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An Experimental Study on Strength Properties of Ceramic Waste Concrete

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ABSTRACT: 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. A ceramic waste powder is also used as a binder with partial replacement of cement which takes some part of reaction at the time of hydration, and also it acts as a filler material. In this study, waste ceramic powder was used as a replacement to the concrete ingredient i.e. cement and the mechanical properties like compressive strength was measured and the size effect of ceramic waste powder on strength of concrete. For checking strength effect of replacement of cement by ceramic waste powder, the cement is replaced at 10%, 20%, 30%, 40% and 50%. For study of size effect of ceramic waste powder, the ceramic waste powder is divided in to two grades one is ceramic waste powder having size less than 90 micron and another is ceramic waste powder having particle size ranges from 90 micron to 150 microns. For this study, M60 grade concrete mixtures were casted and the test results are compared with the conventional concrete results.

KEYWORDS – Ceramic waste powder, Size effect, compressive strength, Strength Properties, conventional concrete.

I. INTRODUCTION

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.

Ceramic products made up with different raw materials like china clay, ball clay, potash feldspar, dolomite, talc and different chemicals for a glazing and finishing. Ceramic production conducts on temperature 200°C to 2000°C, So the possibility of pozzolonic reactivity in such products, which is responsible for long term strength and good durability. Ceramic wastes are produced as a result of the ceramic processing. These wastes cause soil, air, and groundwater pollution. Ceramic wastes can be separated in two categories in accordance with the source of raw materials. The first one are all fired wastes generated by the structural ceramic factories that use only red pastes to manufacture their products, such as brick, blocks, and roof tiles. The second one is all fired waste produced in stoneware ceramic such as wall, floor tiles and sanitary ware. These producers use red and white pastes; nevertheless, the usage of white paste is more frequent and much higher in volume.

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. 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 to achieve different properties of concrete.

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OBJECTIVES OF THE STUDY

The present work is aimed to analyze and give technical specifications on strength characteristics of concrete and optimum percentage of the partial replacement by replacing cement with ceramic waste. The main objective of the experimental investigation is to assess the utility of ceramic waste in the production of structural concrete. To fulfill the objective, the work is aimed at the following.

- To carry out the mix design for high grade M60 for both Conventional concrete and concrete on partial replacement of cement with ceramic waste.
- To Study the strength characteristics of concrete like compressive strength.
- To arrive at the optimum percentage replacement of cement with ceramic waste in the production of Structural Concrete.

II.LITERATURE REVIEW

In 2010, *Torgal and Jalali* examined the feasibility of using ceramic wastes in concrete and their results show that concrete with 20% cement replacement although has a minor strength loss but possess increased durability performance, while when concrete mixes with ceramic aggregates show better results than the control concrete mixtures concerning compressive strength, capillary water absorption, oxygen permeability and chlorine diffusion thus leading to more durable concrete structures.

In 2013 *Raval et al.* also performed the almost the same investigation and their results show that the use of 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.

In 2015 Daniyal and Ahmad also investigated the effect of addition of crushed waste ceramic tiles as a replacement for natural coarse aggregates with 10%, 20%, 30%, 40% and 50% of substitution and analyzed that the optimum value of waste ceramic tile to be used within the concrete mix with a water/cement ratio of 0.5was about 30%. The compressive and flexural strength of optimal concrete was found 5.43% and 32.2% higher than reference concrete respectively. Their findings reveal that using waste ceramic tile leads to enhancing the properties of concrete.

Amit Kumar D. Raval et al. studied the (OPC) cement has been replaced by ceramic waste in the range of 0%, 10%, 20%, 30% 40%, & 50% by weight for M30 grade concrete. Test results have reflected, the compressive strength achieved up to 30% replacement of cement with ceramic waste will be optimum without effecting properties of fresh and hardened concrete.

III. EXPERIMENTAL PROGRAM

In this study, total two groups of concrete mixes were prepared in laboratory. First group was cement replacement by ceramic waste powder of particle size less than 90 microns with replacement from 10% to 50%. Second group was cement replacement by ceramic waste powder of particle size from 90 micron to 150 micron with replacement from 10% to 50%. For this study we were used high grade M60 concrete.

Cube of standard size 150mmx150mmx150mm were casted to arrive the strength parameters at the ages 7, 28, 56, 90 and 180 days. Concrete mix with 0% ceramic waste powder forms the basic reference mix to compare the results of mixes with different percentage of replacement of ceramic waste.

MATERIALS

The various materials used in the experimentation namely cement, fine aggregate and coarse aggregate have been tested in the laboratory. The specifications and properties of these materials were presented in the subsequent sections. All the materials used in the study were tested in accordance to the Indian standards.

CEMENT

Cement used in experimental work was Ordinary Portland Cement of 53 Grade. Cement used was fresh, of uniform color, free from any lumps and foreign matter, and from the same batch. Ordinary Portland cement of 53 grade conforming to Bureau of Indian standards was used and tested for various properties as per IS 12269-1987.

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Table 1: Properties of Cement

S.No	Property	Value	IS Standards
1.	**Normal consistency**	34 %	33-35%
2.	**Fineness of cement**	6.5%	<10%
3.	**Setting times**		
	Initial setting time(Minutes)	105 Minutes	≥ 30 Minutes
	Final setting time(Minutes)	300 Minutes	≤ 600 Minutes
4.	**Specific Gravity**	3.10	3.1-3.2
5.	**Compressive strength**		
	3 Days	29.39 MPa	27 MPa
	7 Days	43 MPa	-
	28 Days	53.62 MPa	53 MPa

COARSE AGGREGATE

Broken hard Granite was used as coarse aggregate. 20 mm size coarse aggregate were used for all mixes. The aggregate used here are brought from nearby quarries which were beaked from the stone available from near Godavari regions.

Table 2: Properties of Coarse Aggregate

S.No	Property	Value	Range of values AS PER IS:383-1970
1.	**Bulk density gm/cc**	1.451(loose state)	1.45-1.80
		1.576(dry rodded)	
2.	**Specific gravity(G)**	2.85	2.6-2.9
3.	**Water absorption (%)**	0.6	0.5-1.0
4.	**Fineness Modulus**	7.21	6.5-8

FINE AGGREGATE

The river sand, passing through 4.75 mm sieve and retained on 600µm sieve, conforming to Zone II as per IS 383-1970 was used as fine aggregate in the present study. It is clean, inert and free from organic matter, silt and clay.

Table 3: Properties of Fine Aggregate

S.No	Property	Results	Range of values AS PER IS:383-1970
1.	**Specific Gravity**	2.69	2.5-2.8
2.	**Bulk Density gm/cc**	1.584 (loose state)	1.45-1.65
		1.656 (dry state)	
3.	**Fineness Modulus**	2.5	2.2-2.6
4	**Zone**	II	I – IV

WATER

Potable water from laboratory taps was used for concrete production. Water from same source was used for curing. P^H value not less than 6 as per IS 456-2000.

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CERAMIC WASTE:

Ceramic waste can be used in concrete to improve its strength. Ceramic waste can be used as a partial replacement of cement, the ceramic powder is collected from SILICA CERAMICS PVT LIMITED situated near Narayanapuram, West Godavari District, Andhra Pradesh.

Table 4 Chemical Properties of Ceramic waste

Materials	Ceramic powder (%)
Sio_2	68.11
Al_2O_3	16.48
Fe_2O_3	0.59
K_2O	3.14
Na_2O	3.78
CaO	0.85
MgO	1.61
TiO_2	0.02
L.O.I	4.75

CASTING AND CURING

The materials for preparing the specimens were weighed and mixed as per IS 516-1959 (1989). A laboratory type concrete mixer machine was used to mix the ingredients of the concrete. The aggregates and cement were mixed for one minute and then water was added to the mixture within two minutes. Then they were allowed to mix thoroughly for three more minutes. All the specimens were well compacted using a tamping rod. The specimens were demoulded after 24 hours and immersed in the potable water for curing for a period of 28 days at room temperature of 27ºC ± 2ºC

IV.TEST RESULTS AND ANALYSIS

The compressive strength test was conducted on cube test specimens for concrete mixes made with conventional concrete and ceramic waste concrete (for every percentage of replacement). The test was conducted on test specimens at the ages of 7, 28, 56, 90 and 180 days after proper curing till the day of test. The compressive strength values obtained from the test for Conventional Concrete, Concrete with different percentage (10, 20, 30, 40 and 50) of ceramic waste were presented in tables. The results were plotted below.

Table 5: Compressive Strength (N/mm^2) Results of Cubes of M_{60} grade for < 90 microns and >90 microns ceramic waste concrete for 7,28,56,90, 180 days from 0% to 50%

% of Ceramic Powder	7 days <90 microns	28 days <90 microns	56 days <90 microns	90 days <90 microns	180 days <90 microns	7 days >90 microns	28 days >90 microns	56 days >90 microns	90 days >90 microns	180 days >90 microns
0%	42.50	71.64	73.35	74.66	75.42	42.50	71.64	73.35	74.66	75.42
10%	40.22	65.56	68.55	70.21	71.32	39.54	63.54	66.25	68.54	70.54
20%	35.13	58.44	62.11	63.54	63.01	34.33	55.23	59.54	61.20	60.54
30%	31.25	50.45	52.55	54.98	55.21	29.54	45.33	49.66	50.54	50.61
40%	24.55	41.23	44.54	46.88	47.21	21.55	38.65	42.14	43.55	43.08
50%	19.24	33.54	36.88	38.74	39.11	15.55	30.22	33.54	32.54	33.05

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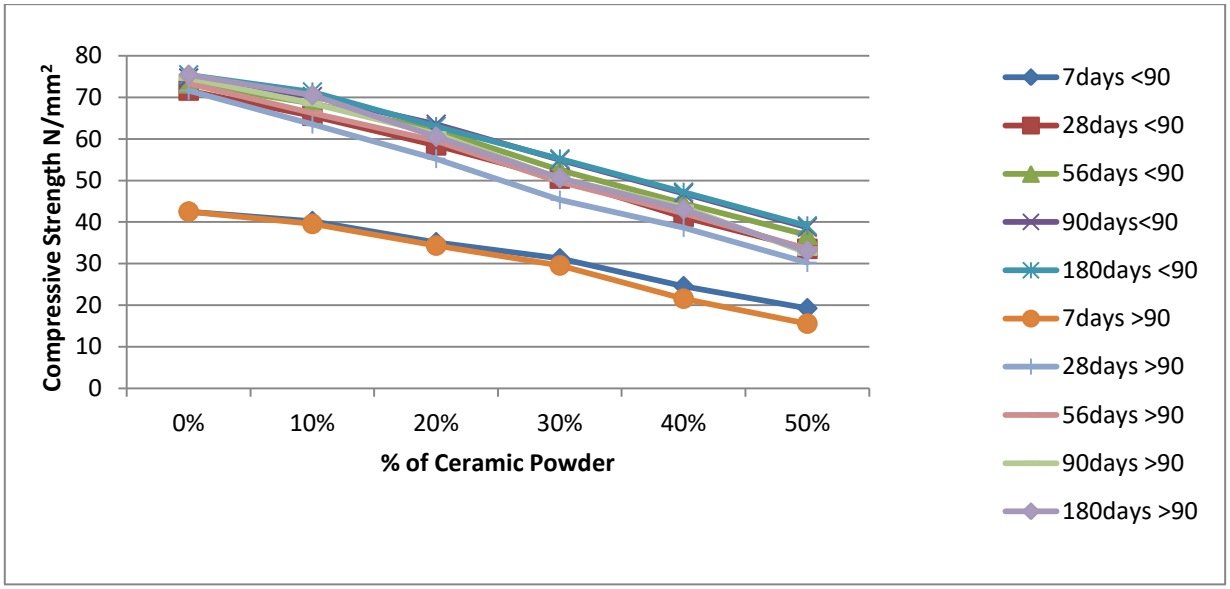

GRAPH 1: Compressive strength results of Ceramic waste powder concrete cured in normal water

Table 6: percentage variation of Compressive Strength (N/mm^2) Results of Cubes of M_{60} grade for < 90 microns and >90 microns ceramic waste concrete for 7,28,56,90, 180 days from 0% to 50%

% of Ceramic Powder	7 days <90 microns	28 days <90 microns	56 days <90 microns	90 days <90 microns	180 days <90 microns	7 days >90 microns	28 days >90 microns	56 days >90 microns	90 days >90 microns	180 days >90 microns
0%	0	0	0	0	0	0	0	0	0	0
10%	2.28	6.08	4.80	4.45	4.10	2.96	8.10	7.10	6.12	4.88
20%	7.37	13.20	11.24	11.12	12.41	8.17	16.41	13.81	13.46	14.88
30%	11.25	21.19	20.80	19.68	20.21	12.96	26.31	23.69	24.12	24.81
40%	17.95	30.41	28.81	27.78	28.21	20.95	32.99	31.21	31.11	32.34
50%	23.26	38.10	36.47	35.92	36.11	26.95	41.42	39.81	42.12	42.37

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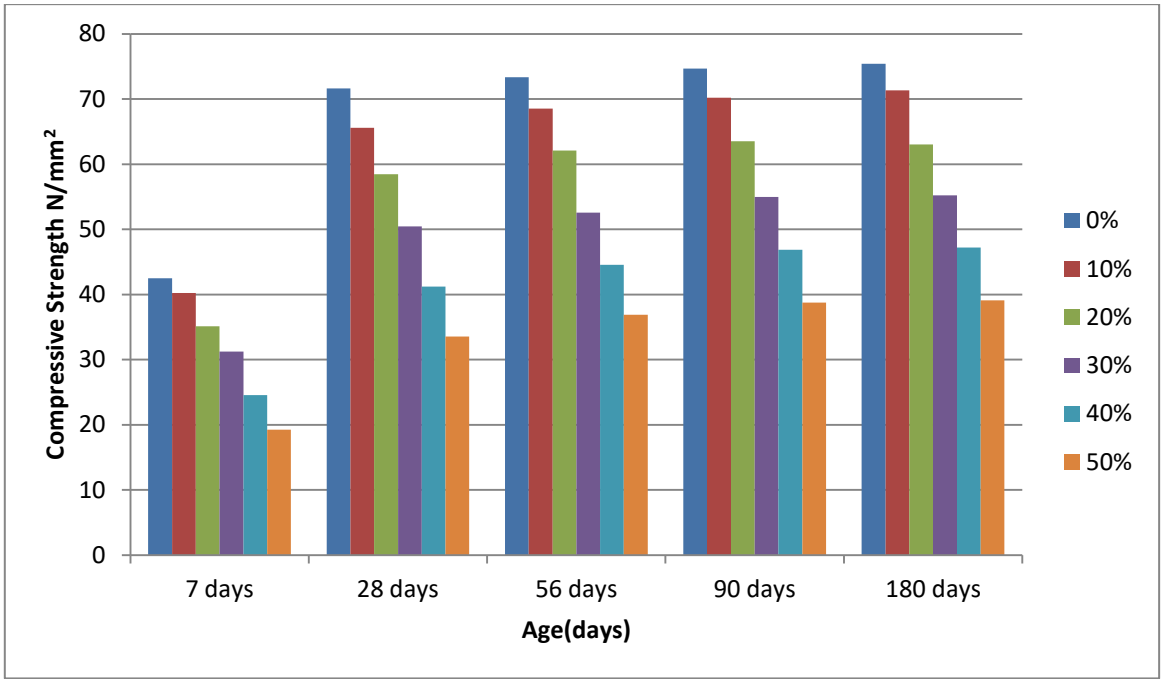
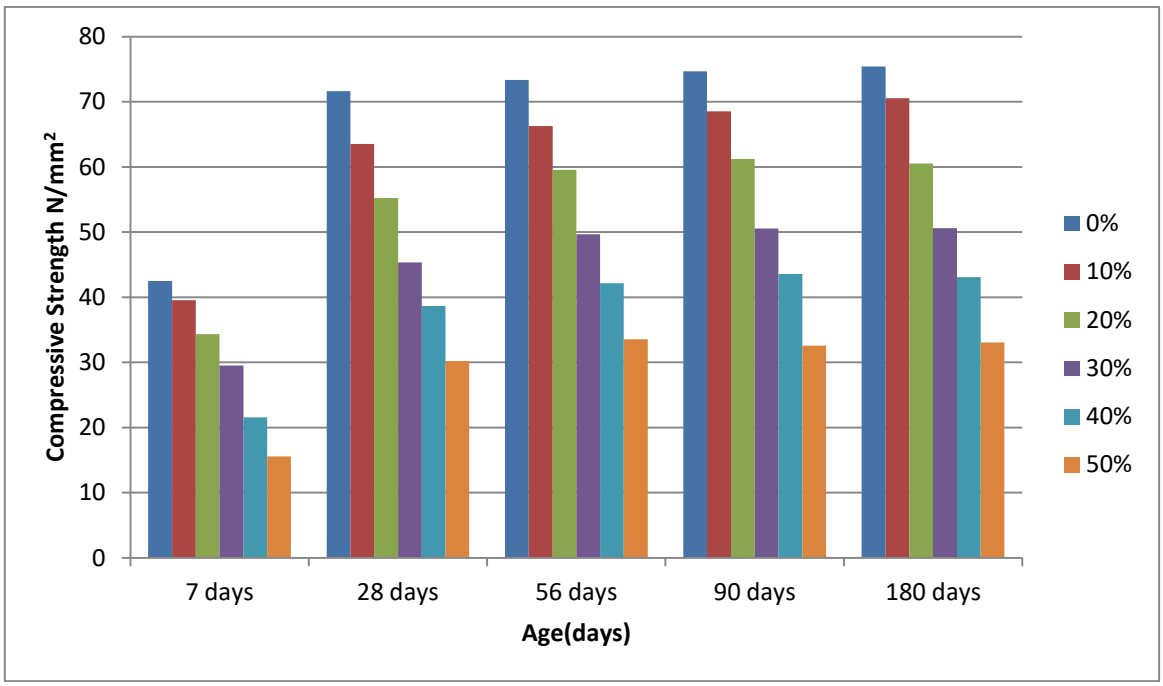


GRAPH 2: Variation of Compressive strength of <90 microns ceramic waste concrete mixes with age



GRAPH 3: Variation of Compressive strength of <90 microns ceramic waste concrete mixes with age

V.CONCLUSIONS

In accordance with the experimental phase carried out in this study, the following conclusions are drawn:

1. The Compressive strength of M60 grade concrete increases when the replacement of cement with ceramic powder (of size < 90 microns and 90-150 microns) up to 10% by weight of cement and further replacement of cement with ceramic powder decreases the compressive strength.

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2. Concrete on 10% replacement of cement with ceramic powder, compressive strength loss obtained is 8.48% in <90 microns ceramic waste concrete and it is 11.30% in >90 microns ceramic waste concrete.
3. There is a safe and alternative disposal of ceramic waste and to form ECO-FRIENDLY environment.
4. Utilization of ceramic waste can reduce cost of concrete and helps in development of construction industry.
5. In concrete cement is the costliest material by replacing we can reduce usage of cement.
6. From environment point of cement has a negative impact, because manufacturing it emits about a ton of greenhouse gas (co_2) into the atmosphere for every ton of cement manufactured.

The experimental study has helped to investigate the strength properties of Ceramic waste concrete as partial replacement of cement with ceramic waste in the production of Structural concrete. In view of the other advantages such as conservation of natural resources, free the ceramic waste material from landfills and elimination of disposal problems, the ceramic waste Concrete can be considered as a potential and suitable alternative material with a bright future.

FURTHER SCOPE FOR RESEARCH WORK

- The study on ceramic waste concrete can be further extended to investigate the behavior of ceramic waste concrete with Pozzolanic or Mineral admixtures like fly ash, Silica fume, Metakaoline etc.
- The study on ceramic waste concrete can be further extended to investigate the behavior of ceramic waste concrete by reinforcing it with Fibers as Fiber Reinforced Concrete (FRC).
- The failure mechanisms of concrete made with ceramic waste can be investigated.
- Strength studies can be carried out on ceramic waste concrete under different environmental conditions.
- Studies could be conducted for other properties such as creep, shrinkage, Carbonation resistance, microstructure, etc

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Venkata Krishna Atkuri received the Bachelor degree in civil engineering from the Acharya Nagarjuna University, Guntur, in 2006 and the Masters in structural engineering from Andhra University, Visakhapatnam, in 2010. He is currently pursuing the Ph.D. degree with the Department of civil Engineering, Andhra University, Visakhapatnam. Since 2010, he has been an Assistant professor with Civil Engineering Department in reputed institutions. He is currently the Assistant Professor in Civil Engineering Department, Swarnandhra College of Engineering and Technology (Autonomous), Narsapur, Andhra Pradesh, India. He is a member of esteemed professional bodies like Member Indian Society for technical Education, Member The Institution of Engineers (India), Member Administrative staff College of India. His research interests include replacement of waste materials in concrete, stabilization of soils and seismic strengthening of buildings.

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He was nominated as “International Engineer of the Year” for 2017 by the International Biographic Centre of Cambridge, England and member in Marquis“ Who’s Who in the World” for 2018 and 2019 by The International Biographic Centre, USA. He is the Life member of FIE, MISTE, MICI, MIGS and MIASE.