Partial Replacement of Cement and Coarse Aggregate with Silica Fume and Ceramic Tile Waste

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Abstract: *This Experimental study investigates the behavior of strengthened concrete with silica fume and ceramic tile waste as a replacing material with cement and coarse aggregates to improve the properties of concrete. Silica fume is a pozzolanic material it creates pozzolanic activity in concrete. Ceramic tile waste is easily available in nature and it is a micro filler material in concrete. Ceramic tile waste is economical and ecological in nature but silica fume is quite more expensive in cost. This paper mainly focuses on silica fume and ceramic tile waste which have wide application in construction. In this investigation different percentages of silica fume and ceramic tile waste of 0% 5% 10% and 15% replacement with cement and coarse aggregates in M40 grade of concrete. At various periodical intervals the specimens of concrete are tested for compressive strength, split tensile strength and flexural strength test.*

Keywords: Concrete, silica fume, ceramic tile waste.

1 Introduction

Concrete is a commonly used in construction material for different types of structures due to its strength and stability. Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Improve strength of concrete by using pozzolanic materials such silica fumes, metaoline, G.G.B.S. as partial replacement to weight of cement by varying percentages, 5, 10, 15 and M40 grade of concrete was used for comparison of strength properties of concrete. Silica fume, metakaoline, G.G.B.S as replace with cement separately with an incremental proportion of 0%, 5%, 10% and 15%. The result of both individual test and each material respect separately the 10% replacement show the high strength [7]. Silica fume is a byproduct from silica alloys gives higher strength and also high durability and acts as filler material. The particle size is less than particle size of cement [1]. undependable evidence has recommended that silica fume is helpful for improving pervious concrete strength and durability. For pervious concrete produced with fixed compaction power changes in workability are reflected in void content which extensively impacted performance. The result shows 5% silica fume produced the best performance of increased workability, strength and durability [6]. In constructions the utilization of ceramic materials is increasing day by day in the type of tiles, sanitary fittings, electrical insulators etc. But large amount of ceramic materials changes into wastage during transporting, processing and fixing due its brittle nature [4]. In this used both silica fume and ceramic tile waste as replacing material of cement and coarse aggregate. Recent advancements in recycling have distorted nonrenewable resources into partially renewable resources [8]. In line with these advancements, the application of wastes, including ceramics, as replacement aggregate materials for construction has elicited substantial research interest. Ceramic waste aggregates can be used to address complex problems, such as the shortage of materials in construction sites, and reduce environmental wastes. Many researchers have studied on only one replacement but combination of both materials is done in this project for finding mechanical properties of concrete strength.

2. Literature survey

- Jagadeesh Bommisetty, Tirukovela Sai Keertan, A.Ravitheja, K. Mahendr (2019)[4] In this paper the use of ceramic tile waste materials in concrete, with maintaining environmental conditions and increasing the strength parameter in concrete. The percentage replacements of ceramic tile waste was used in incremental proportions of 5%,10%,15%,20% and 25% as coarse aggregate. In this paper tests are done on flexural strength, split tensile strength and compressive strength with same percentage replacement of ceramic tile waste. The replacing of 20% of ceramic tile waste shows the high strength compared to other variations in all three tests of concrete.

- Yuko Ogawa, Phuong Trinh Bui , Kenji Kawai , Ryoichi Sato (2019)[5] In this paper the strength behaviour of compressive strength, shrinkage parameter and carbonation resistance of steam curing of concrete are studied. The used of fly ash as replacement of 0%, 20% and 40%by mass of cement and the porous ceramic tile waste replacement ratio amounted to 0%,10% and 20% of coarse aggregate volume. It made internal steam curing to the fly ash replacement and porous ceramic tile waste replacement in concrete, and this result got of 40% replacement and the carbonation action increase the strength in all parameter.

- G. Naga Venkat , K. Chandramouli , Ezaz ahmed ,V. NagendraBabu (2020)[7] In this paper the M40 grade of concrete was used for comparison of strength properties of concrete and partial replacement of cement with silica fume, Metakaolin and GGBS. The M-sand are used instead of river sand. The compressive strength, split tensile strength tests behaviours are studied. In this paper used the Metakaolin, GGBS and Silica fume as cement with an incremental proportion of 0%, 5%, 10% and 15%. The result of both individual test and each material replacement separately the 10% replacement shows the high strength.

- Goran Adil, John T. Kevern, Daniel Mannb (2020)[6] In this paper the use silica fume is advantageous for improving pervious concrete strength and durability. It also tells about how silica fume affects a variety of pervious concrete properties and durability of the concrete. In this paper it studies on rheological concept and silica fume used as replacing material for cement. The rheological testing indicated that 5.5% replacement of silica fume was optimum for workability for mixture. In this the compressive strength results for lime stone samples and river gravel 20% void and free thaw performance (mass) of mixture of containing various amounts of silica fume are studied.

3. Materials

3.1 Cement: It is a binding material that sets, hardens and can bind other materials also. Ordinary Portland cement (OPC 43 grade Birla cement) confirming to Indian standard code is used. Chemical and physical properties of cement are according to the Indian standards and its particle sizes ranges from 1micron to 50micron.

Table 1: Properties of cement

Sl. NO.	PROPERTIES	
1	Fineness % Retain on 90µ sieve	3%
2	Initial setting time	62 minute
3	Final setting time	370minute
4	Specific gravity	3.15g/cc

3.2 Fine aggregate: It is a construction material mixed with cement or mortar. Well-graded river sand passing through 4.75mm is used as fine aggregate. Sand should be free from clay and inorganic resources. The grading zone of fine aggregate is 3 as per Indian standard specifications.

3.3 Silica fume: It is an artificial pozzolanic material. It is a byproduct from an electric furnace used in production of silicon metal.

Table 2: Physical properties of silica fume

Sl. NO.	PROPERTIES	
1	Color	Standard white
2	Size	0.1 to 0.2 micron
3	Surface area	30000m^2/kg
4	Specific gravity	2.22
5	Density	150 to 700 kg/m^3

3.4 Ceramic Tile Waste : It is hard and highly resistant to the all kind of natural degradation forces like biological, chemical and physical. Partial replacement of ceramic tile wastes as coarse aggregate in concrete improve the strength parameters of concrete. Ceramic materials are increasing gradually in the form of tiles, electrical insulators and sanitary fittings etc. Use of tile wastes in concrete could be an effective and in maintaining the environment and increasing the properties of concrete.

3.5 Water: In concrete mix it plays a dynamic role on the strength of the concrete. The clear and clean water is used and pH value of water should be in the range of 6-8.

4. Methodology

- The methodology to execute the experimental work is, study of concrete properties, by replacing silica fume and ceramic tile waste as cement and coarse aggregates.
- First aim is to find best concrete mix by trail mixes by varying different ingredients. Combination of silica fume and ceramic tile waste by 5%, 10% and 15% of cement and coarse aggregates volume.
- Experimental program is carried out in three stages in first stage, for each mix fresh properties (cement properties test, sand properties test, aggregate properties test and slump cone test) are checked in second stage, cubes, cylinders and beams are casted. And kept in water tank for 7 and 28 days. Then in third stage these cured samples are tested.
- The tests carried out on the specimens are compressive strength test, split tensile strength test and flexural strength test.

Fig 1: preparing of moulds

Fig 2: preparing of dry mix

Fig 3: Tamping of concrete in mould

Fig 4: Curing of concrete cubes cylinders and beams

4.1 Compressive strength test

Compressive strength of M4O grade concrete with mineral admixture (silica fume), and normal concrete are compared. The compressive of strength of concrete cubes of standard sizes 150×150×150 mm is obtained for 7 and 28 days of curing periods.

The compressive strength of cubes is finding by the relation,

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

Where,

F=Compressive strength of cube

P=pressure load on cube

A=C/S area of cube

Fig 5: Compressive test on cubes

4.2 split tensile strength test

The Split tensile strength of concrete specimens is measured by crushing of standard cylinders of 150mm diameter & 300mm height under the loading of compressing testing machine. Splitting tensile strength of specimen can find by the relation is,

$T=2P/\Pi Ld$

Where,

T=Splitting tensile strength, N/mm

P=Breaking load indicated by tensile machine, kN

L=Length of specimen

d=Diameter of specimen

Fig 6: Splitting tensile strength test

4.3Flexural strength test

M40 grade of concrete with added mineral admixture (silica fume), and ceramic tile waste and normal concrete are compared. The standard sizes of beam are 700×150×150 mm is obtained for different curing periods of 7 and 28 days. The flexural strength of beam is finding by the relation,

$F_b=P\times L/bd^2 \quad =N/mm^2$

Where,

F_b=Flexural strength

P=Applied load

L=Supported length

b=Width of beam

d=Depth of beam

Fig 7: Flexural test on beam

4. Mix design

In the starting of experimental procedure very first stage is determination of appropriate mix design, so for achieving appropriate mix design some trial mix designs are made with varying cement (OPC 43 grade), fine aggregate, coarse aggregate these quantities are with 0.4 water cement ratio. Then check the properties of concrete.

Table 3: Mix proportions of concrete

Grade	M40
Water cement ratio	0.4
Water content	191.58 lit/m^3
Cement content	478.95kg/m^3
Fine aggregate	740.925kg/m^3
Coarse aggregate	1212.94kg/m^3
Proportion	[1:1.54:2.53]

5. Results and Discussion

5.1 Compressive Strength of Cubes

The Compressive strength of concrete specimens is measured by crushing of standard cubes of sizes (150×150×150) mm under the loading of universal testing machine.

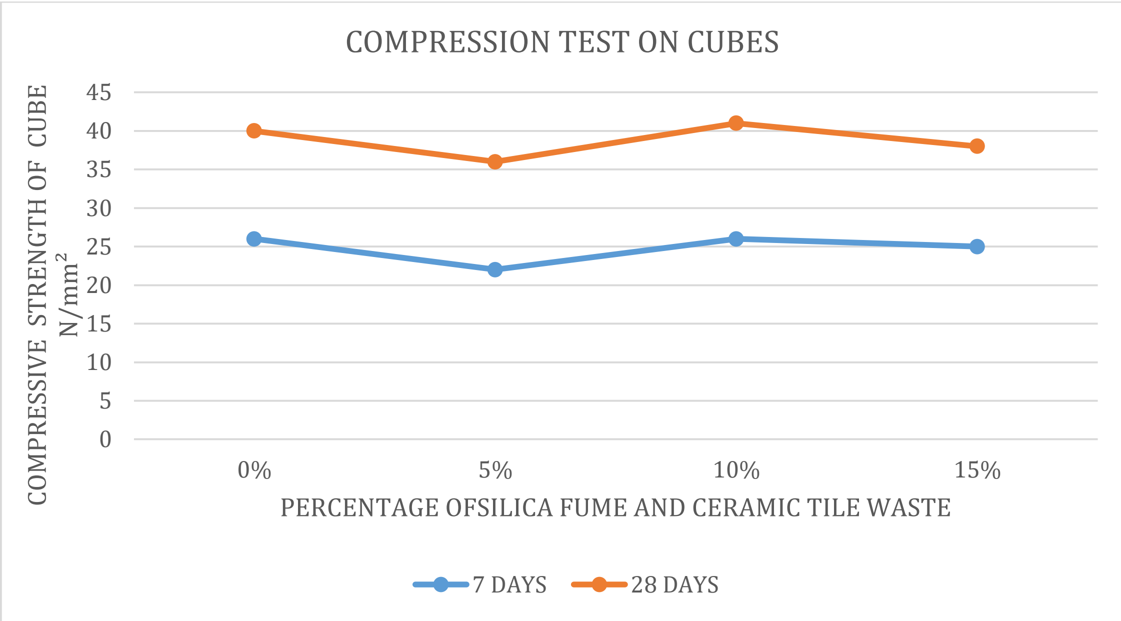

Fig 8: Compressive strength vs percentage replacements

- For normal concrete or zero percent replacement, the concrete cubes strength is 26 N/mm² for 7 days and 40N/mm² for 28 days.
- For 5% replacement, the concrete cubes strength is 22N/mm² for 7 days and 36N/mm² for 28 days.
- For 10% replacement, the concrete cubes strength is 26N/mm² for 7 days and 41N/mm² for 28 days.
- For 15% replacement, the concrete cubes strength is 25N/mm² for 7 days and 38N/mm² for 28 days.

It is a normal concrete and replacement of silica fume and ceramic tile waste. The compressive strength result of concrete for 7 days and 28 days is less in 5% and 15% replacement but slightly equal and more strength getting in 10% replacement. The above figure shows that the compressive strength is increased in 10% replacement but decreases in other percentages.

5.2 Splitting Strength of cylinders

The splitting strength of concrete specimens is measured by crushing of standard cylinder of sizes (150mm diameter and 300mm height) under the loading of universal testing machine.

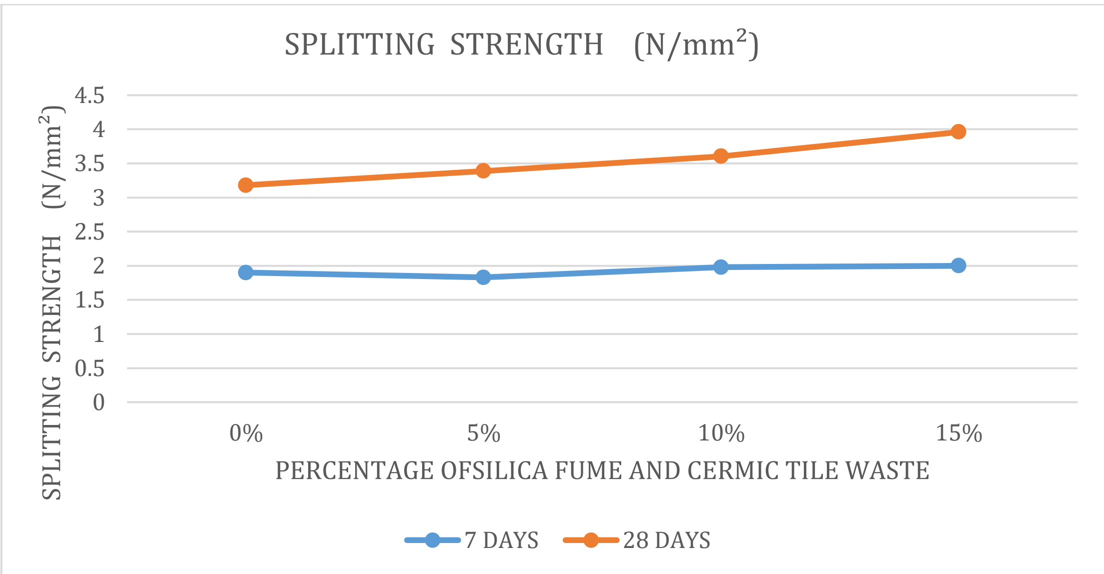

Fig 9: Splitting strength vs percentage replacements

- For normal concrete or zero percent replacement, the concrete cubes strength is 1.9 N/mm² for 7 days and 3.18N/mm² for 28 days.
- For 5% replacement, the concrete cubes strength is 1.83N/mm² for 7 days and 3.39N/mm² for 28 days.
- For 10% replacement, the concrete cubes strength is 1.98N/mm² for 7 days and 3.605N/mm² for 28 days.
- For 15% replacement, the concrete cubes strength is 2.0N/mm² for 7 days and 3.96N/mm² for 28 days.

It is a normal concrete and replacement of silica fume and ceramic tile waste. The split tensile strength result of concrete for 7 days is less in 5% but more getting in 10% and 15% replacement and in 28 days more getting in all three of 5% 10% and 15% replacement when compared to the zero replacement or normal concrete.

5.3 Flexural Strength of beams

The Flexural strength of concrete samples is measured by Center point load test the beam sizes (700×150×150) mm under the loading of universal testing machine.

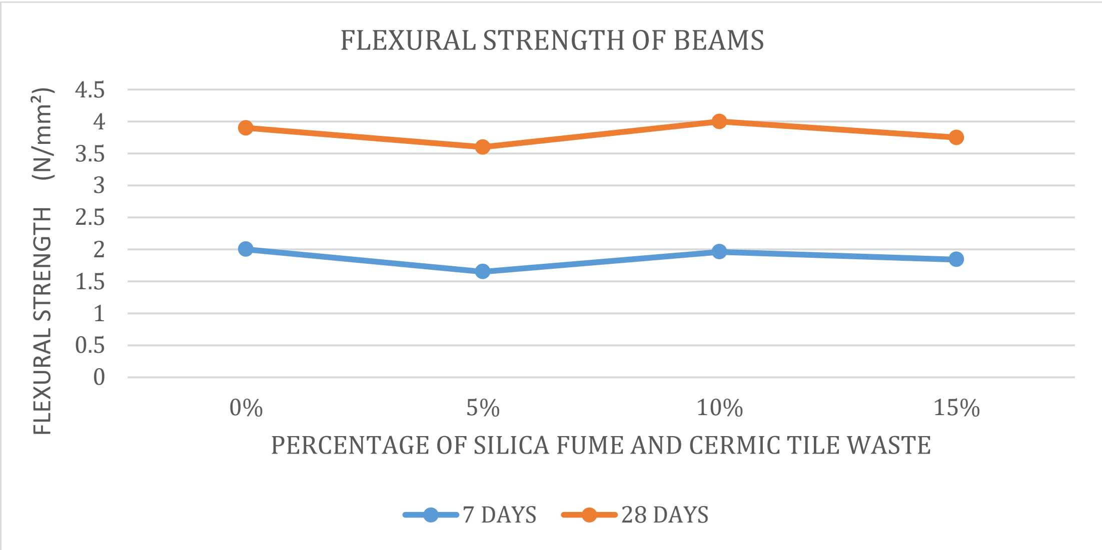

Fig 10: Flexural strength vs percentage replacements

- For normal concrete or zero percent replacement, the concrete cubes strength is 2.0 N/mm² for 7 days and 3.9N/mm² for 28 days.
- For 5% replacement, the concrete cubes strength is 1.65N/mm² for 7 days and 3.6N/mm² for 28 days.
- For 10% replacement, the concrete cubes strength is 1.96N/mm² for 7 days and 4.0N/mm² for 28 days.
- For 15% replacement, the concrete cubes strength is 1.84N/mm² for 7 days and 3.75N/mm² for 28 days.

It is a normal concrete and replacement of silica fume and ceramic tile waste. The flexural strength result of concrete for 7 days is slightly less in 5% 10% and 15% replacement but in 28 days slightly less in 5% and 15% replacement but equal and more getting in 10% replacement. The above figure shows that the flexural strength is increased in 10% replacement but decreases in other percentages. Because the ceramic tile waste acts like micro filler material in concrete. When increased in quantity of ceramic tile waste, it creates more voids in concrete.

6. Conclusions

Based on experimental observations, the following points we have concluded

- The behaviour of concrete by replacing silica fume and ceramic tile waste with 5%, 10% and 15% by mass of cement and coarse aggregates are studied.
- The optimal crushing strength of concrete cube is obtained at 10% replacement and the value is 41 N/mm² it is more than that of normal concrete cube.
- The optimal flexural concrete strength is obtained at 10% replacement and the value is 4.0 N/mm² which is more than that of normal concrete.
- This study assessed and mechanical report of silica fume and ceramic tile waste concrete in an effort to determine its rightness of construction.

- The 10% replacement of cement with silica fume and coarse aggregate with ceramic tile waste, using M-sand instead of river sand give maximum compressive and flexural strength.
- When silica fume are used by the replacement of cement in concrete it gives higher strength values in this project.

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