Ceramic Waste : Effective Replacement Of Cement For Establishing Sustainable Concrete

Amitkumar D. Raval[1], Dr.Indrajit N. Patel[2], Prof. Jayeshkumar Pitroda[3]
[1]Student of final year M.E. C E & M, B.V.M. Engineering college, Vallabh Vidyanagar
[2] Applied Mechenics Department, BBIT, Vallabh Vidyanagar-Gujarat-India
[3]Assistant Professor& Research Scholar, Civil Engg Department, B.V.M. Engineering College, Vallabh Vidyanagar-Gujarat-India

Abstract— Ceramic waste is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. Ceramic waste powder is settled by sedimentation and then dumped away which results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health. Therefore, utilization of the ceramic waste powder in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment. It is most essential to develop eco-friendly concrete from ceramic waste. In this research study the (OPC) cement has been replaced by ceramic waste powder accordingly in the range of 0%, 10%, 20%, 30% 40%, & 50% by weight of M-20 grade concrete. Concrete mixtures were produced, tested and compared in terms of compressive strength to the conventional concrete. These tests were carried out to evaluate the mechanical properties for 7, 14 and 28 days. As a result, the compressive strength achieved up to 30% replacing cement with ceramic waste.This research work is concerned with the experimental investigation on strength of concrete and optimum percentage of the partial replacement by replacing cement via 0%, 10%, 20%, 30%, 40% and 50% of ceramic waste. Keeping all this view, the aim of the investigation is to study the behavior of concrete while replacing theceramic waste with different proportions in concrete.

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

I INTRODUCTION

Indian ceramic production is 100 Million ton per year. In the 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 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.As the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for its disposal.

The advancement of concrete technology can reduce the consumption of natural resources. They have forced to focus on recovery, reuse of natural resources and find other alternatives. The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment.

II EXPERIMENTAL MATERIALS

A. Materials

a) 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 disposals of these waste materials acquire large land areas and remain scattered all around, spoiling the aesthetic of the entire region. It is very difficult to find a use of ceramic waste produced.

Ceramic waste can be used in concrete to improve its strength and other durability factors. Ceramic waste can be used as a partial replacement of cement or as a partial replacement of fine aggregate sand as a supplementary addition to achieve different properties of concrete.

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

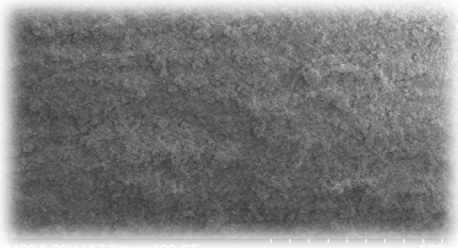

Figure: 2. Microscopic Views of Ceramic Particles
Source: SVNIT, Surat, Gujarat

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

b) Cement (OPC)

The Ordinary Portland Cement of 53 grades conforming to IS: 8112 is beingused.

TABLE-2
PHYSICAL PROPERTIES OF (OPC) CEMENT

PROPERTY	IS CODE IS : 8112 - 1989
Specific Gravity	3.12
Consistency	33
Initial setting time	30 minimum
Final setting time	600 maximum

c) Aggregate

Aggregates are the important constituents in concrete. They 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. Good grading implies that a sample fraction of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids require minimum paste to fill up the voids in the 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. The river sand is washed and screen, to eliminate deleterious materials and oversize particles.

TABLE-3
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
Specific Gravity	2.38	2.76	2.69
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 M20 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 Table 4.

TABLE-4
DESIGN MIX PROPORTION FOR (M20 MIX)

	W (Lit)	C (Kg/m^3)	F.A. (Kg/m^3)	C.A. (Kg/m^3)		Chemical Admixture
				20mm	10mm	
By weight, [kg]	169.30	325.50	730.20	759.20	506.10	2.0
By volume, [m^3]	0.52	1.00	1.80	2.35	1.49	-

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

TABLE-5
CONCRETE DESIGN MIX (M20 MIX) PROPORTIONS

Sr. No	Concrete Type	Concrete Design Mix Proportion				
		W/C ratio	C	F.A.	C.A.	C.W
1	A0	0.52	1.00	1.80	3.84	-
2	A1	0.52	0.90	1.80	3.84	0.10
3	A2	0.52	0.80	1.80	3.84	0.20
4	A3	0.52	0.70	1.80	3.84	0.30
5	A4	0.52	0.60	1.80	3.84	0.40
6	A5	0.52	0.50	1.80	3.84	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	A0	Standard Concrete
2	A1	10% replacement
3	A2	20% replacement
4	A3	30% replacement
5	A4	40% replacement
6	A5	50% replacement

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 1:1.80:3.84 concrete mix with partial replacement of cement with a w/c ratio as 0.52 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 loading rate on the cube is 35 N/mm^2 per min. The comparative studies were made on their characteristics for concrete mix ratio of 1:1.80:3.84 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
A0	23.55	28.44	30.40
A1	21.98	26.64	28.14
A2	20.38	24.33	26.46
A3	18.60	21.24	22.98
A4	16.48	18.97	19.68
A5	14.95	17.63	18.33

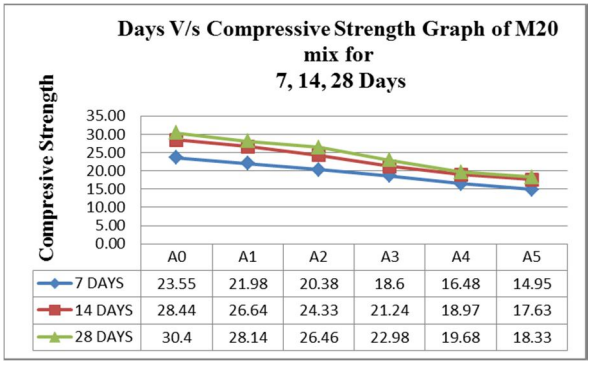

Figure: 3 Percentage Replacement of Ceramic waste V/S Compressive Strength (N/mm^2) of Concrete for M20 mix at 7, 14 and 28 days

V. 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 M20 DESIGNE MIX CONCRETE (1:1.80:3.84) PER m^3

C.T.	Consumption of Design Mix Proportions For M20 Concrete (1:1.80:3.84)					Total Cost /m^3	% Cost Saving
	C	F.A.	C.A.	C.W.	Admixture		
A0	325.50	730.20	1265.30	0.00	2.00	5325.53	-
A1	292.95	730.20	1265.30	32.55	2.00	5100.51	4.22
A2	260.40	730.20	1265.30	65.10	2.00	4875.49	8.45
A3	227.85	730.20	1265.30	97.65	2.00	4650.48	12.67
A4	195.30	730.20	1265.30	130.20	2.00	4425.91	16.89
A5	162.75	730.20	1265.30	162.75	2.00	4200.44	21.12

VI. CONCLUSION

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

(a) The Compressive Strength of **M20 grade** Concrete increases when the replacement of Cement with Ceramic Powder up to **30% replaces** 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 Powder, Compressive Strength obtained is 22.98 N/mm2 and vice-versa the cost of the cement is reduced up to 12.67% in M20 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.

REFERENCES

[1] Ceramic Manufacturing Industry, EUROPEAN COMMISSION, August 2007

[2] A. Piccolroaz, D. Bigoni and A. Gajo, An elastoplastic framework for granular materials becoming cohesive through mechanical densification. Part I - small strain formulation. European Journal of Mechanics A: Solids, 2006, 25, 334-357.

[3] ASTM C 125, Standard Terminology Relating to Concrete and Concrete Aggregate, 1994 Annual Book of ASTM Standards

[4] César Medina1, M.I.Sánchez de Rojas, Moisés Frías and Andrés Juan, "Using Ceramic Materials in Ecoefficient Concrete and Precast Concrete Products", Spain

[5] C. Medina Martínez, M.I.Guerra Romero, J. M. Morán del Pozo and A. Juan Valdés, "USE OF CERAMIC WASTES IN STRUCTURALS ONCRETES", 1st Spanish National Conference on Advances in Materials Recycling and Eco – Energy Madrid, 12-13 November 2009

[6] David Pearce and Giles Atkinson, "The concept of sustainable development: an evaluation of its usefulness ten years after brundtland", CSERGE Working Paper PA 98-02

[7] D. Bigoni, Nonlinear Solid Mechanics: Bifurcation Theory and Material Instability. 2012, Cambridge University Press.

[8] Gérard Valenduc, Patricia VendraminScience, "Technological Innovation and Sustainable Development",International Conference "Science for a Sustainable Society"Roskilde, 27-29/10/97

[9] Hasnat Dewan, "Re-Defining Sustainable Human Development to Integrate Sustainability and Human Development Goals"Thompson Rivers University, Canada.

[10] İ.B.TOPÇU And M.CANBAZ, "Utilization of crushed tile as aggregate in concrete", Iranian Journal of Science & Technology, Transaction B, Engineering, Vol. 31, No. B5, pp. 561-565, 2007

[11] Philip J. Vergragt, "How Technology Could Contribute to a Sustainable World", GTI Paper Series, 2006

[12] P.K. Mehta, Puzzolanic and cementitious by products as mineral admixtures for concrete, fly ash, silica fuÈme, slag and other mineral byproducts in concrete, ACI SP (79)(01)(1983)

[13] Sustainable Development: An Introduction, Internship Series, Volume-I, Centre for Environment Education, 2007

[14] "STRATEGYFOR SUSTAINABLE CONSTRUCTION" HM Government,JUNE 2008

[15] K. S. Al-Jabri, A. W. Hago, R. Taha, A. S. Alnuaimi and A. H. Al-Saidy "Strength and Insulating Properties of Building Blocks Made from Waste Materials", Journal of Materials in Civil Engineering, 2009, Vol.21, No. 5,page no: 191–197

[16] Fernando and Said "Compressive strength and durability properties of ceramic wastes based concrete", Materials and Structures, 2009, vol. 44,page no:155–167

[17] K.Abdullah, M.W.Hussin, F.Zakaria , R.Muhamad, Z.Abdul Hamid "POFA : A Potential Partial Cement Replacement Material in Aerated Concrete", Proceedings of the 6th Asia-Pacific Structural Engineering And Construction Conference, (APSEC 2006), 2006

[18] Weerachart Tangchirapat, Tirasit Saeting, Chai Jaturapitakkul, Kraiwood Kiattikomol, AnekSiripanichgorn "Use of waste ash from palm oil industry in concrete", Waste Management, 2007, vol.27, page no: 81–88.

[19] Yadav Ishwar Singh, Maneek Kumar and Shweta Goyal, "Laboratory Investigations Of The Properties Of Concrete containing Recycled Plastic Aggregates", M.Tech Thesis, Thapar University, 2008.

AUTHORS BIOGRAPHY

Amitkumar Dipakbhai Raval was born in 1990 in Anand District, Gujarat. He received his Bachelor of Engineering degree in Civil Engineering from the Birla Vishwakarma Mahavidyalaya,Sardar Patel in 2011. At present he is Final year student of Master`s Degree in Construction Engineering and Management from Birla Vishwakarma Mahavidyalaya, Gujarat Technological University. He has a paper published in international journals.

Dr. I. N. Patel was born in 1964 in Anand city. He received his Bachelor of Engineering degree in Civil (Structural) Engineering from the Sardar Patel University in 1986. In 2007 he received his Master's Degree in M.E. Structural Engineering from the Sardar Patel University. In 2012 he received his PhD Civil Engineering, SVNIT, Surat, Gujarat. He joined B. & B. Institute of Technology as a faculty where he is Assistant Professor in Applied Mechanics Department with a total experience of 25 years in the field of Research, Designing and education. He has published 12 papers in National Journals /Conferences and 14 papers in International Journals/Conferences.

Prof. Jayeshkumar R. Pitroda was born in 1977 in Vadodara City. He received his Bachelor of Engineering degree in Civil Engineering from the Birla Vishvakarma Mahavidyalaya, Sardar Patel University in 2000. In 2009 he received his Master's Degree in Construction Engineering and Management from Birla Vishvakarma Mahavidyalaya, Sardar Patel University. He joined Birla Vishvakarma Mahavidyalaya Engineering College as a faculty where he is Assistant Professor of Civil Engineering Department with a total experience of 12 years in the field of Research, Designing and education. He is guiding M.E. (Construction Engineering & Management) Thesis work in the field of Civil/ Construction Engineering. He has papers published in National Conferences and International Journals.