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Partial Replacement of Coarse Aggregate by Waste Ceramic Tile in Concrete

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Abstract: The main focus of this research is to study the strength of concrete with ceramic waste as coarse aggregate. Increased construction activity and continuous dependence on conventional materials of concrete marking are leading to scarcity of the material and increased construction cost. In this study an attempt has been made to find the suitability of ceramic coarse aggregate as a possible substitute for conventional aggregate in concrete. The ceramic industry is known to generate large amounts of calcined-clay wastes each year. So far a huge part is used in landfills. Reusing these wastes in concrete could be a within situation. So we prefer ceramic waste to increase the strength and stability of concrete.
***Keywords*: Ceramic waste, Economical, Waste products, Dumping, Failure mode.**

I. INTRODUCTION

A. General

Today Ceramic has become synonymous with flooring. Each waste product has its specific effect on properties of fresh and hard concrete. The use of waste products in concrete not only makes it economical but also solves some of the disposal problems. In ceramic industry, about 30% productions go as waste. 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. As the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for its disposal [1]. The use of crushed ceramic aggregate can be used to produce lightweight concrete, without affecting strength [2]. Crushed Insulator bush scrap was used as a coarse aggregate in the present study. This insulator bush was used in manufacturing of transformers. This type of Ceramic waste from industries is mounting day by day in processing, transporting and fixing due to its brittle nature. It is reported that toughness and soundness of recycled coarse aggregate is 30% less than the natural aggregate and loss of strength is about 30% as compared to the conventional aggregate concrete. Similar trends were reported even for split tensile strength also [3-4]. Reduction of slump was 5.3% when recycled ceramic aggregate was used at a replacement level of 25% and its water absorption was 0.55%, which was higher than that of natural aggregate at 0.23% [5]. The development of concrete properties was observed by substitution of crushed stone coarse aggregate with crushed wasted ceramic aggregate and sand fine aggregate with quarry dust aggregate [6]. The conventional crushed stone aggregate reserves are depleting fast, particularly in some desert regions of the world [7].

II. EXPERIMENTAL PROGRAMS

A. Types of Materials

1) *Cement:* The cement for the whole work was procured in a single consignment and properly stored. The properties of cement (IS: 12269, 1987) used in the investigation are presented in Table 1.
2) *Fine Aggregate:*

a) Sand: River sand was used as fine aggregate. The specific gravity of sand was 2.63 and fineness modulus of fineness was 2.52.

3) *Coarse Aggregate:*

a) *Conventional Coarse Aggregate:* Machine crushed stone obtained from a confined Quarry was used as coarse aggregate.
b) *Ceramic Scrap:* The ceramic crumb was obtained from a local ceramic insulator industry. The ceramic insulators are initially broken into pieces with mallet into required size.

The properties of Conventional aggregate and crushed insulator ceramic scrap are shown in Table 2.

B. Preparation of Specimens

The quantities of the constituent of the concrete are obtained from the Indian Standard Mix Design method (IS: 10262, 1982). The variation of strength of hardened concrete using ceramic scrap as partial / full replacement is studied by casting cubes, cylinders and prisms. The concrete was prepared in the laboratory-using machine mixer. The cement, fine aggregate and coarse aggregate were

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first mixed in dry condition to obtain uniform colour and calculated amount of water required from workability test was added and the whole concrete was mixed for five minutes in wet state. Meanwhile the moulds are screwed firmly to avoid leakage; oil was applied on inside surface of the moulds. The concrete after mixing was filling into moulds in three layers by poking with a tamping rod. The cast specimen was removed from moulds after 24 hours and the specimens were immersed in a clean water chamber. After curing the specimen for a period of 28 days, the specimens were removed from the water chamber and allowed to dry under shade.

Table 1
Properties of cement

SL.No	Porperty	Value
1	Specific gravity	3.15
2	Fineness of Cement by Sieve	4%
3	Initial setting time	55 min
4	Final setting time	9 hour 30 min
5	Standard consistency	30 %
6	Compressive strength	54.20 N/mm^2

Table 2
Properties of coarse aggregate

SL.No	Porperty	Conventional Coarse Aggregate Value	Ceramic Coarse Aggregate Value
1	Specific gravity	2.70	2.65
2	Fineness	6.50	7.00
3	Impact strength	17 %	18.5%
4	Crushing strength	20.50	22.75

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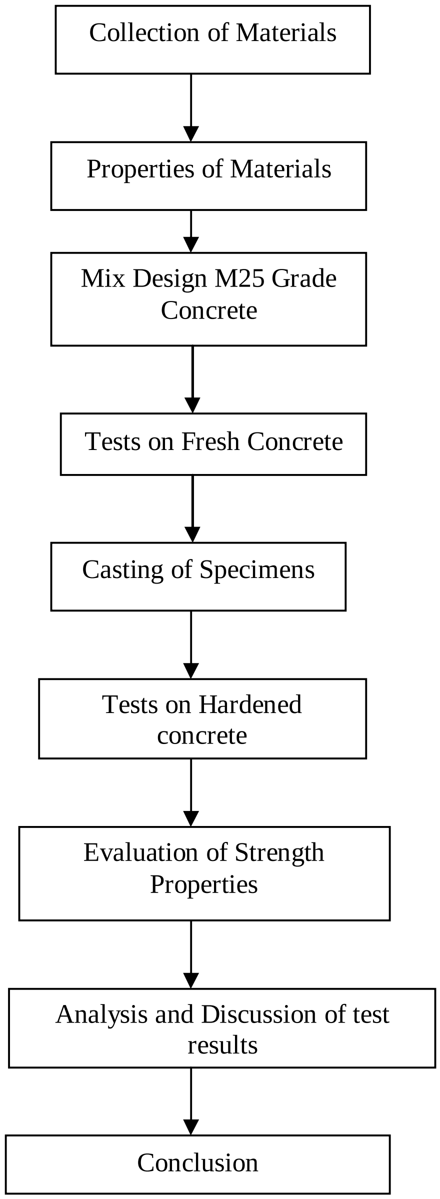
III. METHODOLOGY



A. Compressive Strength Test

It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 7days and 28 days, determines the nominal water-cement ratio of the mix. Compressive strength of concrete is usually found by testing Cube specimen. Cube of size 150 mm x 150 mm x 150 mm were casted using M_{25} grade concrete. Specimens with Control Concrete and Ceramic Waste Concrete (ceramic waste is replaced with crushed stone) were cast. During casting the cubes were manually compacted using tamping rods. After 24 hours, the specimens were removed from the mould and subjected to water curing for 7days and 28 days. The specimens are not to be allowed to become dry at any time until they have been tested. The specimens are tested immediately on removal from the water whilst they are still in a wet condition. The dimensions of the specimens are their weight was recorded before testing. The specimens were tested for compressive strength as per IS 516-1959 using a calibrated compression testing machine as shown in fig 1 of 2000 KN capacity. After placing the specimen the compression load is applied due to compression the specimen fails this failure is noted and shown below.

The compressive strength of the specimen was calculated by using the formula

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$$fc = P / A \quad N/mm^2$$

Where,

P = Load at which the specimen fails in Newton
A = Area over which the load is applied in mm^2
fc = Compressive stress in N/mm^2

Fig 1 Specimen for Compressive Strength

B. Behaviour and Mode of Failure

The cube was subjected to compressive force to expose its behavior. The failure pattern of various concrete cubes is shown in figure. As the load increases, the diagonal crack width is also increased and extended towards the top of the cube. The concrete was crushed and spalling down.

Fig 2 Failure mode (CC)

Fig 3 Failure mode (CWC 15%)

Fig 4 Failure mode (CWC 30%)

Fig 5 Failure mode (CWC 45%)

C. Crack Pattern

1) *Control Concrete (CC):* The first crack is appeared at a load of 350kN further increasing the load the crack width also increased and it was collapsed at a load of 610kN.

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2) *Ceramic Waste Concrete (CWC 15%):* The first crack is appeared at a load of 325kN further increasing the load the crack width also increased and it was collapsed at a load of 600kN.
3) *Ceramic Waste Concrete (CWC 30%):* The first crack is appeared at a load of 300kN further increasing the load the crack width also increased and it was collapsed at a load of 565kN.
4) *Ceramic Waste Concrete (CWC 45%):* The first crack is appeared at a load of 280kN further increasing the load the crack width also increased and it was collapsed at a load of 550kN.
5) *Split Tensile Strength Test***:** Split tensile strength of concrete is usually found by testing concrete cylinder. Cylinders of size 150 mm x 300 mm were cast using M25 grade concrete. Specimens with Control Concrete and Ceramic Waste Concrete were cast. During moulding, the cylinders were manually compacted using tamping rods. After 24 hours, the specimens were removed from the mould and subjected to water curing for 28 days. After curing, the specimens were tested for compressive strength as per IS: 5816-1999 using a calibrated compression testing machine as shown below fig 6 of 2000KN capacity.

Two packing strips of plywood 3 mm thick were provided between the specimen one at top and another at bottom. The specimen was placed on the plywood strip and aligned so that, the central horizontal axis of the specimen is exactly perpendicular to the load applying axis. The second plywood strip was placed length wise on the cylinder and the top platen was brought down till it touched the plywood. The load was applied without shock and increased continuously until the resistances of the specimen to the increasing load broke down as shown in fig 7 and no greater load can be sustained.
The Tensile Strength of the specimen was calculated by using the formula.

$$f_t = \frac{2p}{\pi d l}$$

Where,

p = Maximum load in N applied to the specimen
d = Measured length in cm of the specimen
l = Measured diameter in cm of the specimen
ft = Tensile strength N/mm^2

Fig 6 Test setup for Split Tensile Strength of Cylinder   Fig 7 Failure mode of Cylinder

IV. RESULT AND DISCUSSION

A. General

To study and compare the behaviour of concrete using ceramic waste as coarse aggregate experimental investigations as mentioned were carried out on concrete samples for their strength properties. To compare the test results, control concrete with crushed stone as coarse aggregate was tested for all replacement.
The concrete samples were cast with mix 1: 1.65: 2.82 and 1:1.56:2.82. The tests were carried out after 7days and 28 days of the casting of concrete specimen. The percentage variation in properties of concrete using ceramic waste, with respect to that using crushed stone is tabulated in the table for comparative study.

B. Ultrasonic Pulse Velocity Test

Ultrasonic pulse velocity testing method involves measurement of travel time, T of ultrasonic pulse of 50 to 54 kHz, produced by an electro-acoustical transducer, held in contact with one surface of the concrete member under test and receiving the same by a similar transducer in contact with the surface at the other end. With the path length L and time of travel T, the pulse velocity (V=L/T) is calculated. From Table 3 it will be obsevered that for all the concrete time of travel of an ultrasonic pulse is very good on 15% and

30%. Because as per Central Water and Power Research Station Khadakwasla (India) if velocity value is more than 4.5 km/sec quality of concrete is excellent. The velocity value is determined is shown in below table 3.

Table 3
Result of Ultrasonic Pulse Velocity

Types of concrete	Time travelling(μ)	Velocity value (km/sec)
Control concrete	21.4μ	4.67
Ceramic Waste Concrete (15% Replacement)	20.5μ	4.88
Ceramic Waste Concrete (30% Replacement)	21.6μ	4.63
Ceramic Waste Concrete (45% Replacement)	22.2μ	4.51

C. Compressive Strength of Concrete

The cube specimens tested for compressive strength of hardened concrete at the age of 7 days and 28 days. This test is considered one of the most important properties and is often used as an index of the overall quality of concrete. From table 4 the ceramic waste aggregate 15%, 30%, 45% partial replacement, the strength of concrete obtained is noted down.

Table 4
Test Result of Cubes for Compression

Sl. No	Specimen designation	Ceramic Waste %	Average Compressive Strength in N/mm^2	
			7 Days	28Days
1	Conventional concrete	0	10.00	28.00
2	Ceramic Waste Concrete (15% Replacement)	15	8.00	27.00
3	Ceramic Waste Concrete (30% Replacement)	30	7.25	25.00
4	Ceramic Waste Concrete (45% Replacement)	45	6.50	24.85

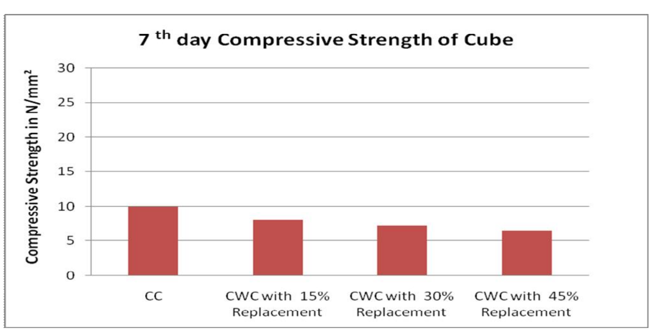

Fig 8 Development of Compressive Strength of Cubes for 7 days

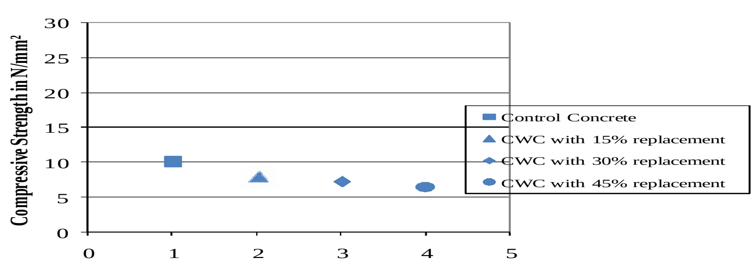

Fig 9 Comparison of Cube Compressive strength for 7 days

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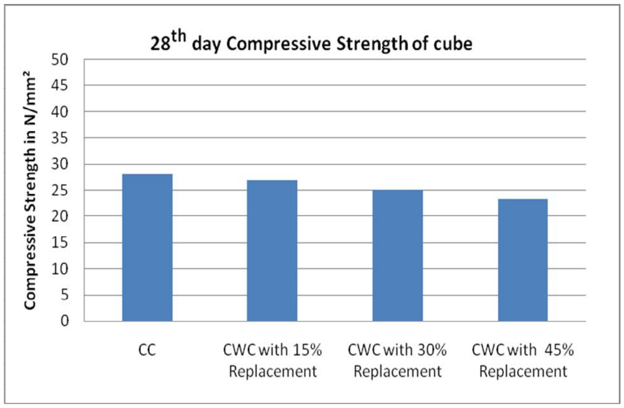

Fig 10 Development of Compressive Strength of Cubes for 28 days

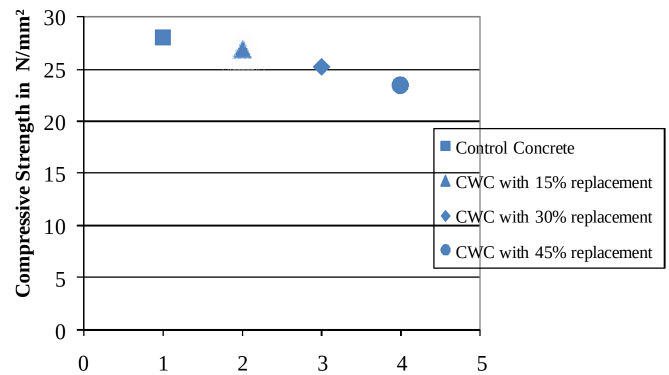

Fig 11 Comparison of Cube Compressive strength for 28 days

D. Split Tensile Strength of Concrete

The cylinder specimens tested for split tensile strength of hardened concrete at the age of 28 days. The test result shown in table 5 revealed that the ceramic waste aggregate of different proportions decreased, when compared to normal convention concrete.

Table 5
Test Result of Cylinders for Split Tensile

SI. No	Specimen designation	Ceramic Waste in %	Average split tensile strength of cylinder in N/mm^2
			28 days
1	Conventional concrete	0	2.80
2	Ceramic Waste Concrete (15% Replacement)	15	2.20
3	Ceramic Waste Concrete (30% Replacement)	30	1.80
4	Ceramic Waste Concrete (45% Replacement)	45	1.20

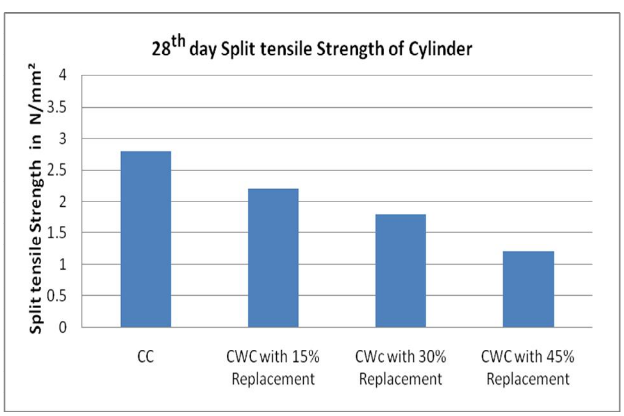

Fig. 12 Development of Split Tensile Strength of Cylinders for 28 day

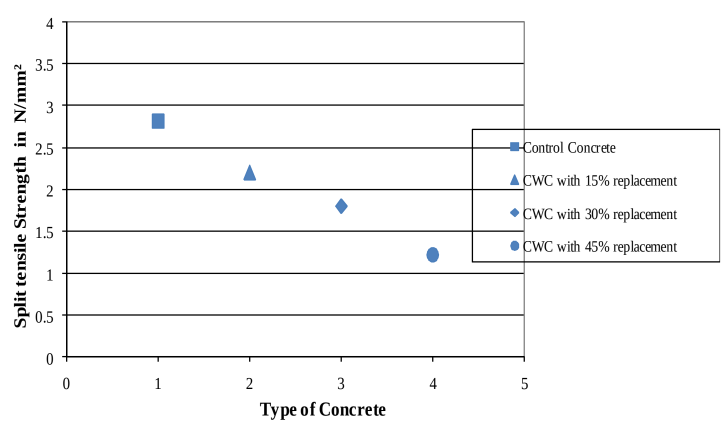

Fig. 13 Comparison of split tensile strength cylinder for 28 days

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V. CONCLUSION

The following conclusions are drawn from the study on ceramic scarp coarse aggregate concrete and they are applicable for the range of parameters and materials used in this study. Ceramic waste can be formed into useful coarse aggregate. It is observed that there is a strength increase with addition of ceramic waste of 15% and beyond which there appears to be no specific enhancement in strength. This strength increase appears to be true for compression.

The specific gravity for ceramic waste is 2.65 whereas for crushed stone is 2.70. The maximum size for both, ceramic waste and crushed stone are the same i.e. 20 mm. The water absorption for ceramic waste is 1.76 percent whereas for crushed stone is 1.53 percent. The properties of ceramic waste coarse aggregate are within the range of the values of concrete making aggregates.

The surface hardness of ceramic waste concrete with 15% replacement of crushed stone aggregate is 6.6 % higher than control concrete. The velocity value of ceramic waste concrete with 15% replacement of crushed stone aggregate is 4.30% higher than control concrete. The compressive strength of ceramic waste concrete with 15% replacement of crushed stone aggregate is 6.4 % higher than control concrete.

Thus, it concluded that the replacement of coarse aggregate with ceramic waste upto 15% replacement reaches optimum level. However, more research studies are being made on the ceramic waste concrete necessary for the practical application as coarse aggregate. In the control concrete beam the ultimate load was 610 kN. After the replacement of coarse aggregate with 15% of ceramic wastage the ultimate load was found to be 600 kN. But 30% and 45% replacement of ceramic scrap has reduced the ultimate load to565 kN and 550KN respectively. Hence the optimum percentage replacement of ceramic scrap should be at 15%.

A. Scope of Future Studies

Investigation on behaviour of concrete in structural applications. Fatigue resistance of concrete can be studied. Applications of these concrete in road works may be explored. Flexural strength and other workability and durability studies can be undertaken.

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