Eco-Efficient Concretes: Use Of Ceramic Powder As A Partial Replacement Of Cement

Amitkumar D. Raval, Indrajit N. Patel, Jayeshkumar Pitroda

Abstract*— The ceramic industry inevitably generates wastes, irrespective of the improvements introduced in manufacturing processes. In the ceramic industry, about 15%-30% production goes as waste. These wastes pose a problem in present-day society, requiring a suitable form of management in order to achieve sustainable development. In this research study the (OPC) cement has been replaced by ceramic waste powder accordingly in the range of 0%, 10%, 20%, 30% 40%, & 50% by weight for M-25 grade concrete. The wastes employed came from ceramic industry which had been deemed unfit for sale due to a variety of reasons, including dimensional or mechanical defects, or defects in the firing process. The results demonstrate that the use ceramic masonry rubble as active addition endows cement with positive characteristics as major mechanical strength and the economic advantages. Reuse of this kind of waste has advantages economic and environmental, reduction in the number of natural spaces employed as refuse dumps. Indirectly, all the above contributes to a better quality of life for citizens and to introduce the concept of sustainability in the construction sector.

***Keywords*—Ceramic Waste,Compressive Strength, Eco-Friendly, Industrial Waste, Low Cost, OPC Cement, Sustainable**

I. INTRODUCTION

This research analyzed the impact of the use of ceramic powder, obtained as residue from theceramics industry, on the mechanical properties of conventional concrete. The councils of large-and medium-sized towns have for years been increasingly concerned with the collection, storage andmore recently treatment of domestic waste. Parallel to this, there has been a growing social and political awareness of environmental issues, particularly where this relates to the deteriorationof the environment. Ceramic waste from factories producing constructionindustry materials has been accumulating on frequentlyillegal rubbish tips, creating increasingly large piles.Although they are usually chemically inert, the rubbishtips where this waste accumulates, given their size andthe scant environmental control exercised, have asignificant visual impact that destroys the intrinsicquality of the landscape.The advancement of concrete technology can reduce the consumption of natural resources and energy sources. 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 the environment and humans. The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment.

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Indian ceramic production is 100 Million ton per year. In ceramic industry, about 15%-30% waste material generated from the total production. This waste is not recycled in any form at present. However, the ceramic waste is durable, hard and highly resistant to biological, chemical, and physical degradation forces. The Ceramic industries are dumping the waste 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.As the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for its disposal

II. EXPERIMENTAL MATERIALS

A. Materials

b) Cement (OPC)

The Ordinary Portland Cement of 53 grade conforming to IS: 8112 is be use. Physical property of cement is as per table 2.

a) Ceramic waste

Ceramic material is hard, rigid. 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. Chemical properties of ceramic waste is as per table 1.

Figure: 1. Ceramic waste powder Source: Kohinoor tiles, Himmatnagar, Gujarat

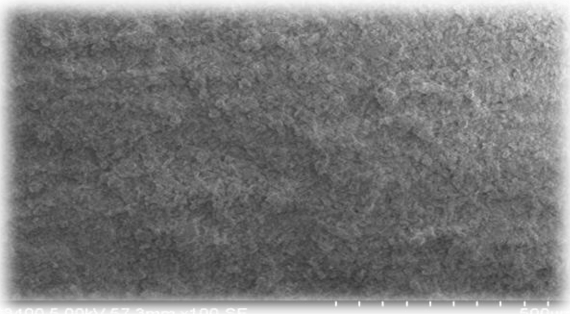

Figure: 2.Microscopic Views of Ceramic Particles Source: SVNIT, Surat, Gujarat

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Table–1
Chemical Properties Of Ceramic Waste

Materials	Ceramic Powder (%)
SiO_2	63.29
Al_2O_3	18.29
Fe_2O_3	4.32
CaO	4.46
MgO	0.72
P_2O_5	0.16
K_2O	2.18
Na_2O	0.75
SO_3	0.10
CL^-	0.005
TiO_2	0.61
SrO_2	0.02
Mn_2O_3	0.05
L.O.I	1.61

Source: GEO TEST HOUSE, Baroda, Gujarat

Table-2
Physical Properties Of Materials

Materials	Specific Gravity	IS CODE
Cement	3.12	IS : 8112 - 1989
Ceramic Waste	3.11	-
Fine Aggregate	2.38	IS: 383
Coarse Aggregate	2.76	IS: 383
Super Plasticizer	1.20	IS: 9103:1999

c) Aggregate

Aggregate give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is a good gradation of aggregates. Minimum paste means less quantity of cement and less water, which are further mean increased economy, higher strength, lower shrinkage and greater durability.

d) Coarse Aggregate

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 is being use. The Flakiness and Elongation Index were maintained well below 15%.

e) Fine aggregate

Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. The river sand is used in combination as fine aggregate conforming to the requirements of IS: 383.

Table-3
Physical Properties Of Fine Aggregate, Course Aggregate

Property	Fine Aggregate	Coarse Aggregate	
		20 mm down	10 mm down
Fineness modulus	3.35	7.54	3.19
Bulk Density (gm/cc)	1753	1741	1711
Water absorption (%)	1.20	1.83	1.35

f) Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water are required to be looked into very carefully.

III. DESIGN MIX

A mix M25 grade was designed as per Indian Standard method (IS 10262-2009) and the same was used to prepare the test samples.The design mix proportion is done in Tab 4.

Table-4
Design Mix Proportion For (M25 Mix)

	W (Lit)	C (Kg/m^3)	F.A. (Kg/m^3)	C.A. (Kg/m^3)		Chemical Admixture
				20mm	10mm	
By weight, [kg]	174.8	364.3	696.9	749.6	499.7	2.5
By volume[m^3]	0.48	1	1.80	2.07	1.31	-

W= Water, C= cement, F.A. = Fine Aggregate, C.A. = Coarse Aggregate

Table-5
Concrete Design Mix (M25 Mix) Proportions

Sr. No.	Concrete Type	Concrete Design Mix Proportion				
		W/C ratio	C	F.A.	C.A.	C.W.
1	B0	0.48	1.00	1.80	3.38	-
2	B1	0.52	0.90	1.80	3.38	0.10
3	B2	0.52	0.80	1.80	3.38	0.20
4	B3	0.52	0.70	1.80	3.38	0.30
5	B4	0.52	0.60	1.80	3.38	0.40
6	B5	0.52	0.50	1.80	3.38	0.50

IV. EXPERIMENTAL SET UP

Table-6
Design Mix Proportion For Various Concrete

Sr.No.	Concrete Type	OPC cement Replacement with Ceramic waste
1	B0	Standard Concrete
2	B1	10% replacement
3	B2	20% replacement
4	B3	30% replacement
5	B4	40% replacement
6	B5	50% replacement

V. EXPERIMENTAL METHODOLOGY

The evaluation of ceramic waste for use as a replacement of cement material begins with the concrete testing. Concrete contains cement, water, fineaggregate, coarse aggregate and grit. With the control concrete, i.e. 10%, 20%, 30%, 40%, and 50% of the cement is replaced with ceramic waste,the data from the ceramic waste is compared with data from a standard concrete without ceramic waste. Three cube samples were cast on the mould of size 150*150*150 mm for each 1:1.80:3.38 concrete mix with partial replacement of cement with a w/c ratio as 0.48 were also cast. After about 24 h the specimens were de-moulded and water curing was continued till the respective specimens were tested after 7, 14 and 28 days for compressive strength test.

Compressive strength

Compressive strength tests were performed on compression testing machine using cube samples. Three samples per batch were tested with the average strength values reported in this paper. The comparative studies were made on their characteristics for concrete mix ratio of 1:1.80:3.38 with partial replacement of cement with Ceramic waste as 10%, 20%, 30%, 40% And 50%.

Table -7
Compressive Strength Of Cubes(150x150x150)For M25 Mix At 7, 14, 28 Days

Concrete Type	Average Compressive Strength [N/mm^2]		
	7 days	14 days	28 days
B0	25.39	31.21	32.92
B1	23.67	29.66	31.21
B2	21.65	28.65	29.31
B3	20.04	26.77	27.63
B4	18.11	23.59	24.78
B5	16.06	21.63	23.51

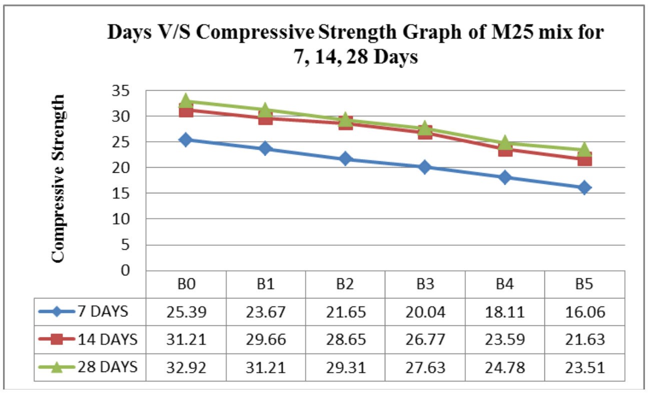

Figure: 3 Percentage Replacement of Ceramic waste V/S Compressive Strength (N/mm^2) of Concrete for M25 mix at 7, 14 and 28 days

VI. ECONOMIC FEASABILITY

Table- 8
Costs Of Materials

Sr. No.	Materials	Rate (Rs/Kg)
1	Cement (OPC 53 grade)	6.40
2	Fine aggregate (Regional)	0.60
3	Coarse aggregate (Regional)	0.65
4	Ceramic waste	0.20

Table - 9
Total Cost Of Materials For M25designe Mix Concrete (1:1.80:3.38) Per M^3

C.T.	Consumption of Design Mix Proportions For M25 Concrete (1:1.80:3.38)					Total Cost per m^3	% Cost Saving
	C	F.A.	C.A.	C.W.	Admixture		
A0	364.30	696.90	1249.30	0.00	2.00	5690.97	-
A1	327.87	730.20	1249.30	36.43	2.00	5439.11	4.42
A2	291.44	730.20	1249.30	72.86	2.00	5187.28	8.85
A3	255.01	730.20	1249.30	109.29	2.00	4935.44	13.27
A4	218.58	730.20	1249.30	145.72	2.00	4683.60	17.70
A5	182.15	730.20	1249.30	182.15	2.00	4436.18	22.04

VII. CONCLUSION

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

(a) The Compressive Strength of M25 grade concrete increases when the replacement of cement with ceramic waste up to 30% by weight of cement and further replacement of cement with ceramic powder decreases the compressive strength.

(b) Concrete on **30%** replacement of cement with ceramic waste, compressive strength obtained is **26.77 N/mm^2** and vice-versa the cost of the concrete is reduced up to **13.27%** in **M25** grade and hence it becomes more economical without compromising concrete strength than the standard concrete. It becomes technically and economically feasible and viable.

(c) Utilization of ceramic waste and its application are used for the development of the construction industry, Material sciences.

(d) It is the possible alternative solution of safe disposal of ceramic waste.

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