentioned and discussed in the following section.

IV. RESULTS AND DISCUSSION

The causes of heat stress identified through the literature review were assessed further via the interviews and questionnaire surveys. The results were grouped into four categories as shown in Fig. 1 below: "Wearing of PPEs", "Metrological Factors",

“Personal Factors” and “Working Practices”. The topmost emphasized and causative factors of heat stress were found out to be high air temperature, high humidity, low wind speed, unavailability/no usage of rest tents, sun radiations after the survey. Several others are mentioned in Fig. 1 with respect to their ranks.

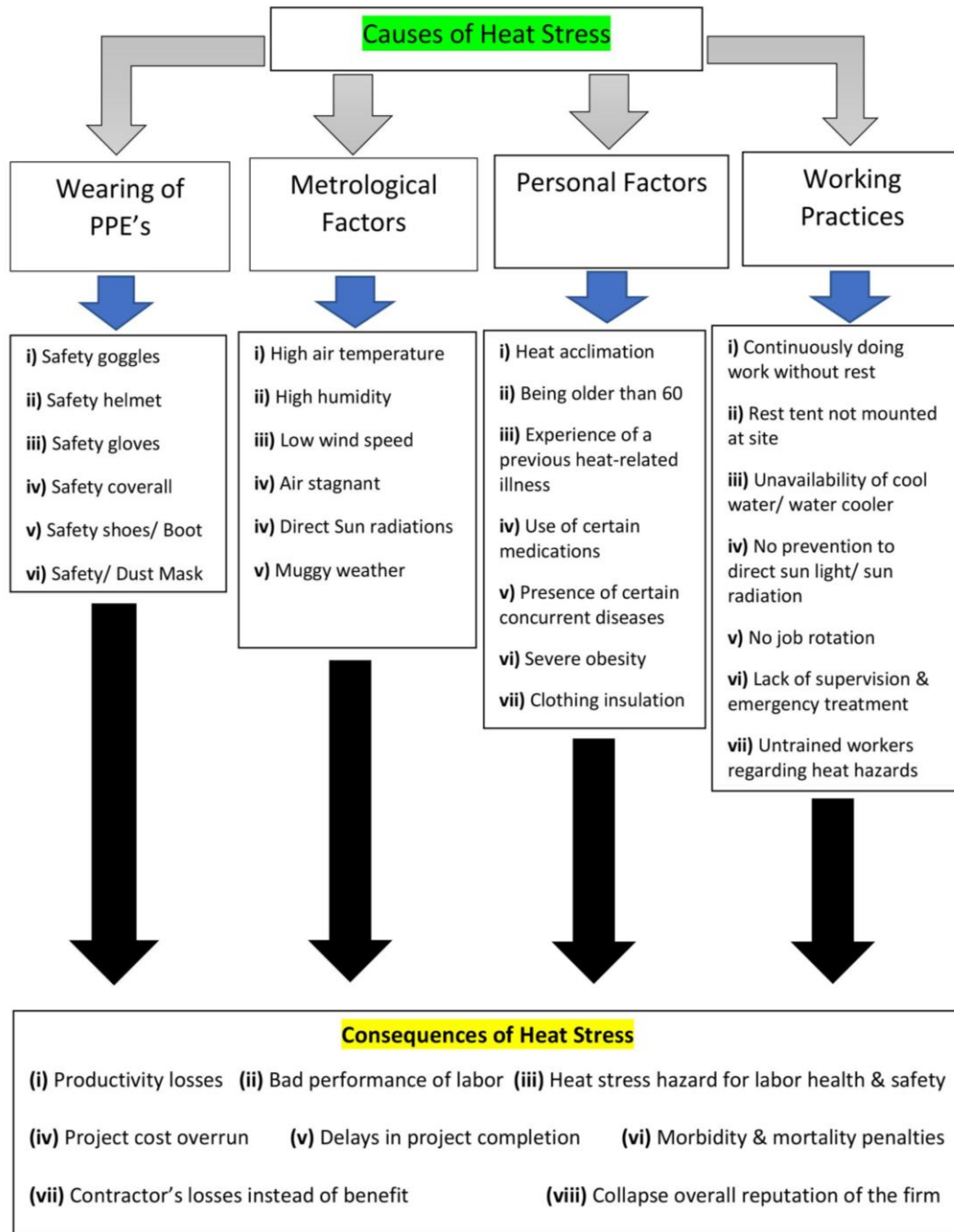


Fig. 1: Causes of heat stress

Further, focusing on the second part of this research work, which is the consequences of the heat stress. The survey results are tabulated below (Table 1). The highest ranked consequence was the Productivity losses with the mean value of 4.64, which is ultimately leading to all other errors and faults. It affects the quality (2nd ranked factor: Bad performance of labor), Heat stress hazard for labor health & safety, ranked 3rd. Project cost overrun (ranked 4th with the mean value of 3.82), and in terms of delay (5th ranked factor: Delays in project completion). Whereas, due to heat exhaustion mostly manpower takes the short-cuts to do and finish work fast, in this scenario (6th ranked factor: Morbidity & mortality penalties) comes into play. Hence, (7th ranked

factor: Contractor's losses occur instead of benefits). At the last contractor goes in trouble from all aspects (8th ranked factor: Collapse overall reputation of the firm) with mean value of 2.83.

Table 1: Consequences of Heat Stress at Work Site

Consequences of Heat Stress	Mean	Rank
Productivity losses	4.64	1
Bad performance of labor	4.23	2
Heat stress hazard for labor health & safety	3.97	3
Project cost overrun	3.82	4
Delays in project completion	3.39	5
Morbidity & mortality penalties	3.02	6
Contractor's losses instead of benefit	3.00	7
Collapse overall reputation of the firm	2.83	8

V. CONCLUSIONS AND SUGGESTIONS

The conclusions are drawn based on relative literature review factors and structured interviews survey with the field experts of construction industry. During the course of research, it has been successfully pointed out the wide-ranging catastrophic effects heat stress has on the laborers, not only it is damaging their health and creating a serious threat to their live afterwards, but it also effects negatively on the projects being carried out. The methodology adopted to ascertain the issue is initially affirmed by an extensive literature review, and the results point out the similar problems associated with hot weather areas. By adopting the preventive and corrective measures the hazard to the life can be minimized or altogether eliminated and can vastly improve the performance of the project. UAE & other gulf Countries, Hong Kong and many other developed countries are made the efficient and effective rules, procedures, methods, laws, techniques, etc. for outdoor working industries including construction industry to utilize the labor in healthy and safe environment, to achieve optimal productivity with good quality performance. Because, the outdoor temperature of some months in summer season become very hot in most of the countries around the world is recorded up to 50°C +, which is also recorded in Pakistan by Metrological department. Whereas in Pakistan still follow the previous working practices, methods, procedures, hence accidents happen. This is an alarming situation for the outdoor industries including construction industry to ponder for the safe working and efficient working conditions for the labor resource.

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