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Evaluation of Mechanical Properties of Concrete by Partial Replacement of Cement with Ceramic Waste

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***Abstract*— Ceramic waste is one of the most active research areas that hold within a number of regulations including civil engineering and construction materials. Ceramic waste powder is settled by alluviation and then dumped away which results in environmental pollution, in addition to forming dust in summer and menacing 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In this research study the (OPC) cement has been replaced by ceramic waste powder accordingly in the range of 10% 20%, 30% by weight ofM_{25} grade. Concrete mixtures were produced, tested and compared in terms of compressive strength, split tensile strength and flexural strength to the conventional concrete. These tests were carried out to evaluate the mechanical properties for 7, 14 and 28 days. This research work is concerned with the experimental investigation on strength of concrete and optimum percentage of the partial replacement by replacing cement via 10%, 20%, 30%, of ceramic waste. Keeping all this view, the aim of the analysis is to study the performance of concrete while replacing the ceramic waste with different proportions in concrete.

***Index Terms*— Ceramic Waste, Compressive Strength and some mechanical properties, Eco-Friendly, Industrial Waste, Low Cost, OPC Cement, Sustainable concrete.**

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. This research analyzed the impact of the use of ceramic powder, obtained as Residue from the ceramics industry, on the mechanical properties of conventional concrete.

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.

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II. EXPERIMENTAL MATERIALS

A. Cement

Cement must develop the appropriate strength. It must represent the appropriate rheological behavior. Generally same types of cements have quite different rheological and strength characteristics. The Ordinary Portland Cement of 53 grade conforming to IS: 8112 is be use. Physical property of cement is as per table 1.

Table-I
Physical property of cement

S.no.	Parameter	Test results
1	Normal Consistency	32%
2	Fineness of cement (%)	6
3	Specific Gravity	3.138
4	Initial setting time	70mins
	Final setting time	300mins

B. 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. 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. Chemical properties of ceramic waste is as per table II.

Fig-I(a): ***Ceramic waste powder. Source: Ceramic industry Gudur***

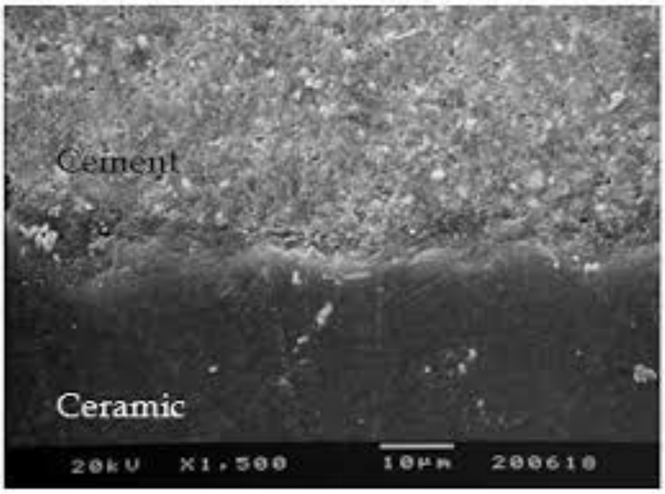


Fig-I(b): ***Microscope view of Ceramic powder particles in cement paste***

Table-II
Chemical property of ceramic

Materials	Ceramic Powder (%)
SiO_2	63.29
Al_2O_3	18.29
Fe_2O_3	4.14
CaO	3.91
MgO	0.61
P_2O_5	0.18
K_2O	2.12
Na_2O	0.81
SO_3	0.08
CL^-	0.005
TiO_2	0.65
SrO_2	0.02
Mn_2O_3	0.05
L.O.I	1.5

C. Aggregates

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 incombination 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-III
Properties of Fine Aggregate, Coarse Aggregate

Property	Fine Aggregate	Coarse Aggregate	
		20 mm down	10 mm down
Fineness modulus	3.15	7.23	3.01
Specific Gravity	2.44	2.77	2.69
Bulk Density (gm.cc^{-1})	1746	1738	1716
Water absorption (%)	1.20	1.81	1.29

III. WORKABILITY TEST

A. Slump Test

The slump test is the most commonly used method. Consistency is a term very closely related to workability. It is a term which describes the state of fresh concrete. It is used for the determination of the consistency of freshly mixed concrete, where the maximum size of the aggregate does not exceed 38 mm. The slump test is suitable for slumps of medium to high workability, slump in the range of 25 – 125 mm; the test fails to determine the difference in workability in stiff mixes which have zero slumps, or for wet mixes that give a collapse slump

The size of the slump cone is 20-cm diameter base, 10 cm diameter top and 30 cm height. Foot pieces can be fixed to the clamps on the base plate. The base plate has lifting handle for easy transportation. One graduated steel tamping rod 16 mm diameter x 600 mm long rounded at one end graduated in mm. The types of slump are as follows.

Collapse: In a collapse slumps the concrete collapses completely.

Shear: In a shear slump the top portion of the concrete shears off and slips sideways.

True: In a true slump the concrete simply subsides, keeping more or less to shape

B. Compaction Factor Test

Compacting factor of fresh concrete is done to determine the workability of fresh concrete by compacting factor test as per IS: 1199 – 1959. This test gives behaviour of concrete under the action of external forces. If measures the compactability of concrete, by measuring the amount of compaction. This test is suitable for mixes having medium and low workability's i.e. compaction factor in between 0.91 to 0.81, but is not suitable for concretes with very low workability's, the compaction factor below 0.71.

The test is a dynamic test and thus is more appropriate that static tests for highly thixotropic concrete mixtures.

TABLE-IV
Slump and Compaction factor test results

S.no.	Slump(mm)	
1	Conventional mix	78
2	10% Replacement	32
3	20% Replacement	38
4	30% Replacement	44
	Compaction factor	
1	Conventional mix	0.91
2	10% Replacement	0.919
3	20% Replacement	0.925
4	30% Replacement	0.931

IV. RESULTS

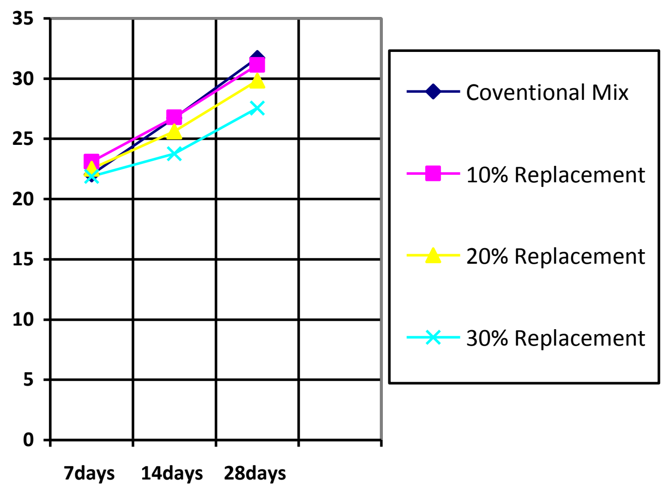
The mix proportion for M25 is 1: 1.18: 2.86 and W/C ratio of 0.44 was casted. Slump and compaction factor tests were tested when the concrete in fresh state. The cubes, cylinders and beams were tested for compressive strength, split tensile strength and flexural strength.

A. Compressive strength Test Result:

TABLE-V Observations

Compressive Strength (N/mm^2)			
	7days	14 days	28days
Conventional mix	22.04	26.74	31.71
10% Replacement	23.11	26.79	31.12
20% Replacement	22.52	25.63	29.83
30% Replacement	21.89	23.77	27.55

Graph-I
Compressive strength Vs Time in days

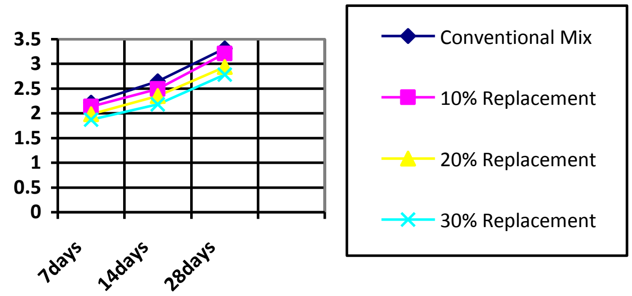


B. . Split Tensile Test Results

TABLE-VI Observations

	7days	14days	28days
Conventional Mix	2.22	2.65	3.31
10% Replacement	2.14	2.49	3.21
20% Replacement	1.95	2.35	2.94
30% Replacement	1.87	2.18	2.18

Graph-II
Split tensile strength Vs Time in days

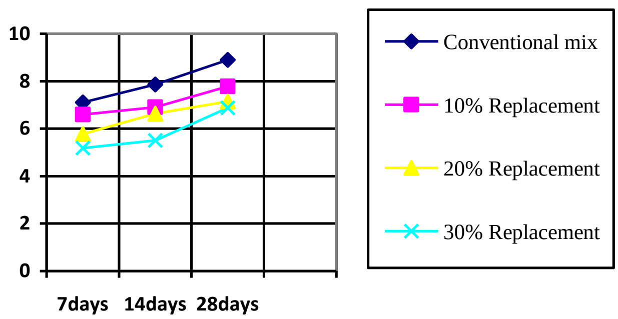


C. Beam Flexural Strength Test Results

TABLE-VII Observations

S.no.	Slump(mm)	
1	Conventional mix	78
2	10% Replacement	32
3	20% Replacement	38
4	30% Replacement	44
	Compaction factor	
1	Conventional mix	0.91
2	10% Replacement	0.919
3	20% Replacement	0.925
4	30% Replacement	0.931

Graph-III
Flexural Strength Vs Time in days



D. Bar Charts:

The bar charts are drawn for compressive strength, split tensile strength and flexural strength results. These are drawn between strength and percentage replacement of Ceramic waste at 7 days, 14 days, 28 days to observe the variation of strength.

Chart-I: Compressive Strength Vs % of Ceramic Replacement at 7days

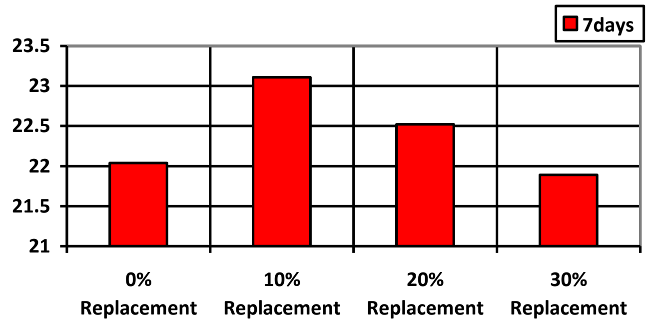


Chart-II: Compressive Strength Vs % of Ceramic Replacement at 14days

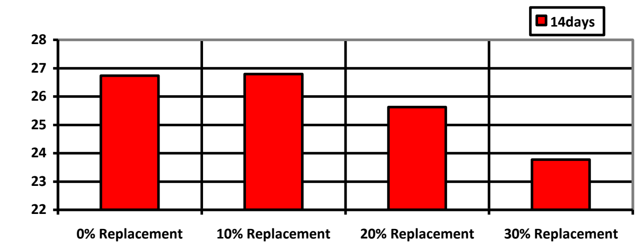


Chart-III: Compressive Strength Vs % of Ceramic Replacement at 28days

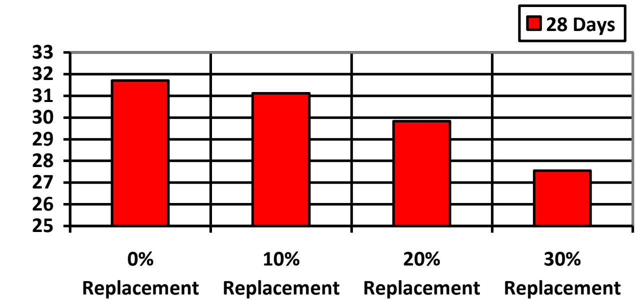


Chart-IV: Split Tensile Strength Vs % of Ceramic Replacement at 7days

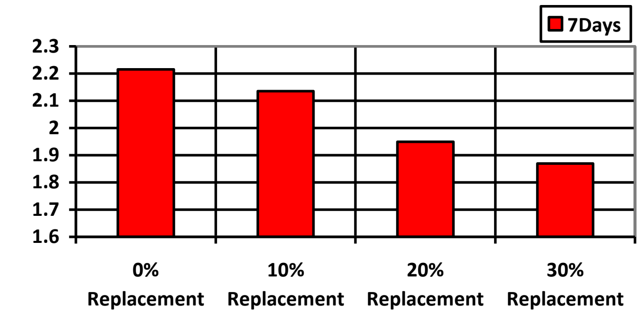


Chart-V: Split Tensile Strength Vs % of Ceramic Replacement at 14days

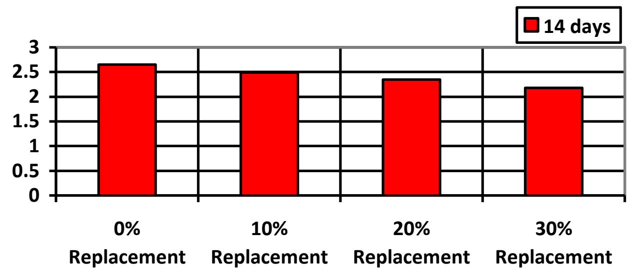


Chart-VI: Split Tensile Strength Vs % of Ceramic Replacement at 28days

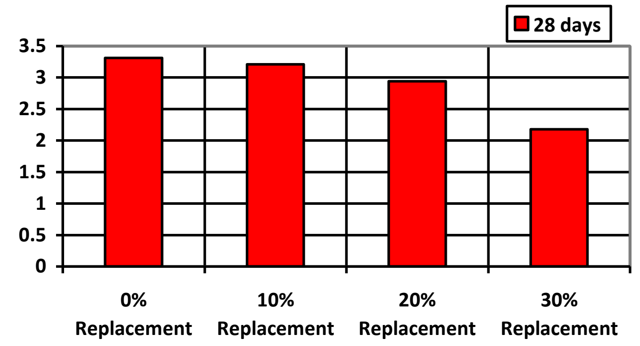


Chart-VII: Flexural Strength Vs % of Ceramic Replacement at 7days

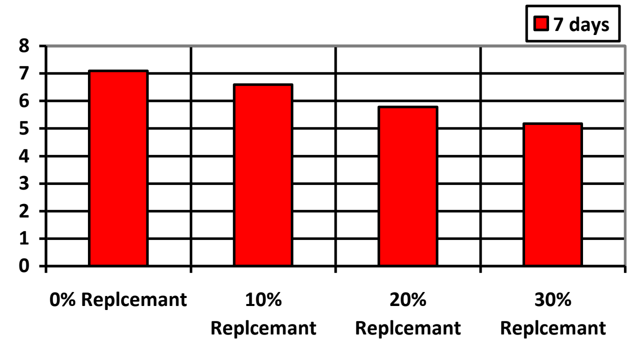


Chart-VIII: Flexural Strength Vs % of Ceramic Replacement at 14days

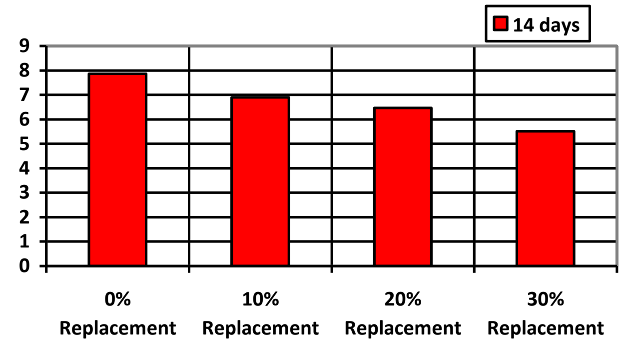
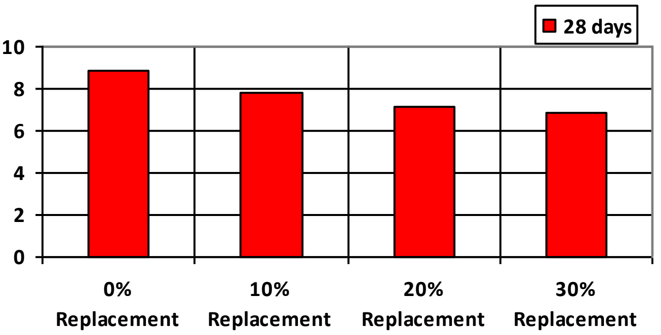


Chart-IV: Flexural Strength Vs % of Ceramic Replacement at 28days



V. CONCLUSION

The compaction factor increased as the percentage of coconut shell increases and increased in comparison with the conventional concrete.

1) The slump of the concrete increased as the percentage of ceramic waste increases and decrease in comparison with the conventional concrete.
2) The compaction factor increased as the percentage of ceramic waste increases and increased in comparison with the conventional concrete.
3) The Compressive strength of concrete for 7days of curing 10% replacement had the more strength compared to conventional concrete.
4) In later stage 10% and 20% replacement of cement with ceramic powder strength values are nearer to the conventional concrete.
5) Increasing to 30% of ceramic waste, compressive strength is reduced when compared to 10% and 20% replacement.
6) In case of split tensile strength, 10% replacement of ceramic waste strengths are increased similar to conventional concrete for 7, 14, 28 days respectively. but 20% and 30% replacement the strengths are reduced.
7) In flexural strength 10% replacement of ceramic waste strengths are increased.
8) The compressive, split tensile and flexural Strength with percentage replacement of cement decreased is very less and hence can be used for less important work utilizing the waste material which is produced in large quantities.

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