Grenze International Journal of Engineering and Technology, Jan Issue

Effect of Ceramic Waste on the Mechanical Properties of Concrete

Raj Mulchandani[1], Arth Shah[2], Tejas Joshi [3] and Sonal Thakkar[4]
[1-4] Department of Civil Engineering, Institute of Technology, Nirma University, Ahmedabad, India.
17bcl092@nirmauni.ac.in , 17bcl104@nirmauni.ac.in, tejas.joshi@nirmauni.ac.in, sonal.thakkar@nirmauni.ac.in

***Abstract*—Waste management generated by industries is one of the major problems faced by world. Majority of the waste generated by industries fall in non-biodegradable category like plastic, rubber, glass, fly ash and ceramic waste. Being generated in large quantity and as it is non-biodegradable, its disposal possesses huge challenge, ceramic waste being one of them. As these kinds are generally dumped as landfilling it pollutes land and water. Mostly ceramic waste is generated from wastage of tiles and have silica (SiO_2) and alumina (Al_2O_3) ions. In present study, three concrete mixtures were prepared for M 25 grade of concrete. Mix A with 0% replacement, Mix B with 20% replacement and Mix C with 20% replacement of ceramic fine powder with cement. Mechanical properties were evaluated for all three-mixture design. It was observed that, the compressive strength and flexural strength of mix B which is partial replacement of 10% with cement have nearly gives same results compare to mix A. The density of mix B is decreased compare to Mix A due to fineness of ceramic powder.**

***Index Terms*— Ceramic Waste, Manufacturing process, Replacement percentage, compressive strength.**

I. INTRODUCTION

The ceramic waste is the major waste from construction Industries which uses roof and floor tiles as a construction material. The global production of ceramic waste powder exceeds 25 billion tons. In last 10-15 years, ceramic waste has become the problematic waste as limited scope of recycling is possible. The global production ceramic tiles according to the demand is around is 8700 million square meters and around 500 million square meters in India. Generally, around 56% of ceramic waste produced by wall tile industries in India. The ceramic waste also hard, durable and highly resistant to its physical, chemical, and biological properties. While in another side, concrete is as largest used construction material in the world. Thus, the replacement of ceramic waste in concrete is the innovation and effective effort. Main aim of the work was to use higher percentage of ceramic waste as construction materials which will lead to saving of natural resources and environmental and also set new trends in construction techniques. Production of wall tiles is done mainly by combination of two materials as binding stone that first in mixtures of clays and second is glazes. Generally, clay particles are checked carefully and uniformity is maintained for the binding purpose and hence the size must be reduced. The mixtures of raw materials are atomized and spray dried. Dust play important role in manufacturing of wall tiles. It is loaded in silo and placed through finishing. Pressing in vertical direction is very high. After the pressing, optimum amount of drying is done because high drying will cause cracks in tiles. The

Grenze ID: 01.GIJET.7.1.540

glazes used on surface of the tile to allow creation of different design. The main technique for design patters in ceramic industry which is called "Digital Ink Injection". In this system, different types of design are made easily. It is also used to resist chemical attack. The firing is done in single layer roller kilns. It takes very fast cycle of 45-60 minutes. The chamber has large size of 100m length. The temperature of kiln is around 1373°K to 1473°K. After this sorting and Packing is done where defective tiles are thrown out by checking or testing chamber. At last, the bulk of 6 or 12 tiles per one unit packed with their company markers.

II. Literature Review

Karthika et al. [1] evaluated use of ceramic waste powder as a partial replacement for cement. Ceramic waste was substituted for cement and 10 - 40% replacement of cement was done for M 30 grade of concrete. Polyproplene fiber were also added to increase the strength in second phase. It was observed that when 30% replacement was done compressive strength of 42 MPa, split tensile strength of 3.9 MPa and flexural strength of 5.5 MPa was obtained. El Deib et al. [2] in their study on ceramic waste have used as replacement of coarse aggregate in concrete and mortar. Authors found that due to high water absorption of coarse aggregate. It was observed that there was 25% decrease in weight and compressive strength due to replacement of natural coarse aggregate. Similarly, it was observed there was decrease in compressive strength due to inclusion of ceramic waste due to low pozzolanic activity index [3,4]. Devi and Venkateswarlu [5] in their work on ceramic waste observed that the compressive strength and split tensile strength of M30 & M 40 grade concrete increased when 15% replacement of ceramic waste by weight of cement was used compared to no replacement (0% replacement). It was recommended to use 15% replacement for ordinary construction purposes as it would lead to economy. Uniyal and Singh [6] in their work on ceramic waste found that ceramic tile powder of 15% gave optimum strength and compressive strength decreased if more amount of waste is used.

II. Need of Study

Replacement of cement with ceramic waste in concrete is ideal solution of disposal of ceramic waste. As replacement of cement with ceramic waste it can be lead to decreases the strength of concrete. Therefore, this study is aimed to find optimum percentage of cement replacement with ceramic waste powder (CWP).

III. Experimental Programme

A. Material Properties

Cement

Ordinary Portland cement 53 grade as per IS 8112:1889 [7] was used for this investigation. The physical properties of are presented in Table I.

TABLE I. PHYSICAL PROPERTIES OF ORDINARY PORTLAND CEMENT

Sr.No.	Properties	Obtained value
01	Specific gravity	3.15
02	Initial setting time	30 min
03	Final setting time	270
04	3 days compressive strength in MPa	29.70
05	7 days compressive strength in MPa	39.50
06	28 days compressive strength in MPa	56.25

Ceramic Waste

CWP are crushed uniformly to about 0.15mm size manually by using hammer. The various test was conducted on the ceramic tiles are specific gravity, water absorption, bulk density and moisture content, the results are as shown in Table II.

TABLE II. PHYSICAL PROPERTIES OF CWP (CERAMIC WASTE POWDER)

Sr. No.	Properties	Obtained value
01	Specific gravity	2.67
02	Bulk density	0.5g/cm^3
03	Particle size	<0.5mm
04	Moister content	>0.5%

Coarse and Fine Aggregates

Locally available sand is used as fine aggregate. In the present study the sand is conformed to zone I as per the IS 383-2016 [8]. Fineness Modulus, Specific gravity and water absorption tests were conducted both on coarse and fine aggregate. Table III, shows the results of the tests on aggregates.

TABLE III. PHYSICAL PROPERTIES OF FINE AND COARSE AGGREGATES

Sr. No.	Properties	Obtained value	
		Fine Aggregates	Coarse Aggregates
01	Fineness modulus	2.56	2.25
02	Maximum size	2.36mm	20mm
03	Specific gravity	2.65	2.67
04	Water absorption	1%	0.6%

B. Mixture Design

Proportions of concrete mixture was done to produce concrete having adequate workability, strength and void ratio, in accordance to IS 10262 [9]**.** In order to find optimum dosage of replacement of cement, three mix (Mix A, Mix B, Mix C) with replacement of cement as 0%, 10%, 20% respectively were prepared. Mix A had 0% replacement of CWP (ceramic waste powder) with cement. Whereas, Mix B had 10% and Mix C is 20% replacement of CWP with cement respectively while other quantities like coarse aggregate and fine aggregate remained same. In the Table IV gives mix proportion of all three mixtures.

TABLE IV. MIXTURE PROPORTIONS

Material	Mix A	Mix B	Mix C
Cement (kg/m^3)	9.78	8.8	7.82
Ceramic Waste (kg/m^3)	0	0.9	1.96
Fine Aggregate(kg/m^3)	16.95	16.95	16.95
Coarse Aggregate (kg/m^3)	31.95	31.95	31.95
Water (kg/m^3)	4.8	5.3	5.6

C. Mechanical Properties

Density

Evaluation of density was done on cubes of 150 mm × 150 mm × 150 mm size. The specimens cast were demoulded after 24 hours and kept in normal curing for 28 days. Density of concrete has been evaluated by ratio of weight of cube to the volume of cubes as shown in equation (1).

$$p = \frac{w}{v} \qquad .. (01)$$

Where,

W= weight (kg),

V= volume (mm^3)

Compressive Strength

Compressive strength test was carried out at specified ages on the cube size 150 mm ×150 mm × 150 mm as per IS 516 [10] codal provisions. Load was applied perpendicular to the age and the bottom surface was fixed and the top surface was applying the load at gradual rate. The load at failure condition were noted and by taking ratio of failure load to the surface area gives compressive strength of specimen. Equation 2 is used for the calculation of compressive strength of concrete.

$$\sigma = \frac{P}{A} \qquad (02)$$

Where,

P = Force (kN)

A = Area (mm^2)

Flexural Strength

The load at which the test beams of size 100 mm × 100 mm × 500 mm failed was recorded and used to calculate the flexural strength the flexural strength was calculated using the formula in equation (3).

$$F_r = \frac{pl}{bd^2} \quad (03)$$

Where,
F_r= Modulus of rupture in N/mm^2
P = failure load in N
b = beam width in mm
d = beam depth in mm
Spilt Tensile Strength
The split tensile strength was carried out on cylinder of size 150mm diameter and 300 mm height by splitting along its middle plane parallel to the edges by applying the compressive load to opposite edges as per IS: 516 [10]. The split tensile strength of cylinder is calculated by the as follows

$$f_{st} = \frac{2p}{\pi ld} \quad (04)$$

P = maximum load in newton's applied to the specimen (kN)
l = length of the specimen (mm)
d = cross sectional dimension of the specimen (diameter)

IV. Result & Discussion

Density
Table V shows the results the result for cube at the age of 7 days and 28 days for density. the result suggest that the density of concrete made by 10% and 20% replacement of cement with ceramic waste has less density with compare to normal concrete mix. i.e., Mix A has 0% replacement of cement with ceramic waste it has density of 2707.27 kg/m^3, whereas Mix B, which has 10% replacement of cement by ceramic waste, has density of 2650.34 kg/m^3 it has comparatively less density compare to Mix A which is more reduced in Mix C.

TABLE V. RESULTS OF DENSITY OF CONCRETE FOR VARIOUS MIXTURE DESIGN

Mixture	7 days (kg/m^3)	Average	28 days (kg/m^3)	Average
A	2715.32	2707.17	2730.67	2730.20
	2698.13		2710.43	
	2708.08		2749.50	
B	2644.18	2650.34	2685.61	2670.48
	2632.48		2666.62	
	2674.37		2659.21	
C	2621.10	2590.10	2588.52	2608.56
	2567.30		2610.24	
	2581.9		2626.92	

Compressive Strength
The test of compressive strength for M 25 grade of concrete the results are as shown in table VI. As per IS 456, for M 25 grade of concrete the strength cube after 28 days must be obtain more than 33 MPa. The strength for Mix A and Mix B has the strength more than 33MPa whereas the Mix C has slightly lower compressive strength more the 33MPa. Mix A and Mix B satisfy the requirement of compressive strength.

TABLE VI. RESULTS OF COMPRESSIVE OF CONCRETE FOR VARIOUS MIXTURE DESIGN

Mixture	7 days (MPa)	Average	28 days (MPa)	Average
A	24.8	24.95	35.2	35.22
	25.1		34.7	
	25.25		35.76	
B	24.31	24.15	34.02	34.3
	24.11		34.42	
	24.03		34.46	
C	23.1	23.24	34.2	32.58
	23.5		33.34	
	23.12		30.2	

Flexural Strength

The flexural strength test was performed according to IS: 516 [10] using two-point load method. The results are as per table VII. According to IS standard the flexural strength of M25 grade of concrete after 28 days must be more than 4.02 MPa. However, the flexural strength of Mix C is not as per requirement other than that Mix A and Mix B has flexural strength as per requirement.

TABLE VII. RESULTS OF FLEXURAL STRENGTH OF CONCRETE FOR VARIOUS MIXTURE DESIGN

Mixture	7 days (MPa)	Average	28 days (MPa)	Average
A	3.48	3.38	4.15	4.15
	3.50		4.12	
	3.17		4.18	
B	3.45	3.43	4.08	4.09
	3.43		4.10	
	3.43		4.10	
C	3.36	3.37	4.09	3.99
	3.39		4.04	
	3.36		3.84	

Split Tensile Strength

Test was carried out on cylinder specimen of size 150 mm diameter and 300 mm height. The split tensile strength test was performed according to IS: 516 [10] using Universal Testing Machine. The results are as per table VIII. According to IS coddle provision 516, the split tensile strength of M25 grade of concrete after 28 days must be more than 2.65 MPa.

However, the split tensile strength of Mix C is not as per requirement other than that Mix A and Mix B has split tensile strength as per requirement.

TABLE VIII. SPLIT TENSILE STRENGTH OF CONCRETE FOR VARIOUS MIXTURE DESIGN

Mixture	7 days (MPa)	Average	28 days (MPa)	Average
A	2.3	2.24	2.74	2.74
	2.32		2.72	
	2.10		2.76	
B	2.28	2.67	2.70	2.69
	2.27		2.69	
	2.25		2.70	
C	2.22	2.14	2.69	2.62
	2.21		2.65	
	2.21		2.52	

V. CONCLUSION

The following conclusions are drawn based on the experimental investigations carried out on concrete made by replacement of ceramic waste with cement.

- It was found that density of concrete with replacement is less than that of control concrete, and as the replacement increases the density decreases
- The compressive strength obtained for 10% replacement are acceptable whereas the replacement of cement of 20% has less compressive strength then required so 10% replacement of ceramic waste is acceptable.
- The flexural strength obtained for 20% replacement is less than required flexural strength for M25 grade of concrete, where as 10% replacement has more than required flexural strength which is acceptable.
- The split tensile strength obtained for 20% replacement is less than required split tensile strength for M25 grade of concrete, where as 10% replacement has more than required split tensile strength which is acceptable.

REFERENCES

[1] Strength characteristics on concrete with ceramic waste as a partial replacement of cement, Karthika.V, Sathanandham T, Vijayan V, Sathes Kumar K, Manikandan M, Journal of Chemical and Pharmaceutical Sciences, October-December 2015, Volume 8 Issue 4

[2] The Use of Ceramic Waste Powder (CWP) in Making Eco-Friendly Concretes, El-Dieb Amr S., Taha Mahmoud R. and Abu-Eishah Samir I, Ceramic Materials - Synthesis, Characterization, Applications, Recycling and Environmental Impact, IntechOpen, DOI: http://dx.doi.org/10.5772/intechopen.81842
[3] Rahhal V, Irassar E, Castellano C, Pavslík Z, Čern. R. Utilization of ceramic wastes as replacement of Portland cements. In: Proceedings of the International Conference on Construction Materials and Structures (ICCMATS-1); 24-26 November 2014; South Africa. Amsterdam: IOS Press; 2014. pp. 208-213
[4] Steiner LR, Bernardin AM, Pelisser F. Effectiveness of ceramic tile polishing residues as supplementary cementitious materials for cement mortars. Sustainable Materials and Technologies. 2015; 4:30-35. DOI: 10.1016/j.susmat.2015.05.001
[5] A Study on Various Properties of Concrete by Using Ceramic Dust Powder as a Partial Replacement of Cement, Ch.Devi, D.Venkateswarlu, International Journal of Engineering and Technical Research (IJETR), Volume-3, Issue-12, December 2015.
[6] Atul Uniyal and Karan singh, "Partial Replacement of Cement in Concrete using Ceramic Waste, International Journal of Engineering Research & Technology, Volume-7, Issue-12, December 2019
[7] IS 12269, "Specification for 53 grade ordinary Portland cement", *Bureau of Indian Standards* (2013).
[8] IS 383, "Specification for Coarse and fine aggregate from natural sources for concrete", *Bureau of Indian Standards* (2016).
[9] IS 10262, Indian Standards "Recommended guidelines for concrete mix design proportioning"-code of practice (2009).
[10] IS 516, "Indian standard methods of tests for strength of concrete". *Bureau of Indian Standards* (2016).