iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL
FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: VI Month of publication: June 2023

DOI: https://doi.org/10.22214/ijraset.2023.53691

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VI Jun 2023- Available at www.ijraset.com

Utilization of Ceramic Tiles Waste as a Partial Replacement of Fine Aggregate in Cement Mortar

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Abstract: The rapid growth of the construction industry has led to an increased demand for building materials, particularly aggregates. The extraction of natural aggregates has significant environmental impacts, including landscape alteration and depletion of natural resources. Therefore, finding alternative materials for sustainable construction is essential. This project aims to investigate the potential utilization of ceramic tile waste as a partial replacement for fine aggregate in cement mortar.

The research methodology involves collecting ceramic tile waste from local sources and conducting laboratory experiments to evaluate the physical and mechanical properties of cement mortar incorporating different percentages of ceramic tile waste. The properties investigated include workability, compressive strength, flexural strength, and water absorption capacity.

The experimental results demonstrate that the addition of ceramic tile waste as a partial replacement for fine aggregate in cement mortar exhibits promising outcomes. The workability of the mortar is within an acceptable range for construction purposes, and the compressive and flexural strengths show satisfactory performance. Moreover, the water absorption capacity of the mortar reduces with an increase in the percentage of ceramic tile waste, indicating improved durability.

This research contributes to the sustainable utilization of ceramic tile waste, reducing the environmental burden associated with waste disposal and conserving natural resources. The findings provide valuable insights into the feasibility of incorporating ceramic tile waste in cement mortar, potentially leading to the development of cost-effective and environmentally friendly construction materials.

Keywords: Ceramic tile waste, fine aggregate, cement mortar, sustainable construction, physical properties, mechanical properties, waste utilization.

I. INTRODUCTION

The construction industry of India is an important indicator of the development as it creates investment opportunities across various related sectors with a share of around 8.2%, the construction industry has contributed an estimated ₹670,778 crores (US$ 131billion) 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. There is no uniformity among cities to quantify and characterize C&D waste to know how and what to segregate. The source for such a waste may be increase in the population due to modernization, modification in the bye-laws, capacity of old road not being sufficient to accommodate the growing traffic and natural as well as man-made disaster. Furthermore, there is an increased demand for construction materials in housing as well as road development sectors.

Majority of the developing and developed nations assume that the C&D waste as nonhazardous, less toxic and inert materials which does not cause adverse effects to theenvironment. They are often dumped in land without any further treatment even thoughit leads to ill effects such as illegal dumping and land pollution. Further, this creates anadditional 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 also make efforts towards waste reduction. Hence recycling of aggregates from demolition waste may serve as a solution to reduce the problems of demand-supply problems, decrease the burden of dumping and also preserving the natural resources. Mortar is a widely used construction material during any construction of a building. At the same time, it is not environmentally friendly because it destroys and uses up large quantities of natural resources.

River sand being one of the natural resources which is obtained from breaking of rocks is used as fine aggregate in mortar, but 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 is change in bylaws, road have been expanded, zones have been changed, decrease in margins, expansion of building which leads to overcrowding as older building being demolished and newer building are built where it generates a huge amount of waste. Around rough estimation of 21,000 tons of ceramic waste is been generated throughoutIndia and around 40,860 kg of ceramic waste is generated throughout Karnataka. In recent years, recycling of construction and demolition waste has made a greaterpotential and also a target of interest. It mainly focuses on waste management polices encouraging minimization, reuse, recycling, and valorization of the waste as opposed to its final disposal in landfills. We have to make a right choice and refuse wasteful andpolluting products. 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 materials are the mixture of clay, powder and water shaping 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 may be utilized on-site, suchas for excavation pit refill. The disposals of these waste materials acquire large land areas and remain scattered all around, spoiling the aesthetic of the entire region. It is very difficult to find a use of ceramic waste produced as they are durable, hard and highly resistant to biological, chemical and physical degradation forces, is not recycledin any form at present. The rate of growth in waste has put pressure on the ceramic industries to find a solution for its disposal.

II. OBJECTIVE

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

III. LITERATURE REVIEW

1) G Saravana Kumar on [2016] had carried out a study on partial replacement of sandby ceramic waste in concrete. Sand being partially replaced by five percentages (10%, 20%, 30%, 40% and 50%) of ceramic waste by weight for M25 grade concrete. Compressive and tensile strength were determined for different periods of curing like 7, 14 and 28 days. The test results clearly shows that the ceramic waste can be used asa partial replacement of fine aggregate in concrete, however, higher the percentage of ceramic waste it reduces the strength of normal concrete. The tensile strength of 10%, 20%, 30% replacements at 14 days and compressive strength of 10% 20% shows the consistency in attaining the required range. Hence, replacement of river sand using 30%ceramic waste in M25 grade concrete gives the required strength and can be consideredas optimum percentage.
2) Swathi DP on [7] [2020] had carried out study on concrete by partial replacement ofsand with ceramic waste. Fine aggregate being partially replaced by four percentages (10%, 20%, 30% and 40%) of ceramic waste by weight in M20 grade concrete. They were tested on different periods of curing like 3, 7 and 28 days to obtain compressive and tensile strength. She observed that, increase in the percentage of ceramic as a replacement for sand results in increasing the compressive strength up to 30% from the graph. So, she clearly said that, further increase in ceramic percentage beyond 30% results in gradual decrease in strength. For 28 days, there is an increase in tensile strength of concrete with addition of 10% ceramic is about 41.4%, concrete with addition of 20% ceramic is about 61.42%, and concrete with addition of 30% ceramic is about 51.42%. Hence, ceramic waste can be used for M20 grade concrete up to 30%replacement.
3) Murlidharan T on [4] [2018] had carried out a study on partial replacement of fine aggregate in concrete using ceramic wastes. Fine aggregate being partially replaced by four percentages (15%, 20%, 25% and 30%) of ceramic waste by weight for M25 gradeconcrete. Compressive and tensile strength was determined for different periods of curing like 7, 14 and 28 days. The test results clearly shows that the ceramic waste canbe used as a partial replacement of fine aggregate in concrete, however, higher the percentage of ceramic waste it reduces the strength of normal concrete. The tensile strength of 15%, 20%, 25%, 30% replacements at 14 days and compressive strength of15%, 20% shows the consistency in attaining the required range. Hence, replacement of river sand using 30% ceramic waste in M25 grade concrete gives the required strength and can be considered as optimum percentage

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4) Mostafa Samadi on [9] [2014] had carried out study a on effects of ceramic powderon mortar by using ceramic waste as cement replacement. Use of finer ceramic waste by four percentage (10%, 20%, 30%, 40%) by weight. Compressive strength was determined for different periods of curing like 7, 14 and 28 days. The results clearly shows that use of finer ceramic powder at 20% replacement of cement was found to produce the highest compressive strength at all ages of testing. This shows that the ceramic waste in the form of fine powder will act as pozzolanic material that can enhance the performance of mortar. The use of ceramic waste to some extend will reduce the landfill and environmental problems.

IV. MATERIALS

A. Cement

Cement may be prescribed as material with adhesive and cohesive properties which make it capable of bonding material fragments into a compact whole. The most commonly used cement in construction today is Portland cement and hence for experimental study we used Ordinary Portland Cement of 53 grade. The cement according to the Indian specification must satisfy the IS code IS:4031(part 1- 6). Material is procured from shop.

Physical Properties of Cement Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement. The physical propertiesof good cement are based on:

1) Fineness of cement
2) Soundness
3) Consistency
4) Strength
5) Setting time
6) Heat of hydration
7) Loss of ignition
8) Bulk density
9) Specific gravity (Relative density)

These physical properties are discussed in details in the following segment. Also, you will find the test names associated with these physical properties

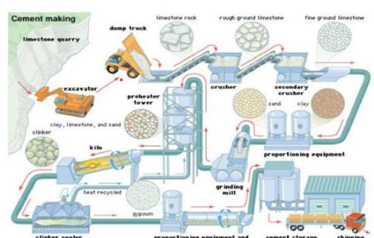

Fig 4.1: Cement Making Process

B. Fine Aggregates

Fine aggregate is an essential component of mortar. They are obtained from the land through mining process.

Fig 4.2: Fine Aggregate

Properties of Fine Aggregates

While making the selection for appropriate aggregates to be used in particular concretemix, few properties need to be considered, such as:

1) Void content.
2) Shape and texture.
3) Absorption and surface moisture
4) Abrasion and skid resistance.
5) Grading Zone of Fine Aggregate

Fine aggregate passes through sieve of 4.75 mm is used for the experimental use. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent. The M sand, according to the Indian specification must satisfy the IS code IS:2386 -part 2. For the studies the M sand of Zone-II is used in all the references. M sand is procured from local site.

A good concrete mix must include aggregates that are clean, hard, strong and free of absorbed chemicals or coatings of clay and other fine materials. Ignorance of these characteristics can cause the deterioration of concrete, thus regulatory authorities have decided grading zone of fine aggregate, where each zone defines the percentage of fineaggregate passed from the 600 microns sieve size:

Zone I: 15% to 34%
Zone II: 34% to 59%
Zone III: 60% to 79%
Zone IV: 80% to 100%

You can assess the quality of fine aggregate with help of the grading zones. However, for precise assessment, you can seek help from experts who are well versed inperforming tests for bulk density, bulkage, and specific gravity to find the best in classmaterial.

C. Ceramic

Ceramic material is an inorganic, non-metallic oxide, nitride, or carbide material. Someelements, such as carbon or silicon, may be considered ceramics. Ceramic materials are brittle, hard, strong in compression, and weak in shearing and tension. They withstand chemical erosion that occurs in other materials subjected to acidic or caustic environments. Ceramics generally can withstand very high temperatures, ranging from1,000 °C to 1,600 °C (1,800 °F to 3,000 °F).

The crystallinity of ceramic materials varies widely. Most often, fired ceramics are either vitrified or semi-vitrified as is the case with earthenware, stoneware, and porcelain. Varying crystallinity and electron composition in the ionic and covalent bonds cause most ceramic materials to be good thermal and electrical insulators(researched in ceramic engineering). With such a large range of possible options for thecomposition/structure of a ceramic (nearly all of the elements, nearly all types of bonding, and all levels of crystallinity), the breadth of the subject is vast, and identifiable attributes (hardness, toughness, electrical conductivity) are difficult to specify for the group as a whole. General properties such as high melting temperature, high hardness, poor conductivity, high moduli of elasticity, chemical resistance and lowductility are the norm, [8] with known exceptions to each of these rules (piezoelectric ceramics, glass transition temperature, superconductive ceramics). Many composites, such as fiberglass and carbon fiber, while containing ceramic materials are not considered to be part of the ceramic family. [9]

Highly oriented crystalline ceramic materials are not amenable to a great range of processing. Methods for dealing with them tend to fall into one of two categories – either make the ceramic in the desired shape, by reaction *in situ*, or by "forming" powders into the desired shape, and then sintering to form a solid body. Ceramic forming techniques include shaping by hand (sometimes including a rotation process called "throwing"), slip casting, tape casting (used for making very thin ceramic capacitors), injection moulding, dry pressing, and other variations.

The principle waste coming into the ceramic industry is the ceramic powder, specifically in the powder forms. Ceramic wastes are generated as a waste during the process of dressing and polishing. It is estimated that 15 to 30% waste are produced oftotal raw material used, and although a portion of this waste may be utilized on-site, such as for excavation pit refill, The disposals of these waste materials acquire large land areas and remain scattered all around, spoiling the aesthetic of the entire region. Itis very difficult to find a use of ceramic waste produced. Ceramic waste can be used inconcrete to improve its strength and other durability factors. Ceramic waste can be used as a partial replacement of cement or as a partial replacement of fine aggregate sand asa supplementary addition to achieve different properties of concrete. Ceramic tile waste is procured from local site. Obtained ceramic tile waste is crushedby UTM and sieved through sieve 4.75mm and used as replacement of sand.

Table 4.1 Composition of ceramic

SL NO	Chemical compound	Test result
1	Al_2O_3	50
2	ZrO_2	0
3	BaO	7.79
4	$(NaK)O_2$	2.65
5	SiO_2	39.25
6	Rest	0.78

D. Water

Water is one of the most important elements in construction and is required for the preparation of mortar, mixing of cement concrete and for curing work etc. The quality of water used has a direct impact on the strength of the motor and cement concrete in the construction work. The water used for curing and mixing must be free from high quantities of alkalis, acid, oils, salt, sugar, organic materials, vegetable growth, etc. thatmight be deleterious to bricks, concrete or iron.

Impurities in water can cause metal corrosion, introduce unwanted silt and clay intothe concrete, adversely affect the hardening process of concrete and also reduce the strength by even 25%. Thus, the need to ensure the quality of water used during construction is vital.

IS 456:2000 standards lays certain parameters for which quality of water must betested. In the same lines, we have in

Fig 4.3 Ceramic, M- sand and Cement used in the Experiment

V. MATHODOLOGY

A. Tests On Materials

1) Tests on cement

Basic tests on cement are tabulated according to IS 4031 part 1 – 6

a) Specific gravity of cement was calculated according to the IS code
b) Compressive strength was conducted for a period of 3, 7 and 28 days
c) Standard consistency of cement
d) Initial and final setting time are assessed
e) Fineness of cement is tabulated

Fig 5.1 90 micron sieve for fineness

Fig 5.2 Initial Setting time of Cement

Fig 5.3 Specific Gravity of Cement

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2) *Tests on M- sand*

Basic tests on M- sand are calculated as per IS 2386 part 2 (1986)

a) Specific gravity of M- sand
b) Fineness of M- sand
c) Fineness modulus of M- sand
d) Bulk density
e) Water absorption

3) *Tests on Ceramic*

a) Specific gravity of M- sand
b) Fineness of M- sand
c) Fineness modulus of M- sand
d) Bulk density
e) Water absorption

Fig 5.4 Pycnometer

Fig 5.5 Fineness modulus

B. *Mix Proportion*

Mortars were casted at a mix ratio of 1:3 (cement: sand) and W/C is 0.5.

The following terminology is used in the thesis; these terminologies represent themortar mixes prepared to conduct various tests.

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

C. *Quantities PER M^3*

Table 5.1 Quantities required per m^3

Material	Cement	Sand	Water	Ceramic
Control mix	479 kg	1915 kg	239.4	0
M – 25	479 kg	1436.4 kg	239.4	548.625 kg
M - 50	479 kg	957.6 kg	239.4	1096.7 kg
M – 75	479 kg	478.8 kg	239.4	1645.875 kg

D. *Compression Strength Test*

1) Mortar cubes of dimensions 70.6 X 70.6 X 70.6 mm are used in the experiment.
2) Materials for each cube will be mixed separately in the cubes and are casted ata ratio 1:3 (cement: sand) and w/c is 0.5.
3) The casted cubes are vibrated mechanically by a vibrating machine. The periodof vibration shall be of 2 minutes at the specified speed.
4) At the end of vibration, mould along with base plate is removed and cube is leftfor drying for 24 hours.
5) At the end of the period, cubes are tested for compressive strength for each period of curing under relevant specifications (3days, 7 days, 28 days)

Fig 5.6 Compression test

a) The bearing of universal testing machine shall be wiped clean. Cubes will be placed in between the plates and load shall be applied and increased at rate untilload is sustained.
b) The maximum load applied to the specimen shall be then recorded and the appearance of the mortar and any unusual feature in the failure should be recorded.
c) Compressive strength is calculated by

$$\sigma = \frac{P_{max}}{A}$$

where,
σ = compressive strength in N/mm^2

P_{max} = load applied
A = Area

E. Water Absorption Test

Water absorption is a measure of porosity of aggregates and its resistance to frost action.Water absorption gives an idea on the internal structure of aggregate. Aggregates havingmore absorption are more porous in nature and are generally considered unsuitable, unless found to be acceptable based on strength, impact and hardness tests.

1) Casted mortars were kept for curing.
2) After the period of curing, (3, 7, 28 days) the cubes were taken out and weighedand that weight is recorded as wet weight.
3) Then the cubes were sundried for 60 minutes.
4) After drying, the cubes were weighed and noted as dry weight.
5) Results were tabulated.

$$\text{Water absorption} = \frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} \times 100$$

F. Density Test

Density is defined as ratio of mass to volume. It represents the degree of compactness.Density determines the sinking property of the material which plays a vital role in design and construction of dams, foundation etc. The value of density is found for materials, not quantities. So different materials have different density.

1) Casted cubes were kept for curing
2) After curing, the cubes were sundried and weighed. The weight was recordedas dry weight.
3) Density is calculated by the following equation

$$\text{Density} = \frac{\text{Dry weight}}{\text{Volume}}$$

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G. Preparation Of Testing Specimen Mixing

Mixing of ingredients is done in pan mixer of capacity liters. The cementitious materials are thoroughly blended and then the aggregate is added and mixed followed by gradual addition of water and mixing. Wet mixing is done until a mixture of uniform color and consistency are achieved which is then ready for casting. Before casting the specimens, workability of the mixes was found by compaction factor test.

Fig 5.7 Preparing Specimen

Fig 5.8 Prepared Specimen

VI. RESULTS AND DISCUSSION

A. Basic Tests on Cement and its Replacement (IS 4031 part 1 – 6)

Table 6.1 Basic Properties of Cement

SL.NO	TESTS	RESULTS	PERMISSIBLE LIMITS
1	Specific Gravity	3.15	3.1 to 3.16
2	Fineness (%)	4.6%	Below 10%
3	Standard Consistency (%)	31%	25% to 35%
4	Initial Setting Time (min)	42	Min 30
5	Final Setting Time (min)	164	Max 600
6	3 Day Compressive Strength, N/mm^2	28.56	-
7	7 Day Compressive Strength, N/mm^2	38.15	-
8	28 Day CompressiveStrength, N/mm^2	54.42	-

B. Basic Tests M- Sand (IS 2386 part 1-3)

Table 6.2 Basic Properties of M Sand

SL.NO	Test	Result	Permissible limits
1	Specific gravity	2.6	2.5 to 2.8
2	Fineness modulus	2.7	2.65 to 2.8
3	Bulk density-Loose	1648.67 kg/m^3	1520 to 1680 kg/m^3
4	Bulk density – Compacted	1829.3 kg/m^3	1600 to 1850 kg/m^3
5	Water absorption	1.01%	
6	Fineness	Zone 2	-

C. Basic Tests on Ceramic

Table 6.3 Basic Properties of Ceramic

SL.NO	Test	Result
1	Specific gravity	2.819
2	Fineness modulus	2.72
3	Bulk density-Loose	1660.4 kg/m^3
4	Bulk density – Compacted	1833.73 kg/m^3
5	Water absorption	1.2%
6	Fineness	Zone 2

D. Compressive Strength (N/mm^2)

Table 6.4 compressive strength

Mix designations	3 days	7 days	28 days
Control mix	17.28	38.3	58.36
25%	22.58	37.82	57.48
50%	19.44	28.57	38.09
75%	6.08	11.02	17.41

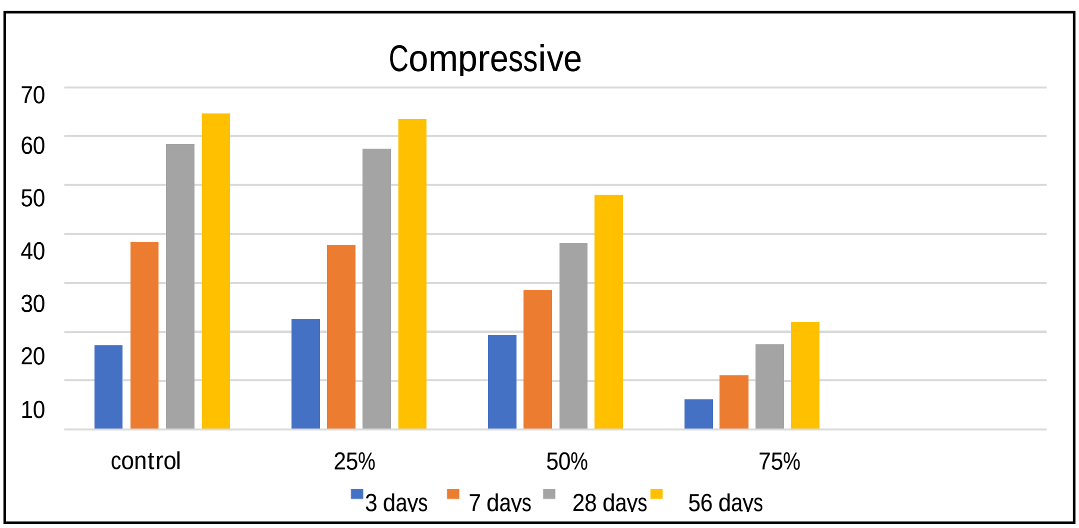

Fig 6.1 Compressive strength Test

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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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.

E. Density Test

Table 6.5 Density Test

Mix designations	3 days	7 days	28 days
Control mix	2227.39	2247.85	2235.18
25%	2119.9	2168.2	2250.66
50%	2102.89	2037.53	2148.36
75%	2085.36	2045.66	2099.35

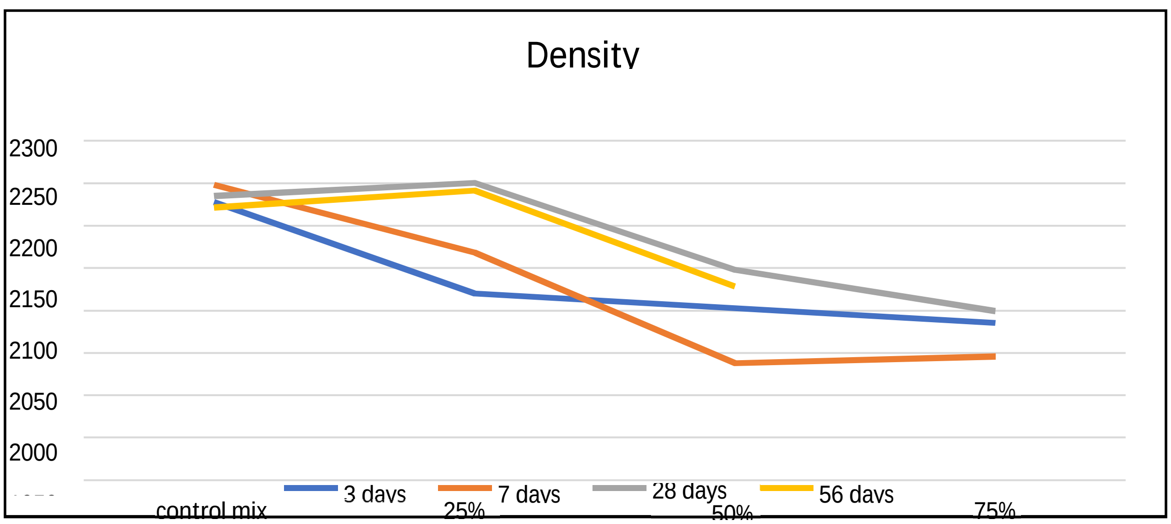

Fig 6.2 Density Test

F. Water Absorption Test

Table 6.6 water absorption test

Mix designations	3 days	7 days	28 days
Control mix	3.04	3.02	3.04
25%	1.453	1.634	1.563
50%	1.566	1.423	1.689
75%	0.711	0.662	0.704

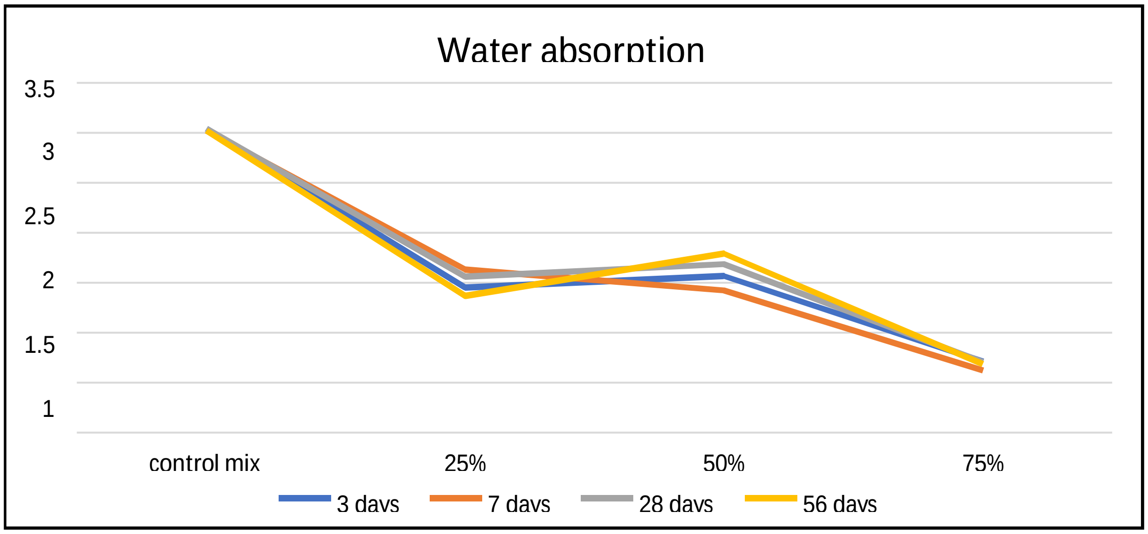

Fig 6.3 Water absorption of Mortar

VII. CONCLUSION

1) The test results show clearly that the ceramic waste can be used as replacement materials for m-sand in mortar.
2) The mortar with 25% replacement of ceramic tiles has the compressive strength compared to the control mix. However, higher the percentage addition of ceramic waste reduces the strength of normal mortar.
3) The mortar with 25% replacement of ceramic tiles has optimum water absorption compared to 50% and 75% replacement of ceramic tiles.
4) The mortar with 25% of replacement of ceramic tiles has high density. Density decreases with increase in ceramic content.

A. *Further Study*

1) So according to this research work, sand is replaced by ceramic waste also further investigation is required for that this replacement to find exact percentage replacementlimit in future utilization.
2) In future it can be increase in the percentage of replacement of ceramic material as ceramic also possess pozzolanic properties.
3) In the concrete ceramic replace by performing of mechanical properties and durability test that is water absorption and penetration test, but for the confirmation of that replacement other durability test i.e., acid attack test, chloride attack test, carbonation test and micro-structure study are required.
4) Ceramic can be added in other percentage for concrete for different water cement ratio. Ceramic waste can be used in mortar cubes and check the properties. Investigation on behavior 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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