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CERAMIC TILES AND SILICA FUME AS A PARTIAL REPLACEMENT FOR COARSE AGGREGATE

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ABSTRACT

Mixed design concrete of grade M25 was subjected to both fresh and hardened-state analyses of the incorporated concrete in order to compare and contrast the various mixes' workability, compressive strength, tensile strength, and flexural strength, as well as to determine the optimal mix composition. In this study, silica fume and ceramic tiles were used as partial replacements for cement and coarse aggregate, respectively. Incorporating ceramic tile aggregate and cement with silica fumes at5%,10%, and 15% (M25) as partial replacements for coarse aggregate led to better performance in concrete compared to concrete made with cement and natural aggregate from local resources, according to the results and experimental approach. By lowering the aggregate cost, it creates an economical infrastructure system and lowers the price of concrete. The creation of lightweight concrete by the recycling of waste materials offers many benefits, including a reduction in building costs and an improvement in the security of trash disposal.

In addition, cubes of concrete were mixed and subjected to compressive strength tests; the outcomes were compared to those of concrete whose only coarse aggregate was river wash gravel. According to the results, broken bricks-sand concrete and gravel-sand concrete have about 30% higher compressive, split tensile, and flexural strengths than regular concrete mixes. Soil bearing capacity is poor, natural aggregates are rare, and structural concrete does not need high concrete strength; hence, the research suggests using broken over burned bricks as coarse aggregate.

Key words: Concrete waste, Coarse aggregate, Fine aggregate, Ceramic tiles, Silica fume, Compressive strength, Flexural strength, Split tensile strength

1.INTRODUCTION

The use of waste material as aggregates in civil engineering applications is beneficial because it reduces the environmental impact and economic cost of quarrying operations, processing, and transport. Reuse of construction and demolition waste is becoming increasingly desirable due to rising hauling costs and tipping fees for putting this material into landfills. In recent years, sustainable construction initiatives have also made reuse of construction and demolition debris (as aggregates and otherwise) an appealing option when considering design alternatives for many types of structures. Incorporating these aggregates into cementitious materials is practical, as cementitious materials are non-homogeneous composites that allow material of different sizes and compositions to be bound in a cementitious matrix.

Fig.1: SILICA FUME

Silica fume, a by product of silicon and ferrosilicon alloy production, and ceramic tiles, a waste material generated from construction and demolition activities, are gaining attention as promising substitutes for conventional coarse aggregates in concrete formulations. The incorporation of these materials not only addresses environmental concerns but also offers potential enhancements in mechanical properties, durability, and overall performance of concrete structures.

Silica fume, also known as micro silica, is an amorphous, fine powder consisting of spherical particles with high silica content. It is obtained as a byproduct during the production of silicon alloys through the reduction of quartz with carbon in electric arc furnaces.

Fig.2: WASTE CERAMIC TILES

Ceramic tiles, on the other hand, constitute a significant portion of construction and demolition waste worldwide. Despite their durable nature, ceramic tiles often end up in landfills, posing environmental challenges and wasting valuable resources.

The utilization of silica fume and ceramic tiles as alternatives to traditional coarse aggregates aligns with the principles of sustainable construction, promoting resource efficiency, waste minimization, and environmental stewardship throughout the concrete life cycle.

More over, the incorporation of silica fume and ceramic tiles has the potential to enhance the mechanical, durability, and sustainability performance of concrete structures, thus extending their service life and reducing maintenance requirements. The densification of the concrete matrix, attributed to the pozzolanic reaction of silica fume and the interlocking nature of ceramic tile particles, can lead to improved compressive strength, flexural strength, and modulus of elasticity.

In summary, the replacement of coarse aggregates with silica fume and ceramic tiles presents a promising avenue for advancing sustainable construction practices while maintaining or even improving the performance of concrete structures.

OBJECTIVES:

- To analyze experimentally and practically all the components of the concrete mix.
- The research will be majorly dealing with the analysis of the properties of silica fume and ceramic tiles to be used as coarse aggregates in concrete.
- Prior to developing mix designs, grading was done to obtain the required particle size distribution and tests were performed to characterize the aggregate.

2. LITERATURE REVIEW

2.1 SILICA FUME

Lucky Chandra & DjwantoroHardjito:(2011)

This is focuses on the use of fly ash in the range of 0-30%, silica lume 0-10% and calcium carbonate 0-15% of the cement content on from this the workability of the fresh mortar way, evaluated. and the compressive strength of hardened mortar were measured.

Reza Bani Ardalan, Alireza Joshaghani & R. Douglas Hooton :(2013)

This paper presents the results of an experimental study carried out to investigate the effect of the use of fly ash , silica fume and calcium carbonate. The results indicate the compressive strength and workability of high strength concrete.

Waheeb A. AI-Khaja :(2010)

The study investigate the efficiency of silica fume in influencing the Compressive Strength, drying shrinkage and creep of high-strength concrete at constant Laboratory condition. The results indicates that the compressive strength is increased and shrinkage and creep of concrete reduced.

S. Wild, B.B. Sabir, and J.M. Khatib :(2009)

This focuses on the relationships between temperature, pozzolanic and cement hydration with particular emphasis on condensed silica fume (CSF) – Ordinary Portland cement blends.

The results indicate that relative strength varies directly with CSF content and that the strength enhancement at early curing periods and achieved by increase in curing temperature.

2.2 CERAMIC TILE

Derrick J. Anderson, Scott T. Smith & Francis T.K. Au :(2011)

A coarse aggregate replacement scheme in concrete is investigated with three different waste ceramic tile materials in replacement ratios including 20%, 25%, 35%, 50%, 65%, 75%, 80% and 100%. Results show waste ceramic as a possible practicable natural coarse aggregate replacement material with minimal changes in mechanical properties.

Muge Tarhan, Baran Tarhan & Tuna Aydin: (2017)

This study investigated the effects of fine fire clay waste on ceramic wall tiles. As the amount of FFC waste increased, bulk density and bending strength increased whereas firing shrinkage decreased. Moreover, the water absorption and open porosity of investigated bodies increased.

Marangoni , B. Nait-Ali, D.S. Smith, M. Binhussain, P. Colombo & E. Bernardo :(2013)

`The body of conventional ceramic tiles warms up to environmental temperature through conduction, convection and radiation. The approach leads to the concept of “cool” tiles, aimed at improving the thermal efficiency of buildings.

Timellini, R. Resca and M.C. Bignozzi :(2015)

All the phases, productive sections, processes of the ceramic tile manufacture are characterized by emissions into the atmosphere of gases (air) containing different pollutant. In an area with a high concentration of ceramic tile manufacturing units, important pollutant emissions into the atmosphere occurred the consequences were both excesses over the air quality standards in force in that time, and environmental problems, with detrimental effects on both cattle and some kinds of plant.

2.3 Combined Use of Silica Fume and Ceramic Tiles:

Taha et al. (2020) and El-Hassan et al. (2017)

Investigated the effects of incorporating silica fume and recycled ceramic aggregates on the mechanical properties and durability of concrete.

3. MATERIAL USED

3.1 Cement:

A cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used as a component in the production of mortar in masonry, and of concrete, which is a combination of cement and an aggregate to form a strong building material. Cements used in construction can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to set in the presence of water .

Fig.3: Portland cement

3.2 Coarse aggregates:

Coarse aggregate refers to irregular and granular materials such as sand, gravel, crushed stone and are used for making concrete.

Material that are Large enough to be retained on the 4.7mm sieve size usually constitute coarse aggregate and can reach a maximum size of 63mm

Fig. 4: Coarse aggregates

3.3 Ceramic Tiles:

A tile is a manufactured piece of hard-wearing material such as ceramic, stone, metal, or even glass, generally used for covering roofs, floors, walls, showers, or other objects such as tabletops. Alternatively, tile can sometimes refer to similar units made from lightweight materials such as perlite, wood, and mineral wool, typically used for wall and ceiling applications.

3.4 Silica fume:

Silica fume is a by product resulting from reduction of high purity quartz with coal or coke and wood chips in an electric arc furnace during the production of silicon metal or Ferro silicon alloys. The specific gravity of silica fume is 2.29.It consist of 0.1 to 1 micron sized fine ,smooth spherical glassy particles with fineness of 20m^2 /gm

3.5 Fine aggregates:

Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. As with coarse aggregates these can be from Primary, Secondary or Recycled sources.

3.6 Water:

The potable water is usually measured reasonable for mingling and curing of concrete. Accordingly potable water was used for making concrete available in Material Testing laboratory. This was free from any detrimental contaminants and was good potable quality.

3.7 Mix design of concrete

Characteristics strength =M25 Target men strength =25+1.65*4 According to IS 456, Maximum water cement ratio =0.45 We have adopted 0.40 w/c ratio

Minimum cement content according to IS456 =300KG/m3 Nominal maximum size of aggregate =20mm

According to 10262:2009 maximum water cement ratio =186g For 50 * 75mm slump = 186+3% of 186 = 191.58KG/m3 Water cement ratio is 0.4 so, cement comes to be 478.98KG/m3

478.95 KG/m3 > 300KG/m3

According to zone of site for fine aggregate Coarse aggregate=w/c*0.4=0.62

Fine aggregate=1-0.62=0.38KG/m3

For pump able type of concrete (IS 10262:2009) Values should be reduced by 10%

Mixing calculation per unit the volume of concrete

a. Volume of cement -1m3 =191.58*1/1000 =0.191 m3

b. Volume of super plasticizer =0.64*1/1.145*1000 =0.005 m3

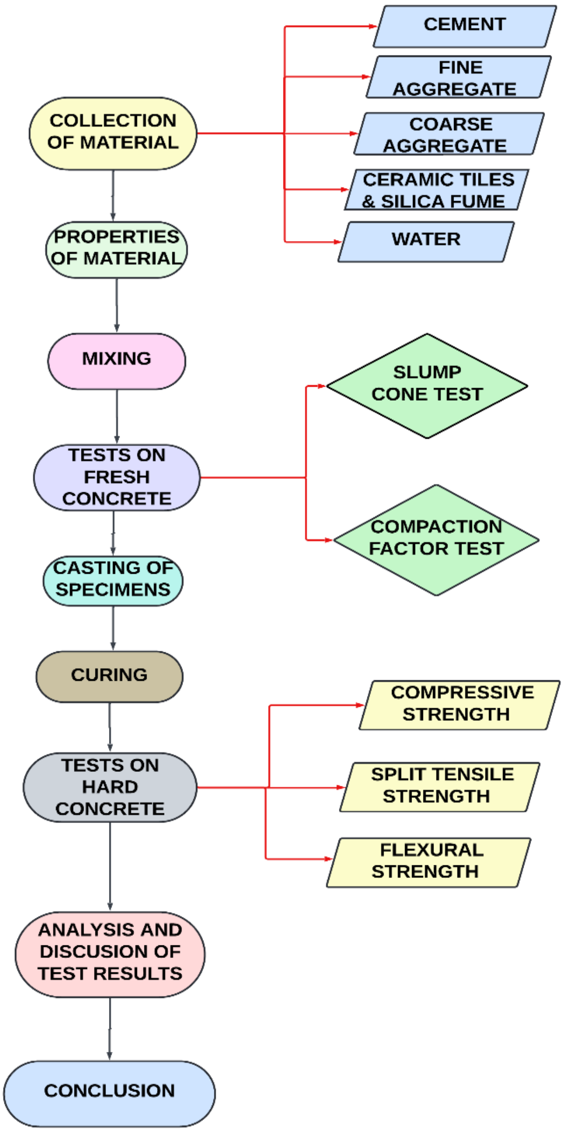
c. Volume of all in aggregate =a-(b+c) =1-(0.15+0.191) =0.659 m3

Mass of coarse aggregate = (e)*vol. of coarse aggregate*specific gravity of coarse aggregate*1000 = 0.659*0.56*2.87*1000

Mass of fine aggregate = (e)*volume of fine aggregate *specific gravity of fine aggregate*1000 = 0.659*0.47*2.53*1000

So the ratio comes out to be= 1:1.53:2.2

4.METHODOLOGY



5. EXPERIMENTAL TESTS

5.1 Slump Cone Test

The slump cone test is to determine the

workability or consistency of concrete mix prepared at the construction site during the progress of the work. On lifting the slump cone filled with concrete, the concrete flows. There are three types of slumps, they are true slump, shear slump, collapse slump.

5.2 Compaction factor test

The test conducted on a concrete mix to check the ratio of its partially compacted weight to the fully compacted weight is called the compaction factor test. This test is carried out primarily to check the workability of concrete. Generally, this test is done on concrete mixes of low workability. On these concrete mixes, the conventional slump test cannot be conducted.

This test is done on the concrete mix to check its water content, cement quality and ratio. All these three factors are quite vital for construction projects. Its prime aim is to calculate the optimum moisture content (MOPT) and the maximum dry unit weight of concrete.

5.3 Compressive Strength of Concrete

Cube specimens of size 150 mm x 150 mm x 150 mm were taken out form the curing tank at the ages of 7, 14 and 28 days and tested immediately on removal from the water (while they were still in the wet condition). Surface water was wiped off, the specimens were tested. The position of cube when tested was at right angle to that as cast. The load (P) is applied gradually i.e. 15.5KN/cm^2. without shock till the failure of the specimen occurs and thus the compressive strength was found.

The magnitude of compressive stress (C) acting uniformly on cube of applied loading is given by formula: $\boxed{C=P/A}$

Where P = Applied load A = Area of cube

Fig.5: Compressive strength test

5.4Split Tensile Strength of Concrete

The split tensile strength of concrete is determined by casting cylinders of size 100 mm x200mm. The cylinders were tested by placing them uniformly. Specimens were taken out from curing tank at age of 7, 14 and 28 days of moist curing and tested after surface water dipped down from specimens. This test was performed on compression Testing Machine. The load (P) is applie 1.8KN/cm^2. The magnitude of tensile stress (T) acting uniformly to the line of action of applied loading is given by formula

$$\boxed{T= 0.637P/DL}$$

Where,

T = Split Tensile Strength in MPa

P = Applied load,

D = Diameter of Concrete cylinder sample

L =Length of Concrete cylinder sample

$$\boxed{T = 0.637P/DL}$$

Fig.6: Split tensile test

5.5 Flexural Strength of Concrete

The flexural strength of concrete is determined by casting beam of size 100 mm x100 mm x 500mm. The beams were tested by placing them uniformly. Specimens were taken out from curing tank at age of 7, 14 and 28 days of moist curing and tested after surface water dipped down from specimens. This test was performed on compression Testing Machine on beam attachment. The load (P) is applied gradually i.e. 6.2KN/cm^2. Beams are tested for two point loading. At 1/3rd from support from both ends.

6. OBSERVATIONS AND RESULTS

6.1 Compression strength

Calculation of strength of cube

Formula used for flexural strength ‘fb’

$$\boxed{fb = PL/bd2}$$

When a > 20.0cm for 15.0cm specimen or > 13.0cm for 10cm specimen) or

fb = 3Pa/bd2 (when a < 20.0cm but > 17.0 for 15.0cm specimen or < 13.3 cm but > 11.0cm for 10.0cm specimen.)

Where,

a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

b = width of specimen

d = failure point depth

L = supported length

P = max. Load

Fig.7: Flexural strength test

Size of Cube = 150*150 mm.

Area of cube = 100^2 mm.

Compression Strength = Load (in Newton)/ Area of Cube (in mm)

Table 1: Compressive strength

Days	(Mix design) Without Replacement	(Ceramic tiles and silica fume) With Replacement (5%)	(Ceramic tiles and silica fume) With Replacement (10%)	(Ceramic tiles and silica fume) With Replacement (15%)
7 Days	15.4	15.5	14.2	20.44
14 Days	18.5	21.4	14.3	23.1
28 Days	30.5	28.7	21.2	32.7

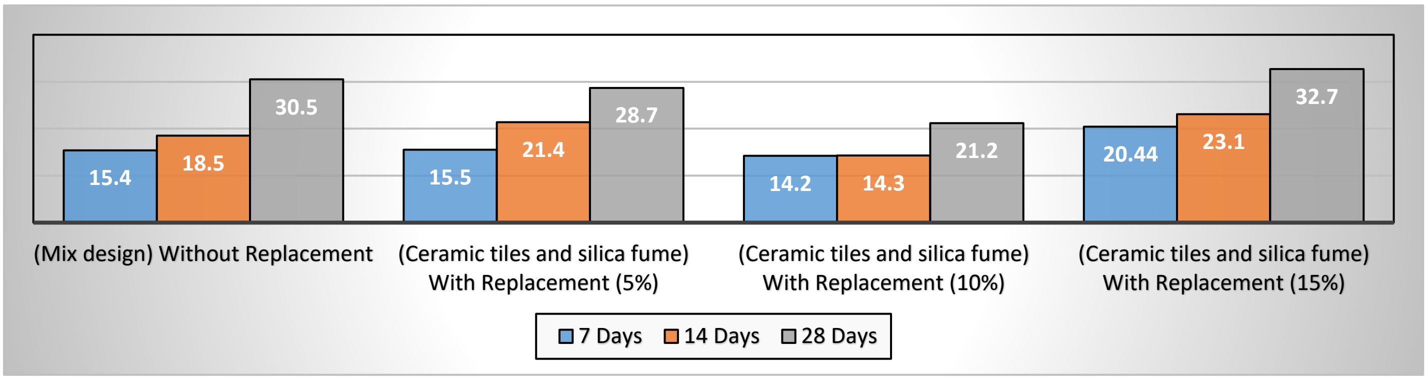


Fig.8:Compressive strength test results

6.2 Split tensile strength

Split tensile strength=2p/3.14

*D*LCalculation of strength of cylinder.

Size of cylinder=300*150(L*D)

Table 2: Split tensile strength

Days	(Mix design) Without Replacement	(Ceramic tiles and silica fume)With Replacement (5%)	(Ceramic tiles and silica fume)With Replacement (10%)	(Ceramic tiles and silica fume)With Replacement (15%)

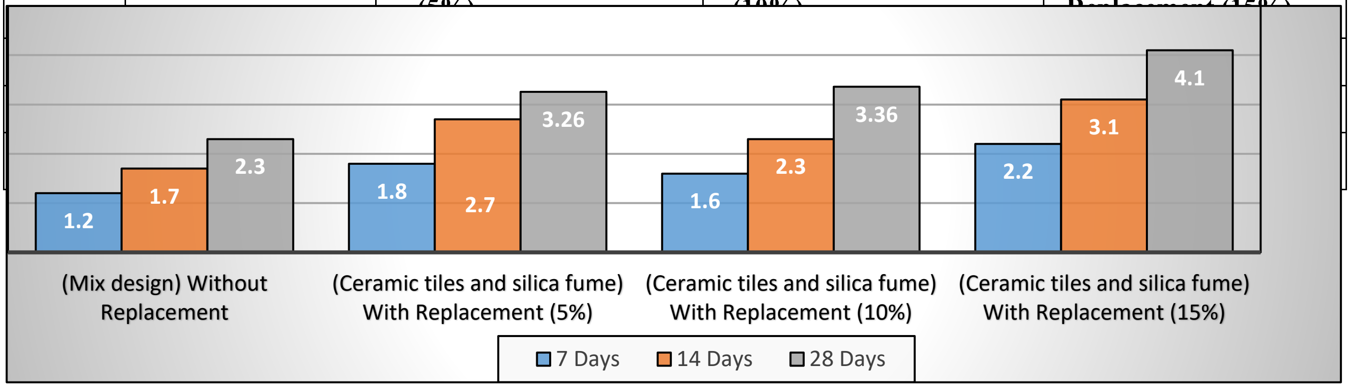


Fig.9:Split tensile strength results

6.3 Flexural strength

Calculation of strength of beam Size of beam=500*100*100

Flexural strength=3pa/bd^2

Flexural strength=p.l/bd^2

Shortest distance from support flexural point of beam= 11mm<a<13.3mm

Table 3: Flexural strength

Days	(Mix design) Without Replacement	(Ceramic tiles and silica fume) With Replacement(5%)	(Ceramic tiles and silica fume) With Replacement(10%)	(Ceramic tiles and silica fume) With Replacement(15%)
7 Days	5	6.2	5.4	6.8
14 Days	7	8.1	5.5	7.5
28 Days	6	9	9.5	11.25

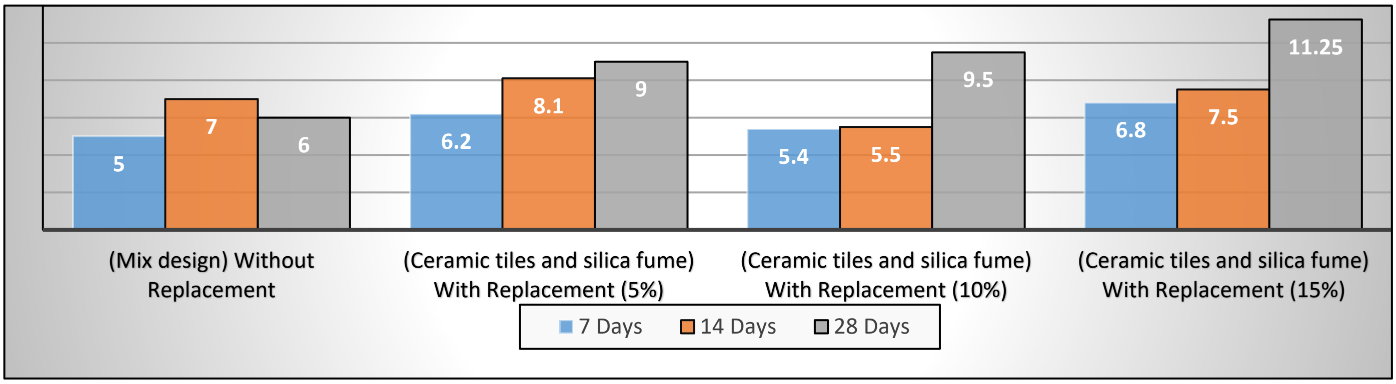


Fig.10:Flexural strength results

7. CONCLUSION

- Silica fume and crushed ceramic tiles waste products gives satisfactory results which can be to produce good quality of concrete of medium to high strength.
- The maximum compressive strength is observed 32.7MPA by replacing 15% of silica fume and ceramic tiles.
- The maximum split tensile strength is observed 4.1MPA by replacing15 % of silica fume and ceramic tiles.
- The maximum flexural strength of concrete is observed 11.25MPA when the silica fume and ceramic tiles are replaced with cement and coarse aggregate by 15%.
- Form this we concluded that the maximum Results obtained when the silica fume and ceramic tiles are replaced by 15% when compared with normal aggregates.
- These conclusions further show that the effects on mechanical behaviour as a result of coarse aggregate replacement are more

variable than traditional concrete.

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