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Strength Behavior of Concrete by Partial Replacement of Fine Aggregate with Ceramic Powder

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***Abstract:** Concrete is currently the world's biggest consumer product that uses natural resources such as sand, crushed stone, and water. Research is under way today to decrease consumption of these materials, due to the depletion of these natural resources for concretion. The fast building growth in India led to a lack of standard building materials. The amount of concrete used and the accessibility of raw material in a developed country such as India are much lower. Ceramics produce wastes inevitably in the ceramic industry, regardless of improved processes; around 15%-30% of production is waste output. The ceramic industry dumps waste in all surrounding storage or empty regions close to the facility, although reported locations are labelled for discarding. The pollution of the dust and the occupation of a broad area of soil is caused by serious environmental contamination especially after the powder is dry. Ceramic dust is the most important waste from the ceramic industry. This paper investigates concrete strength features through fractional substitution of fine aggregates with ceramic powder. The fine aggregate was partly combined with ceramic powders in the current experimental study for M25 concrete grade. The tests were performed with 10 percent, 30 percent, 40 percent, 50 percent substitution of fine aggregates with ceramic powder by weight and 28 days of strength testing to evaluate the mechanical characteristics i.e.; compression, tension, and flexural behavior. The optimum proportion of ceramic powder addition is evaluated in view of the mechanical requirements of concrete*

***Keywords:** Ceramic powder, Concrete, Compression, Flexural, Strengthening, Tension*

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I. INTRODUCTION

Concrete comprises of broken rocks (coarse aggregate), sand (fine aggregate) and cement. It was used in all building work for over a decade. In the latest past, a range of fresh products has been created to satisfy functional, strong, economical and long-lasting demands with the constant supply of the building industry [1]–[3]. The output of Indian ceramics is 100 million tonnes per year. In terms of tile manufacturing India ranks in the top 3 nations worldwide. Production was around 600 million square meters in 2011-12. The enormous ceramic tile manufacturing is due to the boom in the residential industry combined with public measures that stimulate powerful development in the housing industry. About 15% to 30% of waste product is obtained in the ceramic sector from complete manufacturing [4]. While the use of ceramic waste has been carried out, there is still insignificant waste re-used in this manner. Therefore, it is totally essential to apply this in other sectors. All ceramic waste can be used by the construction industry and so help to resolve this environmental issue. All the discarded material is thrown in ceramic stoneware like a wall, boards of the ground and sanitary products. They use red and white pastes; however, the use of the white paste is greater and more common. The fired ceramic waste was categorized by the manufacturing method in each category. The following diagram shows a certain classification (Figure 1)[5][3]. Ceramic products of various kinds such as walls and floors, bricks and roof tiles, household ceramics, refractory products, plumbing pipes, tiles used for the space shuttle, gas burner nozzles, missile nasal cones, Jet engine coatings, ceramic disc break, etc.

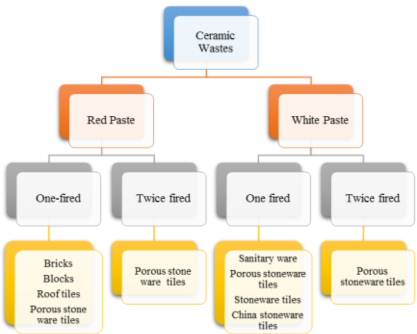

Fig.1: Classification of ceramic wastes by type and production process [5].

In ceramics, waste material produced from complete production is almost 15%-30%. Ceramic wastes cause contamination of soil, air, and groundwater. Ceramic waste is at present a problem in today's society and is not recycled in any course. In order to achieve sustainable growth, an appropriate type of leadership is needed in the community[6][7].
The industries dump waste near their units in a nearby pit or vacant areas, however, reported regions are already labelled for discarding the wastes[8]. This helps to reduce pollution and occupy an enormous area of robust soil particularly when the powder drops, and then ceramics must be disposed of promptly and used in the construction industry[9]. It was projected that approximately 30 percent of daily ceramics manufacturing is wasted. The waste is not currently being recycled in any way. The ceramic waste, however, is durable, difficult and extremely resistant to biological, chemical and physical damage. As ceramic waste pillows up every day, the ceramic industry is under strain to find a way to dispose of it[10]. The application in different industries, particularly the building, would, therefore, contribute to the protection of the environment by the application of marble and ceramic waste powder. Therefore, it results in the development of environmentally responsive concrete[11]. The waste materials obtained from ceramics is regarded as a solid waste that is non-hazardous and has pozzolanic properties. [12]–[15]. Industrial waste is used in a concrete blend as a fine and coarse aggregation of up to 35% of tile waste than cement particles [16][17]. The application of safe industrial waste in India is also becoming more popular for the preparation of building material components for construction work[18]. Anwar et. al. (2014, 2015) analyses consistent reduction in concrete compression behavior when a certain proportion of cement is substituted with ceramic waste or marble dust powder[19][20]. Advancing concrete innovation can decrease natural resource usage. It focused on natural resource regeneration and reuse and found other alternatives[21]. The role of partial replacement of concrete with ceramic waste powder and the fine aggregate with marble dust powder may reduce a certain degree of cement production and natural resource depletion thereby lowered demands for land for resource and industrial waste disposal. [22]–[24] The ceramic waste powder is one of the most vibrant fields of studies covering a variety of topics, including civil engineering and construction fabrics[25]–[27]. This paper provides feasibility in order to obtain economic and environmentally friendly concrete for partially substituting fine aggregates with ceramic waste powder.

II. EXPERIMENTAL DETAILS

A. Material Used and Their Properties

a) Cement

Ordinary Portland (OPC) 43 grade commercially accessible, produced by the JAYPEE Cement Group confirming IS 8112:1989, was used as a binding agent on the mixes [28] (Guidelines, BIS, New Delhi). Table I shows the physical properties of Ordinary Portland Cement.

Table I: Ordinary Portland cement Physical Properties

Properties	Observed Value
Normal Consistency	34%
Initial Setting Time	31minutes
Specific Gravity	3.15

b) Fine Aggregate

Fine aggregates are defined as fractions from 4.75 to 150 microns. Sand passing through IS sieve 4.75 mm is accessible locally, as a good aggregate conforming to IS 383:1970[29] respectively. The effects of the various tests are tabulated in Table II.

Table II: Fine aggregate physical characteristics

Properties	Observed Value
Grade Zone	II
Fineness Modulus	3.09
Specific Gravity	2.53
Silt Content	2.78 %
Water Absorption	1.04 %

c) Coarse Aggregate

Coarse aggregate of fractions between 20 mm and 4.75 mm was utilised. The aggregate from the local quarry is used in accordance with IS 383:1970 [29]. The coarse aggregate with a maximum 20 mm size, 0.45 percent water absorption Table III presents the effects of different tests.

Table III: Coarse aggregate physical characteristics

Properties	Observed Value
Fineness Modulus	7.38
Specific Gravity	2.70
Water Absorption	0.45%

d) Ceramic Powder

The ceramic powder used in this work was brought from SAB Accelerators LLP Rania, Uttar Pradesh, India. Physical and Chemical Properties of ceramic powder used in the Study are tabulated in Table IV. The ceramic powder used in the Experiment is shown in Figure 2

Fig. 2: Ceramic powder

Table 4: Physiochemical Properties of Ceramic powder

Property	Unit	Value
Lightness	-	90-45
The average size of the particle	microns	4-5

Surface Area	Sq. m/gm	14-18
Specific Gravity	-	2.7-2.8
Bulk Density	gm/cc	0.38-0.45
Water Absorption	%	38-42
pH Value	-	5.5-6.5
Moisture	% max	0.2
Silicon dioxide	%	53-55
Aluminum Oxide	%	35-37
Ferric Oxide	% max	0.05
Mixed Oxides	% max	2.2
Ignition Loss	% max	1.5
Residue on 500 mesh	% max	0.5

(Source: SAB LLP Rania Kanpur, Uttar Pradesh, India)

B. Mix Design

The concrete mix design was proposed by using Indian Standard for control concrete. The mix design for M25 grade concrete was carried out using IS 456:2000[30], IS 10262:2009[31]. The yielded mix proportions required as per design mix are given in Table V

Table V: Mix design and proportion of M25 grade concrete.

Grade	M 25
Cement (Kg/m^3)	410.43
Fine Aggregate (Kg/m^3)	577.4
Coarse Aggregate (Kg/m^3)	1212.72
Water (Kg/m^3)	183.57
Water/cement proportion	0.44
Mix Proportion	1:1.4:2.9

III. EXPERIMENTAL METHODOLOGY

The number of concrete components was acquired using the IS: 10262-2009 mix design method [31]. The research examines the strength of the compressive, split tensile and flexure behavior of concrete when the fine aggregate is substituted by ceramic waste powder. The interior measurements of the casting moulds include 150mm × 150mm × 150mm for the cube, 100mm × 100mm × 500mm for beam, 150ϕ × 300mm for the cylinder. Cement, coarse and fine aggregates were carefully blended with the aid of a mechanical blender. The moulds have been located on a vibrator for all tests, and concrete in three layers has been fed into moulds using a tamping bar and the vibration was affected by the vibrator after filling the moulds. For one minute, moulds were placed on a vibration table and likewise persistent for every specimen. On a compression testing machine using cube samples, compressive strength studies have been performed. Similarly, on the universal testing machine using cylinders and beams samples for split tensile and flexural strength test were performed. The average strength values in the present paper were tested with three samples per batch. The ceramic powder was used in different proportions of 0%, 10%, 20%, 30%, 40% and 50% by weight of M-25 grade concrete. A total of 18 cubes, 18 cylinders, and 18 beams were examined, and results were analysed for a period of 28 days after curing of the samples. The samples have then been separated and dried in the shadow of the tank. Compared to standard concrete the consequence achieved from a partial substitution of the coarse aggregate with ceramic powder.

A. Compressive Strength

The compressive resistance experiment is the most popular experiment on concrete, as the characteristics of concrete are quantitatively linked to their compressive behavior[1]. A 3000KN compression test machine (CTM) was used to assess the compression strength (Fig. 3). Concrete compression strength was evaluated using cubic samples of 150 mm. The experiment was done by inserting a sample between the charging areas of a compression testing machine and applying the load so long as the sample fails. In this research 18 concrete cube moulds are filled with concrete at every casting or with different percentage. Following thorough research, we acquired the following results for the Concrete Compressive Strength Tests (M-25, Table VII) (Fig.4 and Fig. 5)

Fig. 3: Testing for Compressive Strength at Advanced Material Testing Lab, Integral University, Lucknow

Mix Proportion Details:

Table VI: Mix Proportion

S.No	Mix	Cement (%)	Coarse aggregate (%)	Fine aggregate (%)	Ceramic waste powder (%)
1	M1	100	100	100	0
2	M2	100	100	90	10
3	M3	100	100	80	20
4	M4	100	100	70	30
5	M5	100	100	60	40
6	M6	100	100	50	50

Table VII: Partial substitution of ceramic powder for fine aggregates (M-25) for compressive strength

S. No.	Specimen	Compressive Strength at 28 days (MPa)
1	M1	30.4
2	M2	33.6
3	**M3**	**28.86**
4	M4	22.34
5	M5	18.82
6	M6	15.53

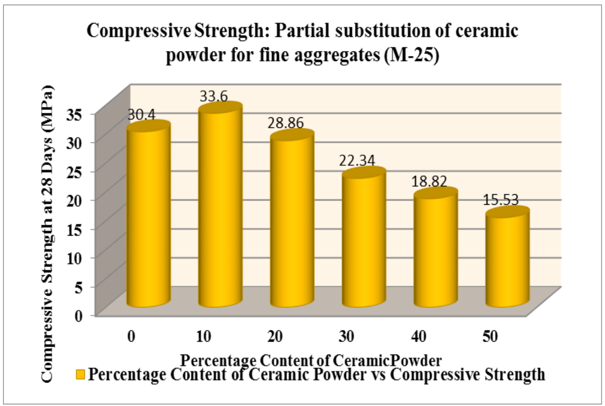

Fig. 4: Contents of ceramic powder compared with compressive strength of concrete (M-25): Bar chart

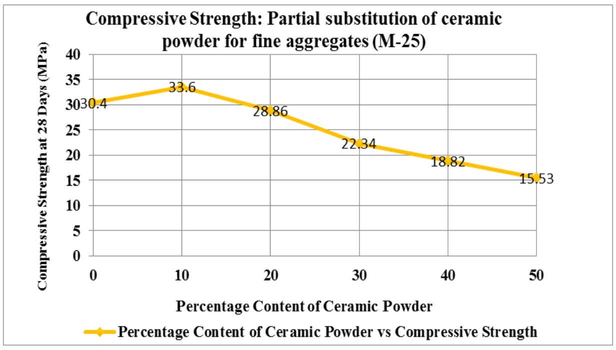

Fig. 5: Bar Chart - Percentage Content of Ceramic Powder vs Compressive Strength of Concrete (M-25)

B. Split Tensile Strength

One of the basic and important characteristics is the tensile strength of concrete. Splitting tensile strength tests on a concrete cylinder is a method for determining concrete tensile strength[32]. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. Because of its fragile nature, the concrete is very tension-weak and should not withstand the immediate stress[33]. The cylinders are inserted into the compression testing machine and are loaded like the cube. The cylinder is horizontally positioned and tested. The load rises until the sample falls and the peak load is registered for the sample. Following a detailed study, we obtained the results for the split-tensile concrete strength test (M-25), as shown in Table VIII (Fig. 7 and Fig. 8)

Figure 6: Split Tensile Strength test at Advanced Material Testing Lab, Integral University, Lucknow.

Table VIII: Split Tensile Strength at 28 days by Partial Replacement of Fine Aggregate with Ceramic Powder (M-25)

S.No .	Specimen	Split Tensile Strength at 28 days (MPa)
1.	M1	2.79
2.	**M2**	**2.84**
3.	M3	2.17
4.	M4	1.96
5.	M5	1.54
6.	M6	1.14

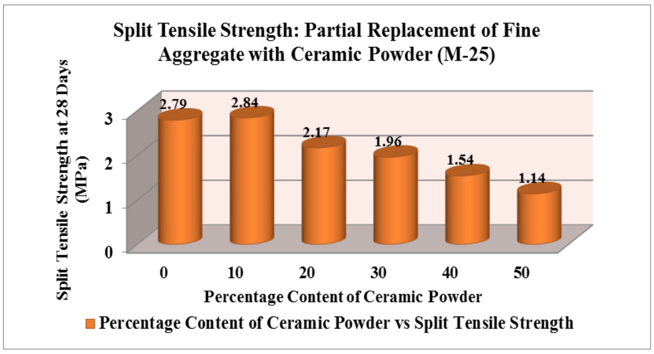

Fig. 7: Bar Chart-Percentage Content of Ceramic Powder vs Split Tensile Strength of Concrete (M-25)

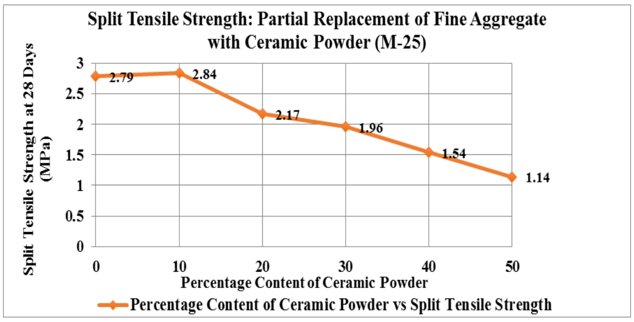

Fig. 8: Percentage Content of Ceramic Powder vs Split Tensile Strength of Concrete (M-25)

C. Flexural strength

Flexural strength is a study that demonstrates the material's deformation resistance when placed under load[34].

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Rectangular samples of the loaded material in a three-point loading experiment setup are used for evaluation of deformation resistance values through flexural tests. At the moment of failure, the bending structure strength appeared in the outermost fibers of samples. A 700 mm x150 mm x 150 mm concrete beam was casted and a whole 18 beams were casted, tested after a 28 day curing process. In a further thorough research, as shown in Table 9, we achieved the following results for the Concrete Flexural Strength Tests (Fig. 10 and Fig. 11)

Fig. 9: Flexural Strength Test at Advanced Material Testing Lab, Integral University, Lucknow

Table 9: Flexural Strength at 28 days by Fractional Substitution of Fine Aggregate with Ceramic Powder (M-25)

S.No.	Specimen	Flexural Behavior at 28 days (MPa)
1.	M1	4.60
2.	**M2**	**4.74**
3.	M3	3.47
4.	M4	2.57
5.	M5	1.81
6.	M6	1.45

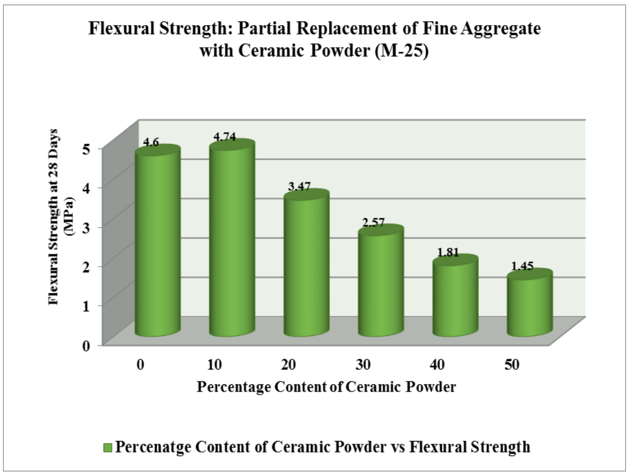

Fig. 10: Bar Chart-Percentage Content of Ceramic Powder vs Flexural Strength of Concrete (M-25)

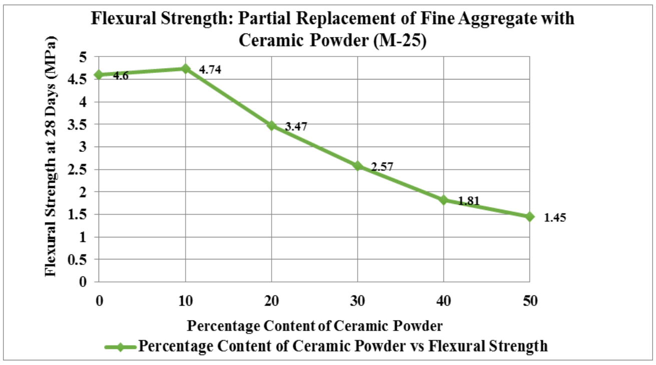

Fig. 11: Percentage Content of Ceramic Powder vs Flexural Strength of Concrete (M-25)

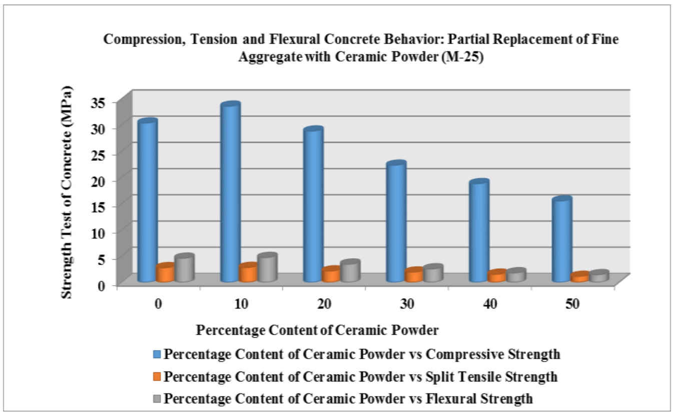

Fig. 12. Combined Graph: (Bar Chart) Percentage Content of Ceramic Powder vs Strength of Concrete (M-25)

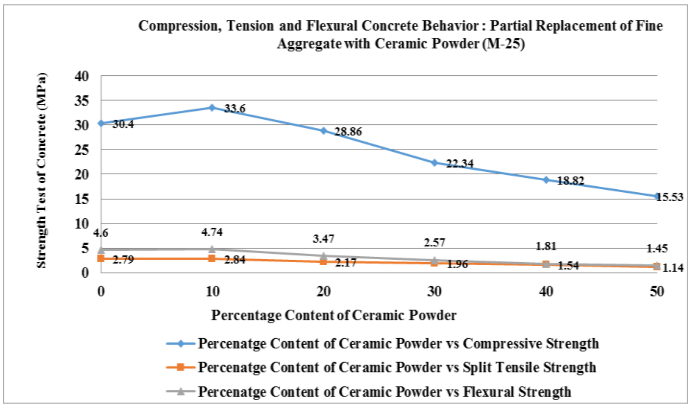

Fig. 13. Combined Graph: Percentage Content of Ceramic Powder vs Strength of Concrete (M-25)

IV. RESULT AND DISCUSSION

The impact of ceramic powder on the mechanical behavior of concrete were evaluated. The rise in the proportion of substitution of fine aggregate by ceramic waste powder at 10 percent shows noteworthy growth in compression behavior. At the 20% partial substitution of fine aggregation by ceramic waste powder, the optimum value of compressive strength was discovered. Similarly, at 10% partial substitution of fine aggregate with ceramic powder, the optimum value for tension and flexural behavior was discovered.

At 10% finer aggregations replaced by ceramic powder the increase in the mechanical performance of concrete was in the proportion of 10.53% for compression, 1.76% for tension, and 2.95% for flexural behavior.

V. CONCLUSION

The experimental information demonstrates that the ceramic powder partial substitution increases the mechanical characteristics of concrete. The research above shows that ceramic powder can be used as a substitute for finer aggregates by 20%. The mechanical characteristics acquired are increased and the price of concrete decreased by 20 percent when the finer aggregate is substituted with ceramic powder, which is, therefore, more economical without compromising the concrete stability. Compression resistance was optimized by fractional substitution of fine aggregate with ceramic powder at 20 percent. Splits tensile strength and flexural strength has an optimum value discovered at a 10% partial substitute with ceramic powder for the fine aggregate. It is technically and financially viable. Concrete meets the mechanical characteristics of M25 grade by 10 percent and 20 percent fractional substitution, alternatively, a greater proportion of powdered ceramic waste decreases the resistance behavior of conventional concrete.

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