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Strength characteristics on concrete with ceramic waste as a partial replacement of cement

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ABSTRACT

This paper reports the results of experiments evaluating the use of ceramic waste powder as a partial replacement for cement and addition of polypropylene fibers in concrete. Ceramic waste powder is settled by sedimentation and then dumped away which results in environmental pollution. This study focused on two different phases: in the first phase, the use of waste ceramic powder as a cement replacement in concrete was investigated. Concrete samples with 10–40% of ground ceramic powder substitution for M30, ratio of 1:1.6:2.6 were made. In the second phase of the study, addition of polypropylene fibers from 0.2% to 0.8% was made. Concrete mixtures were produced, tested and compared in terms of strength to the conventional concrete. These tests were carried out to evaluate the mechanical properties for 7, 28 and 56 days.

KEY WORDS: Ceramic waste Powder, polypropylene fibers, silica fume, cement concrete, compressive strength, split tensile strength and flexural strength.

1. INTRODUCTION

The advancement of concrete technology can reduce the consumption of natural resources and reduce the burden of pollutants on the environment. The cost of natural resources is increased day by day. They have forced to focus on recovery, reuse of natural resources and find other alternatives. Presently large amounts of Ceramic waste are generated in ceramic industries with an important impact on environment and humans. The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment. Indian ceramic production is 100 Million ton per year. In the ceramic industry, about 15%- 30% waste material generated from the total production. However, the ceramic waste is durable, hard and highly resistant to biological, chemical, and physical degradation forces. The Ceramic industries are dumping the powder in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of a vast area of land, especially after the powder dries up so it is necessary to dispose the Ceramic waste quickly and use in the construction industry.

2. EXPERIMENTAL MATERIALS

2.1 Ceramic waste: The principle waste coming into the ceramic industry is the ceramic powder, specifically in the powder forms. Ceramic wastes are generated as a waste during the process of dressing and polishing. It is estimated that 15 to 30% waste are produced of total raw material used, and although a portion of this waste may be utilized on-site, such as for excavation pit refill. The figure 1 shows the ceramic waste.

2.2 Polypropylene fibers: These fibers are used as a concrete additive to increase strength and reduce cracking. They will prevent micro cracks in concrete. Therefore one of the useful and cost benefit ways to increase strength and corrosion resistance, and reduce cracks extension is the usage of polypropylene fibers (PPF) in the mixture of concrete and figure 2 shows polypropylene fibres.

Figure.1.Ceramic waste

Figure.2.Polypropylene fibers

2.3 Cement: In this study, ordinary Portland cement (ACC 53 Grade) is used. It is the most common cement, which is used for general concrete structures. 53 Grade OPC is a higher strength cement to meet the needs of the consumer for higher strength concrete As per BIS requirements the minimum 28 days compressive strength of 53 Grade OPC should not be less than 53 MPa. Many tests were conducted to cement like specific gravity, consistency, initial and final setting test.

Table.1.Properties of Cement

Test	Relevant Code	Results
Standard Consistency test	IS 4031 (PART IV) : 1988	33%
Fineness Test	IS 4031 (PART III) : 1988	3%
Specific Gravity	IS 4031 (PART II) : 1988	3.15
Initial setting time	IS 4031 (PART IV) : 1988	50min
Final setting time	IS 4031 (PART IV) : 1988	180min

Table.2.Properties of Coarse Aggregate

Test	Relevant Code	Results
Specific gravity	IS:383-1970	2.7
Fineness	IS:2386-1963 (PART1)	5.85
Water absorption	IS:2386-1963 (PART3)	1%
Impact value	IS:2386-1963 (PART4)	15.426%
Crushing value	IS:2386-1963 (PART4)	20.2%

Table 3.Properties of Fine Aggregate

Test	Relevant Code	Results
Specific gravity	IS:2386(PART 1) 1963	2.63
Fineness modulus	IS:383-1970	4.578
Bulk density	IS:383-1970	1763 kg/m^3
Water absorption	IS:383-1970	0.51%

2.4. Design mix: A mix M30 grade was designed as per Indian Standard method (IS 10262-2009) and the same was used to prepare the test samples. The design mix ID for various concrete mix proportion is shown in Table 4 and Table 5.

Table.4.Design Mix ID for Various Concrete

Mix ID	OPC Cement Replacement With Ceramic Waste	Silica Fume
C_0	Standard concrete	-
C_{W1}	10% ceramic waste replacement	0.1%
Cw_2	20% ceramic waste replacement	
Cw_3	30% ceramic waste replacement	
Cw_4	40% ceramic waste replacement	

Table.5.Design Mix ID for Various Concrete

Mix ID	OPC Cement Replacement With Ceramic Waste & Addition Of Polrpropylene Fibers	Silica Fume
C_{WF1}	10% ceramic waste replacement +0.2% fibers	0.1%
C_{WF2}	20% ceramic waste replacement +0.4% fibers	
C_{WF3}	30% ceramic waste replacement +0.6% fibers	
C_{WF4}	40% ceramic waste replacement +0.8% fibers	

2.5. Mix proportion for M30 grade of concrete: The design mix proportion is shown in Table 6.

Table.6.Design Mix

Mix ID	Ceme-nt (kg/m^3)	Cera-mic waste(kg/m^3)	Polypr-oylene fibers (kg/m^3)	Fine aggre-gate (kg/m^3)	CoarseAg-gregate (kg/m^3)	Water/ cement ratio	Silica fume (kg/m^3)
C_0	425.7	-	-	691.32	1110.708	0.45	-
C_{W1}	383.13	42.57	-				0.425
Cw_2	340.56	85.14	-				
Cw_3	297.99	127.71	-				
Cw_4	255.42	170.28	-				
C_{WF1}	383.13	42.57	0.851				
C_{WF2}	340.56	85.14	1.702				
C_{WF3}	297.99	127.71	2.55				
C_{WF4}	255.42	170.28	3.40				

3. RESULTS AND DISSCUSSION

The evaluation of ceramic waste for use as a replacement of cement material begins with the concrete testing. Concrete contains cement, water, fine aggregate, coarse aggregate, ceramic waste and polypropylene fiber. With the control concrete, i.e. 10%, 20%, 30%, and 40%of the cement is replaced with ceramic waste and further fibers are added to the cement from 0.2%, 0.4%, 0.6%, 0.8%. The cube samples were cast on the mould of size a) 150*150*150 mm, b) cylinder were cast on mould of size 150*300mm, c) prism were caste on mould of size 500*100*100mm. Table 7, Table 8 and Table 9 shows compressive strength, split tensile strength and flexural strength test results respectively.

Table.7.Compressive Strength of Cubes (150x150x150) for M30 Mix

Mix ID	Relative Compressive Strength		Mix ID	Relative Compressive Strength	
	7 Days	28 days		7 Days	28 days
C_0	1	1	C_0	1	1
C_{W1}	1.10	1.01	C_{WF1}	1.11	1.03
C_{W2}	1.13	1.03	C_{WF2}	1.15	1.11
C_{W3}	1.21	1.08	C_{WF3}	1.28	1.13
C_{W4}	1.15	1.01	C_{WF4}	1.31	1.14

Table.8.Split Tensile Strength of Cubes (150x150x150) For M30 Mix

Mix Id	Relative Split Tensile Strength		Mix Id	Relative Split Tensile Strength	
	7 Days	28 days		7 Days	28 days
C_0	1	1	C_0	1	1
C_{W1}	1.09	1.11	C_{WF1}	1.18	1.14
C_{W2}	1.30	1.23	C_{WF2}	1.43	1.36
C_{W3}	1.43	1.38	C_{WF3}	1.77	1.39
C_{W4}	1.16	1.26	C_{WF4}	1.86	1.47

Table.9.Flexural Strength for M30 Mix

Mix Id	Relative Flexural Strength		Mix Id	Relative Flexural Strength	
	7 Days	28 days		7 Days	28 days
C_0	1	1	C_0	1	1
C_{W1}	1.09	1.02	C_{WF1}	1.10	1.04
C_{W2}	1.18	1.06	C_{WF2}	1.21	1.07
C_{W3}	1.19	1.10	C_{WF3}	1.26	1.11
C_{W4}	0.98	0.98	C_{WF4}	1.28	1.15

The figure 3 and figure 4 shows the compressive strength test results, figure 5 and figure 6 shows split tensile strength test results, figure 7 and figure 8 shows flexural strength test results for 7 days and 28 days.

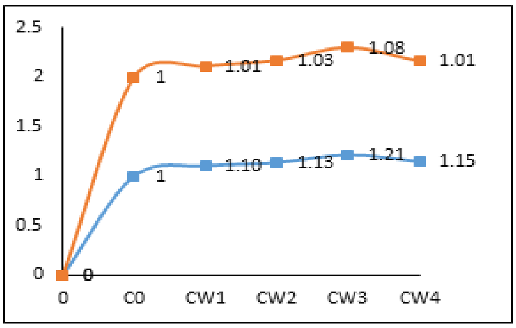

Figure.3.Compressive Strength of Cubes (150x150x150) for M30 Mix for Percentage Replacement of Ceramic waste.

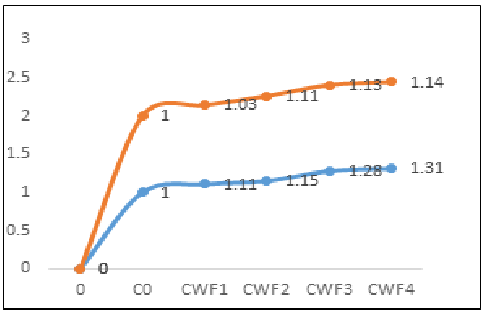

Figure.4.Compressive Strength of Cubes (150x150x150) for M30 Mix for Percentage Replacement of Ceramic waste with addition of fibers

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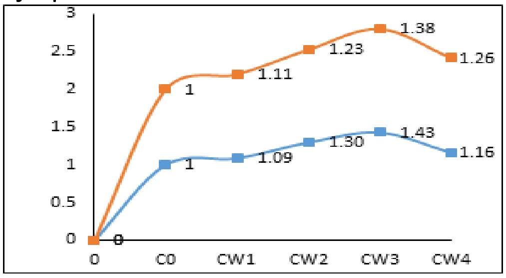

Figure.5. Split Tensile for M30 mix for Percentage of ceramic waste

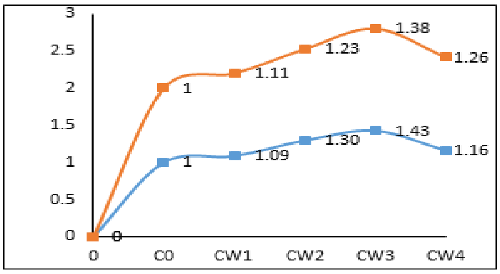

Figure. 6. Split Tensile for M30 Mix for Percentage Replacement of Ceramic waste with addition of fibers

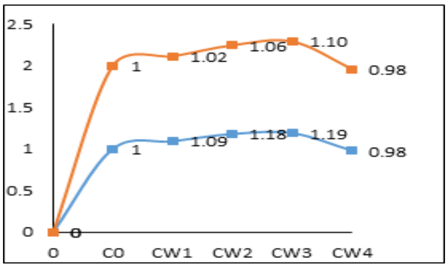

Figure.7. Flexural for M30 Mix for Percentage Replacement of Ceramic Waste

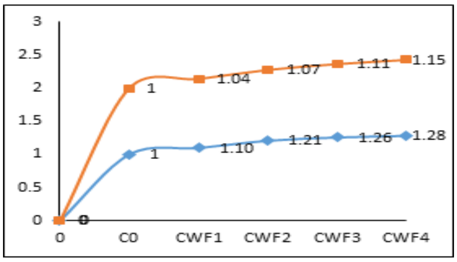

Figure. 8. Flexural for M30 Mix for Percentage Replacement of Ceramic waste with addition of fibers

3.1. Durability tests:

3.1.1. Water absorption test: The concrete blocks shall be completely immersed in water at room temperature for 24 hours. The blocks shall then be removed from the water and allowed to drain for one minute, the saturated and surface dry blocks immediately weighed. After weighing all blocks shall be drained and weighed.

Water absorption (%)= (A-B)/B*100(1)

Where, A= wet mass of unit, B= dry mass of unit

Table.10.Water Absorption test results

Mix Id	Water Absorption (%)	
	7days	28 Days
C_0	1.59	1.57
C_{w1}	1.63	1.62
C_{w2}	1.67	1.65
C_{w3}	1.71	1.70
C_{w4}	1.76	1.74

Table 11. Sorptivity test results

Specimen	Curing method	Sorptivity (10^{-5} (mm/min$^{0.5}$))	
		7 days	28 days
SBAGC 1	Ambient	6.97	6.99
SBAGC 2	Steam	9.29	9.34

3.2. Sorptivity of SBA Geo Polymer Concrete (GPC): Sorptivity is a material property which characterizes the tendency of a porous material to absorb and transmit by capillarity.

S = I / t ½(2)

Where, S = sorptivity in mm, I = Δw / Ad, Δw = change in weight = W2-W1, t = elapsed time in min, A = surface area of the specimen through which water penetrated, d = density of water.

The specimen of size 100 mm diameter x 50 mm thick cylinder is casted. The cylindrical specimens were placed in tray such that their bottom surface up to a height of 5mm is in contact with water. The sides of the specimens were sealed with an adhesive coating. Specimens were removed from the tray and weighted at after 30 min. then the sorptivity is found using the formula. The specimen during sorptivity test is shown in Fig. 10.

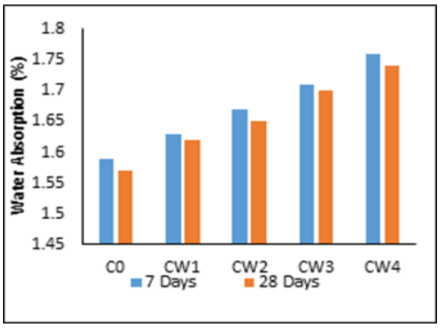

Figure. 9. Water absorption test

Figure. 10. Sorptivity test

4. CONCLUSION

Based on experimental investigations concerning the strength of concrete, the following observations are made:

a) The Compressive split tensile and flexural strength of M30 grade Concrete increases when the replacement of Cement with Ceramic Powder up to 30% replaces by weight of Cement. The optimum strength is obtained at 30% replacement, compressive strength is 42.15 N/mm^2, Split tensile strength is 3.85 N/mm^2 and flexural strength is 5.50N/mm^2 at 28 days. Further replacement of Cement with Ceramic Powder decreases the Strength.

b) Addition of polypropylene fibers to the cement increases the compressive, split tensile and flexural strength.

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