ISSN No:-2456-2165

Experimental Investigation on Utilization of Ceramic Tile Waste as a Partial Replacement of Fine Aggregate in Cement Mortar

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Abstract:- As a result of rapid increase in the demand for river sand from the construction industry, and decrease in its availability led to the immediate need for finding suitable alternatives which can replace fine aggregate partially in higher proportions. Many investigations show the effects of several waste products such as Glass sheet powder, Incinerated Sewage sludge, foundry bed waste, crushed rock flour, building demolition waste in the partial replacement of river sand.

On the other hand, in the ceramic industry, about 15% to 30% waste material is being generated out of total production. These waste production leads to the burden on landfill spaces. Hence, this waste has to be recycled and reused. The aim of this work is to reduce the environmental impact, reduce the consumption of natural resources in the mortar by the replacement of ceramic material as a supplementary fine aggregate. In this study an attempt has been made to find the suitability of ceramic fine aggregate as a possible substitute for conventional aggregate in mortar. This experiment presents the behavior of mortar with partial replacement of sand by ceramic of mix proportion 1:3 at 25%, 50%, and 75%. Efforts are made to study and analyze the key properties and microstructure of the cement mortars.

Keywords:- *Sustainable materials, Landfill spaces, Ceramic waste, microstructure, Suitability.*

I. INTRODUCTION

The construction industry of India is a crucial indicator of the development as it creates investment opportunities across numerous connected sectors with a share of around 8.2%, and has contributed around an estimated amount of ₹670,778 crores (US$ 131 billion) to the national GDP.

According to the Building Material Promotion Council (BMPTC) India generates about 150 million tons of Construction and Demolition (C&D) waste annually, out of which India manages to recover and recycle only about 1% of it. Majority of the developing and developed nations assume that the C&D waste as non-hazardous, less toxic and inert materials that doesn't cause adverse effects to the environment. They are often dumped, without any further treatment even though it leads to ill effects such as illegal dumping and land pollution. Further, this creates an additional burden on landfill spaces and increase in the transportation cost for their disposal. From the viewpoint of sustainable development, it is essential to prevent the over-use of natural resources and make additional efforts towards waste reduction. Hence, utilization of aggregates from demolition waste might function as an answer to reduce the demand-supply problems, decrease the burden of dumping and also conserving the natural resources.

Mortar is a widely used construction material during any River sand being one of the natural resources that is obtained from breaking of rocks is employed as fine aggregate in mortar, however overuse of the material has led to depletion of secured sand deposits. It has a greater impact on environment because after its use, it is generally deposited in landfills.

As there's amendment in bylaws, road have been expanded, zones are modified, decrease in margins, enlargement of building which leads to overcrowding, older building being demolished and newly built building generates a huge amount of waste.

Around rough estimation of 21,000 tons of ceramic waste is been generated throughout India and around 40,860 kg of ceramic waste is generated throughout the Karnataka.

In recent years, recycling and utilization of construction and demolition waste has created a greater potential and also a target of interest. It mainly focuses on waste management polices encouraging minimization, reuse, recycling, and valorization of the waste as an opposition to its final disposal in landfills. We have to make a right alternative and refuse the products which generates a greater amount of waste and pollutes the land. Therefore, it is desirable to obtain cheap, environmentally friendly substitutes for river sand that are preferably by products.

In order to reduce the burden of landfill space, to enrich human inhabitation, ceramic tile waste is extensively used as a partial replacement of fine aggregate in mortar and also improve its strength and other durability factors. Usage of non-conventional aggregate not only turns out to be environmentally friendly but also to be economic.

Ceramic material is the mixture of clay powder and water shaped into desired forms. Ceramic wastes are the waste generated during the process of dressing and polishing which is of 30% of its production. A portion of this waste is also utilized on-site, such as for excavation pit refill. The disposals of these waste materials acquire massive land

ISSN No:-2456-2165

areas and remain scattered all around, spoiling the aesthetic of the entire region. The rate of growth in waste have placed a pressure on the ceramic industries to find an answer for its disposal.

II. EXPERIMENTAL WORK

A. Problem Statement

The use of Ceramic waste sand as a partial replacement for Fine aggregate is undertaken with respect to the mechanical properties and micro-structural behavior of cement mortar. The experimental study focuses on arriving at an optimum replacement level towards better performance with respect to the desired properties.

B. Objectives:

- The objective of this study to replace ceramic tile waste material with fine aggregate in mortar for its utilization.
- To conduct basics tests on (cement, M-sand and ceramic waste sand) all the materials used in study
- To replace the fine aggregates (M-sand) with various percentage of 25%, 50%, 75% ceramic waste in mortar
- To assess the mechanical properties for mortar with the partial replacement of fine aggregate by ceramic waste
- To find out water absorption and density for all the mixes.
- To study the microstructural investigation on the material.
- To conduct cost analysis.

C. Methodology:

Basic materials such as cement and fine aggregate are purchased by local vendors in the city. Ceramic tile waste is procured from local site. Obtained ceramic tile waste is broken into small pieces using a hammer and later crushed by a UTM and sieved through sieve of 4.75mm and used as replacement of sand. The cement used was OPC 53 grade and M-sand 4.75 mm down size is used as fine aggregate. The water of potable quality standards has been used for the study.

By trial and error process, mortar cubes were cast with 1:3 ratio, 0.5 w/c ratio throughout.The details of the mortar mixes used in the study are as follows:

- M-1, Control mix: Mortar containing M sand (100%), cement, and water.
- M-2, 25% ceramic and 75% M sand: Mortar containing 75% of M sand, 25% of Ceramic, cement, and water.
- M-3, 50% ceramic and 50% M sand: Mortar containing 50% of M sand, 50% of Ceramic, cement, and water.
- M-4, 75% ceramic and 25% M sand: Mortar containing 25% of M sand, 75% of Ceramic, cement, and water.

Mixing is done mechanically in order to achieve cohesiveness and compaction. Compressive strength, water absorption, and density are tested for 3, 7, 28, and 56 days respectively for the aforementioned mixes.

III. MIX DESIGN

Table 1: Mix Proportions

Control mix (M1)	**100% cement**	**100% M-Sand**	**0% Ceramic waste sand**
M2	100% cement	75% M-Sand	25 % Quartz sand
M3	100% cement	50% M-Sand	50% Quartz sand
M4	100% cement	25% M-Sand	75% Quartz sand

Table 2: Quantities per m^3

Material	Cement	Sand	Water	Ceramic
M-1	479 kg	1915 kg	239.4	0
M- 2	479 kg	1436.4 kg	239.4	548.625 kg
M- 3	479 kg	957.6 kg	239.4	1096.7 kg
M -4	479 kg	478.8 kg	239.4	1645.875 kg

IV. TEST RESULTS AND DISCUSSIONS

The basic properties of the materials procured are tested as per IS requirements and they are tabulated as below:

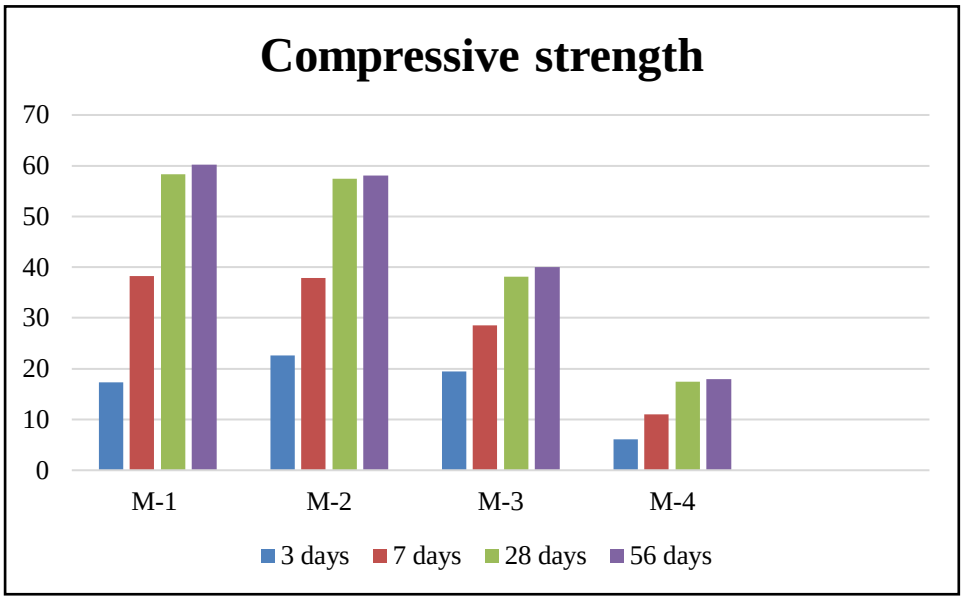
V. MECHANICAL PROPERTIES OF MORTAR

The compressive strength results are given in the table below and represented graphically in the below figure:

Table 3: Compressive Strength

Mix designations	3 days	7 days	28 days	56 days
M-1	17.28	38.3	58.36	60.15
M-2	22.58	37.82	57.48	58.02
M-3	19.44	28.57	38.09	40.02
M-4	6.08	11.02	17.41	18.01

ISSN No:-2456-2165



We can observe that, increase in the percentage of ceramic as a replacement for sand, results in increase in the compressive strength up to 25% from graph; we can clearly say that, further increase in ceramic percentage beyond 25% results in gradual decrease in strength.

Table 4: Density

Mix designations	3 days	7 days	28 days	56 days
M-1	2227.39	2247.85	2235.18	2221.65
M-2	2119.9	2168.2	2250.66	2241.30
M-3	2102.89	2037.53	2148.36	2128.04
M-4	2085.36	2045.66	2099.35	2066.36

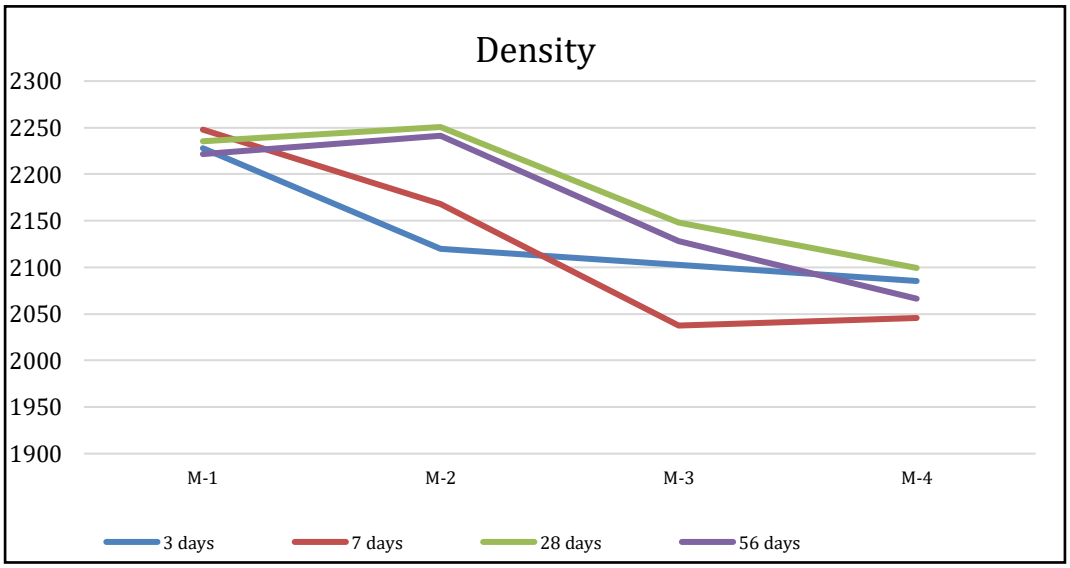


Fig. 2: Density Results

Table 5: Water Absorption Results

Mix designations	3 days	7 days	28 days	56 days
Control mix	3.02	3.04	3.03	2.81
5%	1.02	0.75	0.12	0.09
10%	0.74	0.75	0.49	0.37
15%	0.89	0.64	0.37	0.29
20%	2.13	0.88	0.38	0.26

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ISSN No:-2456-2165

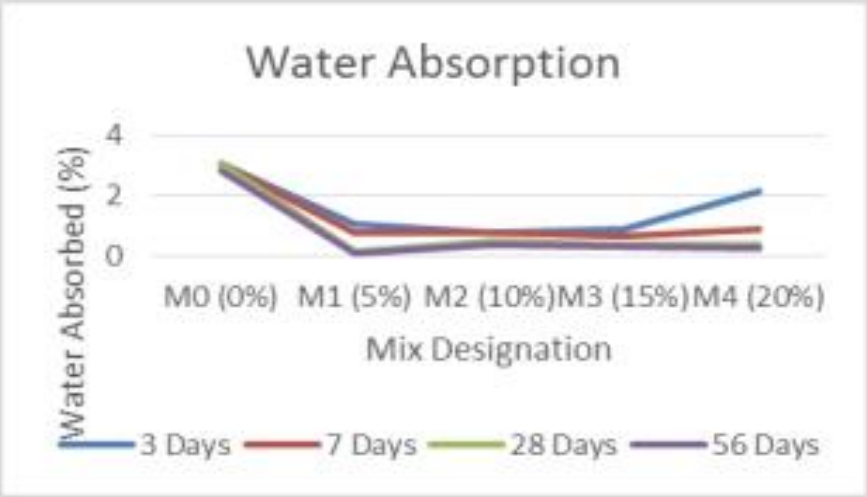
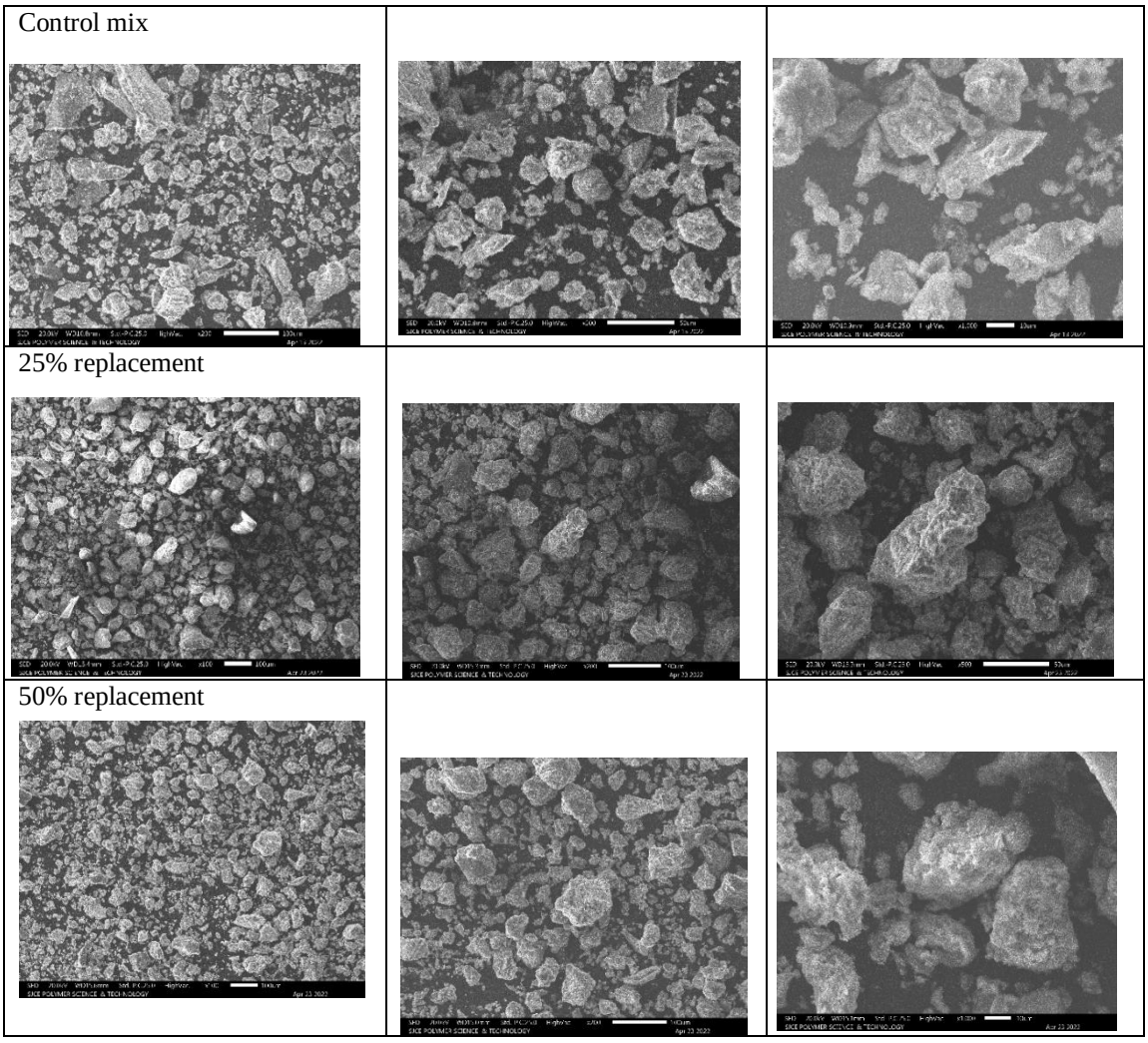


Fig. 4: Water absorption results

Highest water absorption is achieved in M- 3 mortar.

A. SEM Analysis



ISSN No:-2456-2165

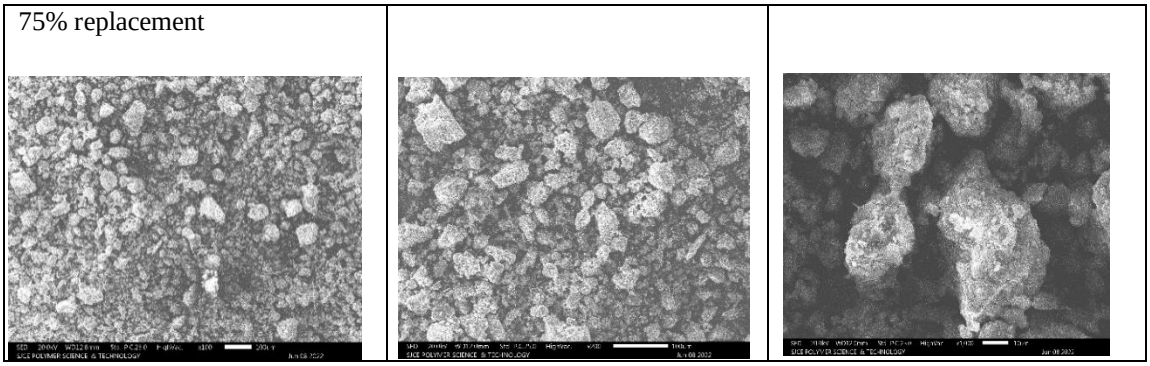


Fig. 4: SEM tests on ceramic and its blending

The surface texture of mixes with ceramic waste sand shows that it has particles with a larger rough surface area which enhances the bond b/w aggregate and cement mortar.

It creates better interlocking b/w the particles and reduces the porosity

Because of this, the strength and the water absorption characteristics may have been benefited.

High fineness and spherical shape of ceramic waste sand results in good filling effects as compare to control mix.

B. X-Ray Diffraction

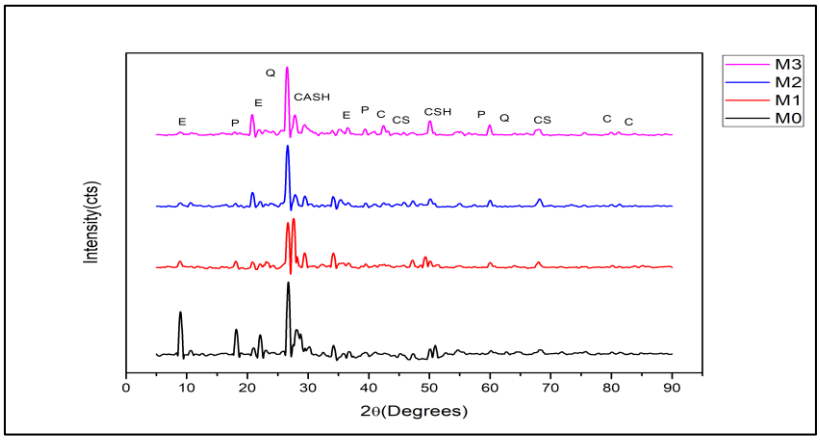


Fig. 5: X-Ray Diffraction

Table 6: Legend

E	Ettringite
P	Portandite
Q	Quartz
CASH	Calcium Aluminum Silicate Hydrate
CSH	Calcium Silicate Hydrate
C	Calcite
CS	Calcium Silicate

- From XRD tests various conclusion can be drawn with respect to the composition of ceramic and its blending with M- sand.
- The graphs obtained shows that the material is of predominant crystalline structure.
- As the % replacement increases (25% and 75%), the extent of crystallinity reduces.
- There is a marginal variation between measured data and calculated data of the XRD passing through the three samples.

VI. CONCLUSIONS

- The test results clearly shows that the ceramic waste can be used as replacement materials for fine aggregate in mortar.
- The mortar with 25% replacement of ceramic tiles has greater compressive strength c to the control mix. However, higher the percentage addition of ceramic waste reduces the strength of normal mortar.
- The mortar with 25% replacement of ceramic tiles has optimum water absorption
- The mortar with 25% of replacement of ceramic tiles has high density. Density decreases with increase in ceramic content.

- SEM images give information regarding the microstructure and surface morphology of calcium silicate hydrate and ettringite in mortar. It was observed that quartz and calcium aluminum silicate in mortar gives less porous structure due to the formation of needles in voids compared to normal mortar at all water to binder ratios.
- XRD analysis is a one of the method to find mineral composition like calcium silicate hydrate (C-S-H), calcium aluminosilicate hydrate (C-A-S-H), portlandite ($Ca(OH)_2$) and ettringite present in the concrete. Graph shows the peak intensities for control and ceramic mortar at same water to binder ratio.

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