Evaluation of Ordinary Concrete Having Ceramic Waste Powder as Partial Replacement of Cement

Muhammad Abubakr[1], Anwar Khitab[1], Shamsher Sadiq[2], Waqas Anwar[1], Seema Tayyeb[1]

[1]*Department of Civil Engineering, Mirpur University of Science and Technology, Mirpur, AJ&K*
[2]*Department of Civil and Environmental Engineering, Hanyang University, South Korea*

Abstract: **Cement is the most important ingredient of concrete mix. Cement is useful as well as an environmentally hazardous material. Huge amount of CO_2 is emitted during its manufacture. Present study aims to partially replace the cement in concrete by ceramic waste powder (CWP). CWP from local ceramic factory was acquired. The chemical composition of CWP confirmed that it possessed the pozzolanic characteristics. Control concrete specimens along with those containing 10 % and 20 % partial replacement of cement by CWP were cast and tested against slump, density, compressive and flexural strengths. The results revealed that the compressive strength reduces by a margin of 11% and 23 % of that of control specimens for 10 % and 20 % replacement respectively. However, there is an increase in workability, density and flexural strength of the concrete. Based on the results, it is recommended that finer ceramic particles passing through ASTM sieve # 200, with an admixture may be used to counter the reduction of compressive strength of the concrete containing partial replacement of the cement by CWP. This will reduce the environmental hazards, posed by the CO_2 emission by cement and environmental burden due to deposition of CP in landfills.**

Keywords: **Concrete, Cement, Ceramic Powder, Workability, density, Compressive Strength, Flexural Strength, Environment.**

I. INTRODUCTION

Concrete is the most versatile and most widely used construction material worldwide. Concrete is the best building material as compared to stone, brick or steel etc. The present use of cement is evaluated to be around 12 million tons for each annum and is as yet expanding by each passing day [1]. Concrete is used in many types of construction like houses, roads, bridges, hospitals and commercial centers etc. Concrete is the combination of cement, coarse aggregate, fine aggregate, water and admixtures. Due to large use of concrete, the demand of cement is also increasing with every passing day. The production of cement is very hazardous to the environment as it produces heat and also an excessive amount of CO_2. Similarly, the materials required for the production of the cement also pollute the environment and cause the depletion of our natural resources. Other constituents of concrete can also pollute the environment like coarse aggregates, which are obtained by cutting and blasting of hills and mountains. Some serious efforts are being made all over the world to minimize the use of concrete and replace concrete with such suitable materials, which give the properties similar to the concrete. The emphasis is being put forth on the utilization of industrial and agricultural wastes, as they are the environmental burden [2,3]. Their safe deposition requires a lot of efforts and still they remain a burden to our environment. Their usage in concrete is very advantageous. It will not only be financially viable, but it will also reduce the demand of cement thus protecting our environment. The utilization of industrial wastes and agricultural wastes will also help us in their safe disposal. In this research project, local pottery industry waste was used which is ceramic waste. This ceramic waste is readily available as, there is no other use of this ceramic waste. The owners of the ceramic industry face many problems in disposing the ceramic waste. Owing to the environmental problems associated with cement, the partial replacement of cement by a local waste material will not only lessen the requirement of cement in construction projects, but also the corresponding dumping of the waste in landfills will be reduced. After detailed examination of its properties with the help of standard tests like XRF, strength activity index, and particle size analysis etc., it was evaluated that waste ceramic powder has the capabilities to partially replace cement in concrete. The waste material was ground to fine powder and was used as partial replacement of cement in concrete. The resulting concrete was evaluated in terms of various physical and mechanical properties.

II. MATERIALS AND METHODS

Three types of specimens were prepared: Control, and the ones having 10% and 20% replacement of cement by CWP. Ordinary Portland Cement (OPC) was acquired from a local industry namely, Best way. The CWP was obtained from a pottery industry of the nearby Gujrat city in Punjab province of Pakistan. The chemical and physical characteristics of OPC and CWP are mentioned in Table 1 and Table 2 respectively.

Table 1 Chemical composition of OPC

Components	Percentage	
	OPC	CWP
Lime	61	2.15
Silica (SiO_2)	30	72.5
Aluminum Oxide	5	20
Iron Oxide	2	1.2
Magnesium Oxide	1	0.02
Gypsum	1	
Na_2O	-	3.2
K_2O	-	0.45
LOI		0.08

Table 2 Physical characteristics of OPC

Color	grey
Specific gravity	3.14
Normal Consistency (%)	26.5
Soundness (mm)	2
Fineness (%)	8.53
Initial setting time (minutes)	30
Final setting time (minutes)	600
Bulk density (Kg/m^3)	1300

Sand was acquired from the local river Jhelum in Mirpur district of Azad Jammu and Kashmir, whereas coarse aggregates were obtained from local Mangla query. The important physical characteristics the aggregates are mentioned in Table 3 and Table 4.

Table 3 Physical characteristics of fine aggregates

Specific gravity	2.61
Fineness Modulus	2.72
Bulk density (Kg/m^3)	1500
Dry roded Bulk density (Kg/m^3)	1850
Water absorption (%)	1.57
Water content (%)	2.00

Table 4 Physical characteristics of coarse aggregates

Specific gravity	2.51
Bulk density (Kg/m^3)	1601
Water absorption (%)	1.49
Void (%)	34.11
Impact value (%)	13.20
Crushing value (%)	28.20

The composition of the concrete is shown in Table 5. The specimens were prepared as per ASTM C31 standard method [4]. The workability was determined by slump method using ASTM C 143 standard method [5]. The fresh density was determined by using ASTM C138/C138M—17a [6]. The compressive strength was determined by using ASTM C 39 [7] and the flexural strength was determined by using ASTM C78/C78M standard method [8].

Table 5 Concrete composition

Specimen ID	Mix Design	W/C ratio	Cement (kg/m^3)	CWP (kg/m^3)	Sand (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (kg/m^3)
C0 (1)	1:0.98:2.45	0.38	16.191	0	15.87	39.668	6.15
C0 (2)	1:0.39:1.90	0.38	21.794	0	8.52	41.409	8.28
C10 (1)	1:0.98:2.45	0.38	14.572	1.619	15.87	39.668	6.15
C10 (2)	1:0.39:1.90	0.38	19.615	2.179	8.52	41.409	8.28
C20 (1)	1:0.98:2.45	0.38	12.953	3.238	15.87	39.668	6.15
C20 (2)	1:0.39:1.90	0.38	17.453	4.341	8.52	41.409	8.28

III. RESULTS AND DISCUSSION

A. Workability

The results of the slump test are mentioned in Figure 1. It can be seen that the workability drastically increases with increase in the CWP content. From the results, it is evident that the waste ceramic powder is acting as an admixture. The workability increases more than two times that of the control specimens. Based on the results, it is recommended to use ceramic powder as partial replacement of cement, where an enhanced workability or ready mix concrete mix is required. The reason for increase in workability lies in the fact that the hydraulic reaction of ceramic waste powder is slow, and as such more water is available than in case of pure cement at the time of casting: The availability of more water results an increase in the workability [9]. The workability results are also in line with those reported by Ahmed et al. [10].

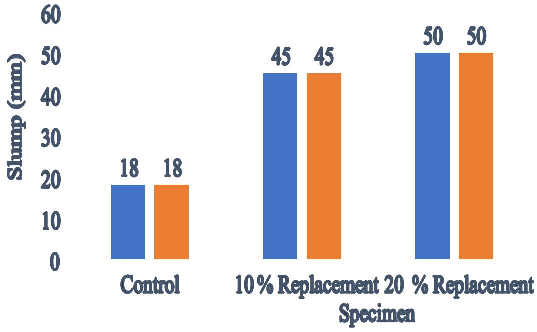

Fig. 1 Workability of concrete as a function of CWP

B. Fresh density

The density results of control, 10 % and 20 % replacement by CWP are shown in Figure 2. Results show that ceramic particles provide higher density, if cement is partially replaced by them in concrete. Ceramic particles owing to their smooth texture provide lesser friction. At the time of casting, the CWP particles are acting as filler owing to slow and late hydration reaction and due to their small size, act as filling narrow voids in the mix. This filling effect of ceramic powder particles result in higher density than that of the control specimens [11].

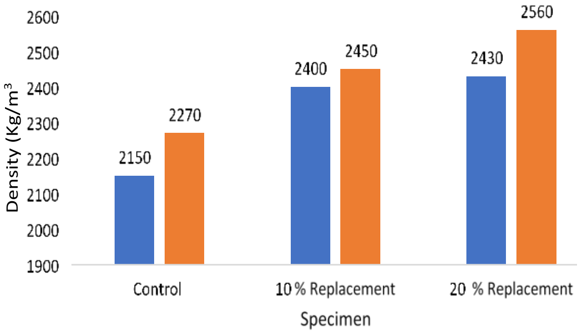

Fig. 1 Variation of fresh density as a function of CWP content

C. Compressive strength

The compressive strength results of control, 10 % and 20 % replacement at 14 and 28 days are shown in Figure 3 and Figure 4 respectively. The compressive strength reduces with increase in the replacement of cement by ceramic particles. The ceramic particles used in this study were those, which passed through ASTM standard sieve # 100. The cement particles are finer as more than 90 % pass through sieve # 200. Coarser the size of a pozzolanic material, lesser is the surface area available for hydration. The coarser size of the ceramic particles therefore resulted in lesser compressive strength. Based on the results of the density measurements, it also follows that a portion of the ceramic particles served the purpose of filling voids and gaps in the mix, which might also be a reason in obtaining lesser compressive strength of the mixes containing partial replacement of cement by ceramic particles.

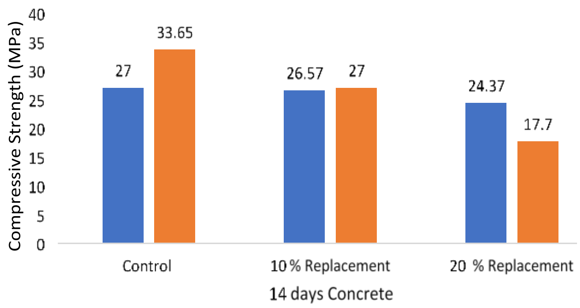

Fig. 2 Variation of compressive strength as a function of CWP content at 14 days age of concrete

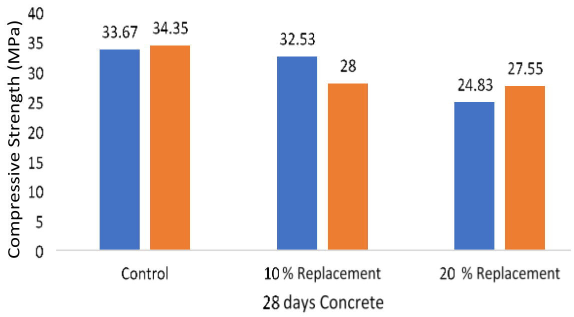

Fig. 3 Variation of compressive strength as a function of CWP content at 28 days age of concrete

D. Flexural strength

The flexural strength results of control, 10 % and 20 % replacement at 14 and 28 days are shown in Figure 5 and Figure 6 respectively. The flexural strength somehow is equal to that of the control specimens. Based on the results, it is recommended to use ceramic powder as partial replacement of cement, where flexural strength is important requirement. Some other pozzolanic materials also increase the flexural strength as reported by Pavan Kumar et al [12].

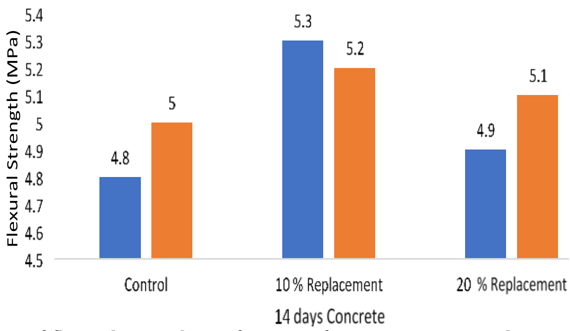

Fig. 4 Variation of flexural strength as a function of CWP content at 14 days age of concrete

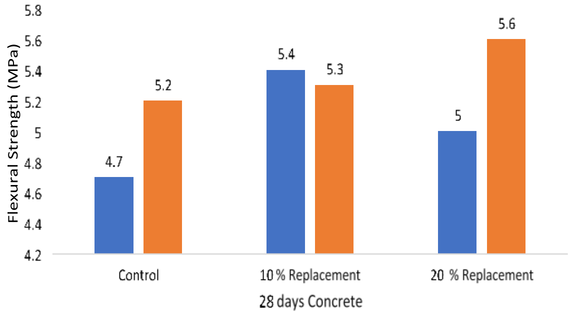

Fig. 5 Variation of flexural strength as a function of CWP content at 28 days age of concrete

IV. CONCLUSIONS

Owing to a number of pottery industry in Pakistan, the resulting waste causes many environmental issues. The dumping of waste material in landfills is also a worldwide problem. Cement itself is an environmentally hazard material. This study is useful as it focusses all three above mentioned issues of extreme importance. From the experimental study, following conclusions are drawn:

1. Ceramic powder results an increase in workability when used as partial replacement of cement.
2. The rate of workability increase is slower beyond 10%.
3. Ceramic powder results a reduction in compressive strength. A 10% replacement causes a decrease of 11% in strength at 28 days.
4. For 10% replacement, flexural strength increases by 7% at 28th day.
5. For future, finer ceramic particles (passing sieve #200) are recommended so as to make a study with comparable size of cement particles.

REFERENCES

[1] A. Khitab, Materials of Construction, 1st ed., Allied Books, Lahore, Pakistan, 2012. https://docs.google.com/document/d/1tLJVz4fQMBccu1sFypSqjWvmW1NkTHHL59N3-BURJKQ/edit (accessed March 8, 2019).
[2] R. Senthamarai, P. Devadas Manoharan, Concrete with ceramic waste aggregate, Cem. Concr. Compos. 27 (2005) 910–913. doi:10.1016/j.cemconcomp.2005.04.003.
[3] M. Batayneh, I. Marie, I. Asi, Use of selected waste materials in concrete mixes, Waste Manag. 27 (2007) 1870–1876. doi:10.1016/j.wasman.2006.07.026.
[4] ASTM, ASTM C31: Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory, Annu. B. ASTM Stand. (2013). doi:10.1520/C0192.
[5] ASTM C143/C143M, Standard Test Method for Slump of Hydraulic-Cement Concrete, West Conshohocken, Pennsylvania UnitedStates, 2015. doi:10.1520/C0143_C0143M-15A.
[6] C138/C138M—17a, Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete, West Conshohocken, Pennsylvania UnitedStates, 2017.
[7] ASTM C39, ASTM C39: Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM Int. (2015) 1–7. doi:10.1520/C0039.
[8] ASTM C78/C78M, Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading), West Conshohocken, Pennsylvania UnitedStates, 2018.
[9] Amr S.El-Dieb, Dima M.Kanaan, Ceramic waste powder an alternative cement replacement – Characterization and evaluation, Sustain. Mater. Technol. 17 (2018). doi:10.1016/j.susmat.2018.e00063.
[10] B. Ahmed, S.M.Z. Islam, M.T. Hossen, H. Ahmed, M.R. Islam, Eco-Friendly and Cost-Effective Design of Concrete Pavement Using Used Foundry Sand and Tiles Dust, Nano Hybrids Compos. 23 (2018) 46–54. doi:10.4028/www.scientific.net/NHC.23.46.
[11] S. Hafiz, Waheed-ul Hasan, Alamgir, H. Ahmed, S. Mubin, EXPERIMENTAL INVESTIGATION OF TENSILE ANDFLEXURAL STRENGTH OF CERAMIC WASTE CONCRETE, Pak. J. Sci. 66 (2014) 67–73.
[12] Y. M. Pavan Kumar, The Behaviour Of Concrete By Partial Replacement Of Fine Aggregate With Copper Slag And Cement With Ggbs - An Experimental Study, Iosr J. Mech. Civ. Eng. 12 (2015) 51–56.