Performance Evaluation of Concrete with Ceramic Waste as Fine Aggregate Replacement and Mica as Admixture

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Abstract- *Concrete is one of the most commonly used materials in civil engineering, made up of cement, aggregates, water, and various admixtures. However, with the rising costs and dwindling natural resources, there's an urgent need to focus on recovering and reusing these materials, as well as developing alternatives. Cement, which is the main binding agent in concrete, is in high demand due to the rapid pace of infrastructure development. Consequently, scientists and researchers around the world are actively looking for alternative binders and materials that can partially replace cement, aiming to boost sustainability without sacrificing strength and durability. Coarse aggregates also make up a significant part of concrete, so finding suitable substitutes for natural stone is crucial. By using alternative materials like industrial by-products, recycled aggregates, or additives derived from waste, we can greatly aid in resource conservation and promote environmental sustainability. By embracing innovative materials and sustainable practices in concrete production, the construction industry can lessen its ecological impact while ensuring long-lasting durability and cost-effectiveness. This study explores the durability of concrete that incorporates ceramic waste as a partial replacement for fine aggregate and mica as a mineral admixture, using specific ratios. The goal of including these materials is to enhance the mechanical properties and lifespan of concrete, while also supporting sustainability through the use of industrial waste.*

***Key Words*: Ceramic waste, Fine aggregate replacement, Mica, Chemical Admixture, Strength characteristics, Durability test**

1.INTRODUCTION

The construction industry is grappling with some serious environmental issues, largely because of the high demand for concrete, which is notoriously resource-intensive. This project dives into some creative solutions by using ceramic waste as a partial substitute for fine aggregate and incorporating mica as an additive in concrete production. Ceramic waste, which comes from broken tiles and sanitary ware, often ends up in landfills; by repurposing it in concrete, we not only cut down on waste but also support sustainability in construction. Mica, a mineral known for its helpful properties, is added to improve the performance of the concrete mix, potentially enhancing both workability and durability. The main goals of this project include evaluating mechanical properties like compressive and flexural strength, analyzing workability, and performing durability tests such as the Rapid Chloride permeability test. Plus, microstructural examinations will shed light on how these materials interact. By showcasing the practicality and benefits of using waste materials, this project aims to encourage sustainable construction practices that lessen environmental impact while keeping the strength and performance of concrete intact. Ultimately, the research aspires to pave the way for a more sustainable future in the concrete industry, promoting innovative strategies for resource management.

2. OBJECTIVES AND SCOPE OF THE STUDY

The Main Scope of the study is

- The study focuses on M40 grade concrete, with a target compressive strength of 40 MPa after 28 days.
- The study evaluates compressive strength, splitting tensile strength, and elastic modulus to assess the impact of ceramic waste and mica on the performance and durability of M40 concrete.
- To evaluate the potential of ceramic waste as a partial replacement for fine aggregate and mica as a mineral admixture by analyzing strength characteristics.
- To assess the importance of incorporating waste materials in concrete production to enhance sustainability in construction.
- To minimize concrete production costs by utilizing locally available alternative materials.
- To promote Sustainable Construction Practices.

The primary objective of this experimental investigation is to evaluate the effectiveness of ceramic waste and mica as mineral admixtures in concrete production. The objectives are

- To investigate the Role of Mica as an Admixture.
- To analyze the Combined Effect of Ceramic Waste.

- To analyze the compressive strength, flexibility, split tensile strength by partially replacing fine aggregate by ceramic waste.
- To compare Performance Against Conventional Concrete.
- To promote Sustainable Construction Practices.
- To conduct Rapid Chloride permeability Test.

3. NEED OF STUDY

• Sustainability: By recycling industrial by-products like ceramic waste and mica, we can significantly lessen our environmental footprint.

• Waste Management: Tackling the growing amounts of ceramic waste and mica by integrating them into concrete provides an effective way to dispose of these materials. • Performance Improvement: Exploring how these materials can boost concrete properties such as strength, durability, and workability might lead to the development of superior and more affordable building materials.

• Economic Benefits: Finding budget-friendly alternatives to traditional fine aggregates can help cut construction costs and encourage more sustainable building practices.

• This study meets both the environmental and practical demands of the construction industry.

4. MATERIALS

A. Cement:

For this project, we used Portland Pozzolana cement. This type of cement is crucial in concrete as it helps create strength and durability through the hydration process when mixed with water. We chose Portland Pozzolana cement (PPC) because it's consistent, widely available, and has a solid track record in structural concrete applications. PPC is known for providing high early strength and dependable performance, which makes it ideal for evaluating how ceramic waste and mica affect concrete properties. Essentially, Portland Pozzolana Cement (PPC) is a blended cement that combines Ordinary Portland Cement (OPC) with pozzolanic materials like fly ash, silica fume, volcanic ash, or calcined clay. These pozzolanic materials improve certain characteristics of the cement, making it suitable for various construction projects, especially where durability and sustainability are key.

B. Coarse aggregate:

Coarse aggregate, which consists of particles larger than 4.75 mm, plays a crucial role in concrete by boosting its strength, durability, and stability. Typically, coarse aggregates account for about 60-70% of the total volume in concrete mixes, serving as the primary load-bearing element. These aggregates are irregular, granular materials such as sand, gravel, or crushed stone, and they are commonly used in concrete production. They are usually sourced from natural deposits through quarry blasting or manual and mechanical crushing, which helps enhance the compactness of concrete mixes. By using coarse aggregates, we can reduce the amount of cement and water needed while also improving the mechanical strength of the concrete, making them vital for building and maintaining durable structures. For this project, we selected coarse aggregates with maximum sizes of 12 mm and 20 mm, sourced from a nearby shop.

C. Fine aggregate:

Fine aggregate, often referred to as natural sand, is a key ingredient in concrete. It fills the gaps between larger aggregates, adds bulk, and enhances the overall strength and durability of the concrete. Commonly known as "sand," fine aggregate is an essential component that plays a significant role in the concrete mix. concrete, mortar, and other construction materials. It consists of smaller particles than coarse aggregates and typically passes through a 4.75 mm sieve. Fine aggregates primarily fill the voids between larger particles, contributing to the concrete mix's workability, strength, and durability. It is collected from near- by shop.

D. Water:

It's absolutely essential in the concrete-making process because it kickstarts the hydration of cement, which is what binds all those aggregate materials together into a solid structure. In this study, we're using fresh, clean water that's free from impurities to ensure that all our samples have consistent hydration and bonding quality. The properties of the water we use are vital for achieving the right workability, setting time, and strength in the concrete. Water is an inorganic, clear, tasteless, and odorless substance, making up a significant part of Earth's hydrosphere and the fluids in all known living organisms. It's crucial for life, even though it doesn't provide any calories or organic nutrients.

E. Ceramic waste:

Ceramic tile waste refers to discarded or broken ceramic tiles generated during the manufacturing process, installation, or demolition of buildings. As a significant contributor to construction and demolition waste, ceramic tile waste has attracted attention for its potential as a sustainable material for construction, especially in concrete production. Using ceramic waste can help reduce landfill space, conserve resources, and lower the environmental impact of traditional concrete materials. Ceramic is a non-metallic, inorganic material made from clay and other natural minerals, shaped and then hardened by high-temperature firing. Ceramics are highly durable, resistant to heat and chemicals, and have low electrical conductivity, which makes them suitable for a wide range of applications, including construction, household products, electronics, and medical implants. Ceramic waste taken in the form of fine powder [1].

F. Mica:

Mica is a naturally occurring mineral known for its unique properties, including its shiny appearance, excellent thermal stability, flexibility, and insulating capabilities. Mica's layered structure allows it to be split into thin sheets, making it valuable across industries such as construction, electronics, cosmetics, and automotive. In sustainable construction, mica can be used as a partial substitute in cement or concrete mixtures. It enhances the thermal insulation properties of concrete and improves its durability, potentially reducing the need for cooling and maintenance. This reduces overall energy costs and contributes to resource conservation [2].

G. Super plasticizer:

Fosroc Auramix 400 Fig-3 is an advanced, high-performance superplasticizer specifically designed for concrete mixes that require high strength and workability. This product, is commonly used in the construction industry to produce highly workable concrete with reduced water content while maintaining flow and durability. The typical dosage of Auramix 400 varies based on the mix design and specific project requirements but generally ranges from 0.5% to 1.5% by weight of cement. Adjustments may be needed based on the desired workability and environmental conditions [3].

Fig – 1 Ceramic

Fig – 2 Mica

Fig – 3 Chemical Admixture

5. EXPERIMENTAL METHODOLOGY

5.1 TESTING OF MATERIALS

To examine the basic properties of the materials chosen the following tests were carried out.

5.1.1 TESTS ON CEMENT

Cement is the most important ingredient in concrete. Therefore, quality of cement should be checked before using it. Various tests on cement are performed to evaluate the specific gravity, standard consistency and initial setting time.

5.1.1.1 Specific gravity of cement

As per IS 4031, the specific gravity is the ratio between the weight of a given volume of material and weight of an equal volume of water. The dry Le Chatelier Flask [4] was cleaned and filled with kerosene up to the mark. 60g of cement was taken. The initial reading of flask (V1) was noted. Add 60g of cement into the flask with care. Care should be taken so that cement is falling properly into the flask. Shake the flask with stopper so that no cement is stick to walls of flask. The cement was allowed to settle. The final reading of flask (V2) was noted.

Specific gravity of cement = $Weight\ of\ cem\quad nt/\ Weight\ of$ equal volume of water

5.1.1.2 Standard Consistency of Cement

As per IS 4031 & IS 269, about 400 g of cement was weighed accurately and placed in an enamel trough. To start with, add clean water and mixed it thoroughly with cement. The gauging time should be carefully maintained between 3 to 5 minutes, starting from the moment water is added to the dry cement until the mould filling begins. The Vicat's mould [5] was filled with this paste. Make the surface of the cement paste in level with the top of the mould. The mould was placed under the rod bearing the plunger. The indicator was adjusted to show 0-0 reading when it touched the surface of the test block. The plunger was released quickly, allowing it to sink into the plate. The trial paste was prepared with varying % of water and the test was repeated as described above until the needle penetrates 5mm to 7mm above the bottom of the mould. The amount of water was expressed as percentage by weight of the dry cement.

$Standard\ consistency = Quantity\ of\ water\ for\ 5 - 7\ mm$

$penetration/Weight\ of$ cement × 100

5.1.1.3 Initial Setting of Cement

According to IS 4031 & IS 269, the initial setting time of concrete is the time when cement paste starts hardening while the final setting time is the time when the cement paste is considered to have hardened sufficiently when a 1 mm needle leaves an impression on the paste in the mould, while a 5 mm needle does not any impression. Take about 400 grams of cement was weighed. A neat cement paste was prepared by adding 0.85 times the percentage of water required for standard consistency. The stopwatch was started at the instant when water was added to the cement. The Vicat's mould was filled with the cement paste prepared. Gauging time should not be less than 3 minutes and more than 5 minutes. Filled the mould completely and smoothened the surface of paste making it level with the top of the mould to give a test block. The test block was placed confined in the mould under the load bearing medium. Lowered the needle gently till it came in contact with the surface of test block and was quickly released, allowing it to penetrate the test block and noted penetration after every two minutes. This procedure was repeated until the needle failed to pierce the block for about 5mm, measured from the bottom of the mould. The stopwatch was stopped and the initial setting time was noted.

Fig – 4 Le Chatelier Specific Gravity Flask

Fig – 5 Vicat Apparatus

Fig – 6 Pycnometer

5.1.2 TESTS ON FINE AGGREGATES

Fine aggregates play a crucial role in concrete, so their quality is really important. To ensure this quality, various tests like specific gravity and sieve analysis are conducted on fine aggregates. The specific gravity test helps us measure the strength of these aggregates.

5.1.2.1 Specific Gravity of Fine Aggregate

According to IS 2386 (part 3), the Pycnometer [6] needs to be cleaned, dried, and weighed accurately with its cap securely in place (W1). Next, we take about 300g to 500g of an oven-dried sample and weigh it again (W2). After that, we add distilled water to the Pycnometer and stir it with a glass rod to eliminate any trapped air. We then fill the Pycnometer with distilled water up to the hole in the conical cap and weigh it (W3). Once that's done, we empty and clean the Pycnometer, then fill it with distilled water again up to the hole in the conical cap and weigh it one more time (W4). The formula for specific gravity is:

Specific gravity = W2 / (W2 - (W - W1))

Water Absorption of Fine Aggregates

According to IS 2386 (part 3) about 2kg of aggregate sample is taken in a wire basket and immersed in water at a temperature of 22ºC to 32ºC. Entrapped air is removed from the sample by lifting the basket 25 mm above for 25 times. The basket with sample kept completely in water for 24 hours. The basket and aggregate are weighed are weighed while suspended in water. The basket and aggregate are removed from water and dried with dry absorbent cloth. The surface-dried aggregates are also measured by weight.

$$Water\ absorption\ (\%) = \frac{W1-W2 \times 100}{W2}$$

5.1.2.2 Sieve Analysis of Fine aggregate

We started with about 1 kg of fine aggregate, using IS sieves [7] with sizes of 4.75mm, 2.36mm, 1.18mm, 600µ, 300µ, 150µ, and a pan, all arranged from largest to smallest. After placing the fine aggregate in the sieves, we sieved the materials, collecting the amount that passed through each larger sieve and retaining what was left on the next one. Finally, we plotted a graph showing the percentage of finer material against the sieve size, based on the results we gathered from our tests.

5.1.3 TESTS ON COARSE AGGREGATE

Coarse aggregates play a crucial role in concrete, so their quality is essential. To ensure this quality, several tests, like specific gravity and sieve analysis, are conducted on coarse aggregates. The specific gravity test, in particular, helps gauge the strength of these aggregates..

5.1.3.1 Specific gravity of Coarse aggregates

About 2kg of thoroughly washed coarse aggregate was placed in the wire basket and immersed it in distilled water. The weight of the saturated aggregate suspended in water with the basket [8] was weighed and noted as (W1). Removed the basket and aggregate from the water and allowed it to drain. Immerse the basket in water and the empty weight

(W2) was taken. Oven dried the aggregates for a temperature of 110°C for 24 hours. The weight of oven dried aggregate (W3) was noted.

Specific gravity = W3 / W3 - (W1- W2)

5.1.3.2 Water Absorption on Coarse aggregates

According to IS 2386 (part 3), you start by taking about 2kg of aggregate and placing it in a wire basket. This basket is then immersed in water that's between 22ºC and 32ºC. To get rid of any trapped air, you lift the basket about 25 mm above the water surface and do this 25 times. After that, the basket with the sample needs to stay completely submerged in water for 24 hours. Once that's done, you weigh the basket and the aggregate while they're still underwater. Finally, you take the basket and aggregate out of the water and dry them off with a clean absorbent cloth. After they've dried on the surface, you weigh the aggregates again.

$$Water\ absorption\ (\%) = \frac{W1-W2 \times 100}{W2}$$

5.1.3.3 Sieve analysis of coarse aggregates

About 1 kg of coarse aggregate taken in IS sieve [9] size of 25mm, 20mm, 16mm, 12.5mm, 10mm, 4.75mm. The sieves were arranged in the decreasing order of size and put the aggregate taken. Sieved the aggregates and the amount which is passing through greater size was taken and retained on the next. The laboratory test on sieve analysis of coarse aggregate was conducted.

Fig – 7 Sieve for Fine

Fig – 8 Wire Basket

Fig – 9 Sieve for Coarse

6. DESIGN MIX

A mix for M40 grade was designed as per IS 10262: 2009 and the same were used to prepare the test samples. The variation of strength of hardened concrete using ceramic waste powder as partial replacement of FINE aggregate and Mica as mineral admixture is studied by casting 3 cubes, 3 cylinders and 3 prisms for each and every replacement. The specimens were tested for compression, split tensile and flexural strengths after curing period of 7days, 14 days, 28 days as per the mix design. The quantities required for casting 3 cubes, 3 cylinders and 3 prisms for each percentage replacement are computed. The design mix proportion is given in table 1.

Materials	Water (Kg/m^3)	Cement (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)	Super Plasticizer (kg/m^3)	Mineral Admixture (Kg/m^3)
Quantity of 1 $m^3$of concrete	148	412	645	1250	3.6	20.6
Mix Ratio	0.36	1	1.6	3	0.0088	0.0075

7. EXPERIMENTAL STUDY

7.1 COMPRESSION TEST

The compressive strength test is a mechanical assessment that measures the maximum compressive load a material can withstand before fracturing. The test specimen, typically shaped as a cube, prism, or cylinder, is placed between the platens of a compression-testing machine and subjected to a gradually applied load. This test is allotted as per the rule given in IS 3495-1992. Compression test is that the main and vital test and this test was dispensed by a Compression Testing Machine [10]. This test was carried out on the seventh, fourteenth and twenty eighth day from the day of casting. For most applications, cubic molds measuring 15 cm × 15 cm × 15 cm are commonly used. This concrete is poured in the mold and appropriately tempered so as not to have any voids. After 24 hours, the molds are removed, and the test specimens are placed in water for curing.

$$\text{Compressive strength} = \frac{Load}{Cross\ sectional\ area}$$

7.2 SPLIT TENSILE STRENGTH TEST

Concrete tensile strength refers to its ability to withstand tensile forces or stresses applied to it. The tensile strength of concrete is measured by the split cylinder test [11] of concrete method. The tensile strength of concrete is measured in units of force per cross-sectional area. ASTM D638 is used to measure the tensile properties of plastics, including ultimate tensile strength, yield strength, elongation, and Poisson's ratio. The universal testing machine is the most commonly used equipment for tensile testing. Tensile strength is a critical property of concrete, as concrete structures are susceptible to tensile cracking due to various effects and applied loads. However, the tensile strength of concrete is significantly lower compared to its compressive strength. This test is allotted as per the rule given in IS:5816-1959. Concrete tensile strength refers to its ability to resist applied tensile forces or stresses. It is commonly measured using the split cylinder test method. The tensile strength is expressed in units of force per cross-sectional area (N/Sq.mm. or MPa).

$$\text{Tensile Strength} = \frac{Load}{Cross\ scetional\ Area}$$

7.3 FLEXURAL STRENGTH TEST

Flexural testing is performed to assess a material's ability to resist bending or flexural stress. Also known as a transverse beam test [12], it involves placing a sample between two supports and applying a load either at a single central point (3-Point Bend Test) or at two points (4-Point Bend Test). Flexural strength is an indicator of the tensile strength of concrete, measuring its ability to resist bending or flexural stress. This test is allotted as per the rule given in IS:516-1959.It is measured by loading 100 x 100mm concrete beams with a span length 500mm. In most cases, the specimen is placed on a support span, and the load is applied at the center using a loading nose, creating three-point bending at a specified rate. Key parameters for this test include the support span, loading speed, and the maximum deflection during the test.

$$\text{Flexural strength} = \frac{Load}{cross\ sectional\ Area}$$

Fig – 10 Compression Testing Machine

7.4 RAPID CHLORIDE PERMEABILITY TEST (RCPT)

The Rapid Chloride Permeability Test (RCPT) [13], standardized under ASTM C1202 and AASHTO T **277**, is used to assess the resistance of concrete to chloride ion penetration, which is crucial for durability in structures exposed to marine environments, de-icing salts, and aggressive chemicals. The test involves a 50 mm thick and 100 mm diameter cylindrical concrete specimen, which is first vacuum-saturated to ensure uniform moisture content. It is then placed between two acrylic cells, with one containing 0.3N sodium hydroxide (NaOH) solution and the other filled with 3.0% sodium chloride (NaCl) solution. A 60 V DC potential is applied across the specimen for six hours, forcing chloride ions to migrate through the concrete. The total charge passed, measured in coulombs (C), indicates the permeability of the concrete, with higher values representing greater chloride penetration. According to ASTM classification, values exceeding 4000 C indicate high permeability, while those below 100 C represent negligible permeability.

Although RCPT provides a quick assessment of chloride penetration resistance, it primarily measures electrical conductivity rather than true diffusion, meaning factors such as pore structure, water-to-cement ratio, admixtures, and supplementary cementitious materials (SCMs) significantly influence the results. Despite its limitations, RCPT remains a widely used durability indicator for concrete mix optimization and quality control in chloride-exposed environments.

Fig -11 Split Tensile Testing Machine

Fig – 12 Flexural Strength Testing Machine

Fig – 13 RCPT Apparatus

8. RESULT AND DISCUSSIONS

8.1.1 Cement

The specific gravity of cement is a crucial property that indicates the density of cement relative to water. According to IS 455:1989, Part II, the acceptable range for the specific gravity of cement is between 2.9 and 3.15. The obtained value of 3.05 falls within this range, suggesting that the cement is of good quality and free from excessive impurities or moisture. Specific gravity is important in concrete mix design as it helps in calculating the correct proportions of materials, ensuring the desired strength and durability of the final structure. It also aids in determining the volume of cement required for a particular mix. In addition to specific gravity, other essential properties of cement include fineness, consistency, setting time, and compressive strength. Fineness affects the rate of hydration and strength development, while consistency ensures uniform mixing. Setting time indicates how quickly the cement hardens, and compressive strength reflects the material's load-bearing capacity. If these properties are within the specified standards, the cement can be considered suitable for construction purposes.

Table 2. Properties of cement

SI No.	Tests conducted	Values obtained	IS Specification and Allowable limit	Inference
1.	Standard Consistency	37%	IS;4013 (PART 5) 1988, limit between 25% –35%	The obtained value is 37%
2.	Specific gravity	2.85	IS;455-1989, limit between 2.9-3.15	The obtained value is 2.85
3.	Initial Setting Time	30 minutes	IS;4301-1968, Not less than 30 minutes	The obtained value is not less than 30 minutes

8.1.2 Aggregates

Table 3. Properties of Fine aggregates

SI No.	Tests conducted	Results	IS Specification and Allowable limit	Inference
1.	Specific Gravity	2.64	IS;2386 (Part 2)-1963, limit is between 2.65 – 2.67	The obtained value is in between 2.65-2.67
2.	Sieve analysis	Fineness modulus=3.89	IS 383-1970, limit is between 2-3.5	The obtained value is in between 3.1-3.6

Table 4. Properties of Coarse aggregates

SI No.	Tests conducted	Results	IS Specification and Allowable limit	Inference
1	Specific Gravity	2.78	IS 2386 (part 3), limit is between 2.5-3	The obtained value is 2.78
2	Sieve analysis	Fineness modulus =3.13	IS 2386 (Part 3), limit is in between 4-8	The obtained value is 3.13
3	Water absorption	0.1%	IS 2386(Part3) limit is less than 2%	The obtained value is less than 2%

9. TESTS ON SPECIMEN

9.1 Compressive strength of M40 grade concrete

The compressive loading test on concrete were conducted on a compression testing machine of capacity 2000kN. The readings from the dial gauge were recorded, and the compressive strength was calculated accordingly. The test was conducted on 150mm cube specimen at 7, 14 and 28 days.

Table 5. Compressive strength test result on M40 concrete

AGE OF CURING	COMPRESSIVE STRENGTH (N/mm2)
7 DAYS	28
14 DAYS	36
28 DAYS	44

9.2 Split tensile strength test of M40 concrete

The split tensile strength test on concrete were conducted on a compression testing machine of capacity 2000kN. The readings on dial gauge were recorded and split tensile strength was calculated. The test was conducted on 150mm diameter and 300mm height cylinder specimen at 7, 14 and 28 days.

Table 6. Split tensile strength test result on M40 concrete

AGE OF CURING	SPLIT TENSILE STRENGTH (N/mm2)
7 DAYS	2.5
14 DAYS	3.4
28 DAYS	4.1

9.3 Flexural strength test of M40 concrete

The flexural strength test on concrete were conducted on a flexural strength testing machine of capacity 2000kN. The readings on dial gauge were recorded and flexural strength was calculated. The test was conducted on 500×100×100mm beam specimen at 7, 14 and 28 days.

Table 7. Flexural strength test result on M30 concrete

AGE OF CURING	FLEXURAL STRENGTH (N/mm2)
7 DAYS	4.3
14 DAYS	5.4
28 DAYS	7.1

9.4 Compressive strength of M40 grade concrete of 20% Replacement

Table 8. Compressive strength test result on M40 concrete

AGE OF CURING	COMPRESSIVE STRENGTH (N/mm2)
7 DAYS	8
14 DAYS	35
28 DAYS	40

9.5 Split tensile strength test of M40 concrete of 20% Replacement

Table 9. Split tensile strength test result on M40 concrete

AGE OF CURING	SPLIT TENSILE STRENGTH (N/mm2)
7 DAYS	2.2
14 DAYS	3.2
28 DAYS	4

9.6 Flexural strength test of M40 concrete of 20% Replacement

Table 10. Flexural strength test result on M40 concrete

AGE OF CURING	FLEXURAL STRENGTH (N/mm2)
7 DAYS	4.1
14 DAYS	5.2
28 DAYS	7

9.6 Compressive strength of M40 grade concrete of 30% Replacement

Table 11. Compressive strength test result on M40 concrete

AGE OF CURING	COMPRESSIVE STRENGTH (N/mm2)
7 DAYS	25
14 DAYS	33
28 DAYS	42

9.7 Split Tensile strength of M40 grade concrete of 30% Replacement

Table 12. Split Tensile strength test result on M40 concrete

AGE OF CURING	SPLIT TENSILE STRENGTH (N/mm2)
7 DAYS	2.2
14 DAYS	3.3
28 DAYS	4.1

9.8 Split Tensile strength of M40 grade concrete of 30% Replacement

Table 12. Split Tensile strength test result on M40 concrete

AGE OF CURING	SPLIT TENSILE STRENGTH (N/mm2)
7 DAYS	2.2
14 DAYS	3.3
28 DAYS	4.1

9.9 Flexural strength test of M40 concrete of 30% Replacement

Table 10. Flexural strength test result on M40 concrete

AGE OF CURING	FLEXURAL STRENGTH (N/mm2)
7 DAYS	4
14 DAYS	5.1
28 DAYS	7.2

9.10 Compressive strength of M40 grade concrete of 40% Replacement

Table 11. Compressive strength test result on M40 concrete

AGE OF CURING	COMPRESSIVE STRENGTH (N/mm2)
7 DAYS	22
14 DAYS	31
28 DAYS	39

9.11 Split tensile strength test of M40 concrete of 40% Replacement

Table 12. Split Tensile strength test result on M40 concrete

AGE OF CURING	SPLIT TENSILE STRENGTH (N/mm2)
7 DAYS	2
14 DAYS	3
28 DAYS	3.9

9.12 Flexural strength test of M40 concrete of 40% Replacement

Table 13. Flexural strength test result on M40 concrete

AGE OF CURING	FLEXURAL STRENGTH (N/mm2)
7 DAYS	3.9
14 DAYS	5
28 DAYS	6

10. Final result

The table shows the strength properties of concrete after 28 days of curing. Three different concrete mixes were tested. The mix with a compressive strength of 42 N/mm², split tensile strength of 4.1 N/mm², and flexural strength of 7.2 N/mm² achieved the highest values, indicating superior performance. The other two mixes showed slightly lower strengths, with compressive strengths of 40 N/mm² and 39 N/mm², split tensile strengths of 4 N/mm² and 3.9 N/mm², and flexural strengths of 7 N/mm² and 6 N/mm², respectively.

Table 14. Strength results of concrete after 28 days

AGE OF CURING 28 DAYS	COMPRESSIVE STRENGTH (N/mm2)	SPLIT TENSILE STRENGTH (N/mm2)	FLEXURAL STRENGTH (N/mm2
20% Replacement	40	4	7
30% Replacement	42	4.1	7.2
40% Replacement	39	3.9	6

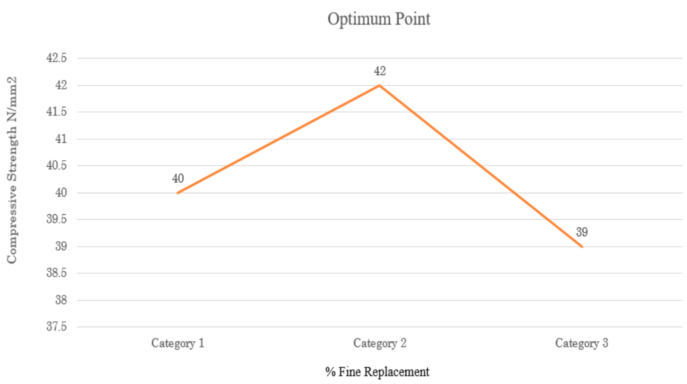

FIGURE 14

Figure 14 illustrates the compressive strength of three concrete categories after 28 days of curing. Category 2 achieved the highest compressive strength of 42 N/mm², marking it as the optimum point for strength enhancement. Category 1 recorded a slightly lower strength of 40 N/mm², while Category 3 showed the lowest strength at 39 N/mm².

10.1 RCPT TEST

The Rapid Chloride Permeability Test (RCPT) measures the resistance of concrete to chloride ion penetration. In this test, a concrete sample is placed between two cells, one filled with a sodium chloride solution and the other with a sodium hydroxide solution. A 60V DC voltage is applied across the sample for 6 hours, and the total charge passed (in coulombs) is recorded. Lower charge values indicate better resistance to chloride ion penetration.

Table 15. Classification of Chloride Ion Penetrability Based on Charge Passed (ASTM C1202)

CHARGE PASSED (COULOMBS)	CHLORIDE ION PENETRABILITY
>4,000	HIGH
2,000-4,000	MODERATE
1,000-2,000	LOW

100-1,000	VERY LOW
<100	NEGLIGIBLE

Qualitative indications of the chloride ion penetrability based on the measured values from this test method are provided in the Table 18. These values were obtained from data collected from slices of cores extracted from laboratory slabs made with different types of concrete.

10.2 RCPT TEST RESULT

Table 16. RCPT test result inference

	CURRENT 1 (mA)	CURRENT 2(mA)
SPECIMEN	1 (M40)	C (30% replaced)
Coulombs	473.9	520.2

The table categorizes chloride ion penetrability based on the charge passed in coulombs, ranging from high (>4,000 C) to negligible (<100 C). The results show that M40 concrete without replacement (Sample 1) recorded an RCPT value of 473.9 C, while M40 concrete with 30% replacement using ceramic waste and mica (Sample C) registered a slightly higher value of 520.2 C. Both values fall within the "Very Low" category, defined by the range of 100 to 1,000 C. This indicates that the inclusion of ceramic waste and mica as partial replacements does not significantly compromise the concrete's resistance to chloride ion penetration. Thus, it is inferred that both concrete mixes exhibit very low chloride permeability, enhancing their durability in chloride-exposed environments.

11. CONCLUSION

The experimental study evaluated concrete using ceramic waste as a fine aggregate replacement and mica as an admixture. Among the tested levels, replacing 30% of fine aggregates with ceramic waste gave the best results. This mix achieved the highest compressive strength of 42 N/mm^2, along with split tensile and flexural strengths of 4.1 N/mm^2 and 7.2 N/mm^2, respectively. The Rapid Chloride Permeability Test (RCPT) showed that both the conventional and modified mixes had "Very Low" chloride ion penetrability, with values of 473.9 C and 520.2 C. This indicates strong resistance to chloride-induced corrosion, improving durability.

The study focused on enhancing concrete's performance and sustainability by testing replacement levels of 20%, 30%, and 40%. The 30% replacement level gave the best results, outperforming the 20% and 40% mixes, which reached compressive strengths of 40 N/mm^2 and 39 N/mm^2, respectively. The 30% mix also showed better split tensile and flexural strengths. Graphs confirmed that 30% replacement was the optimal level for maximum strength, while lower and higher replacements reduced performance. Excessive ceramic waste could weaken the concrete's structure.

In terms of durability, the RCPT results showed that both conventional and modified mixes had excellent resistance to chloride ingress, reducing the risk of reinforcement corrosion and increasing long-term durability. Using ceramic waste and mica not only improves concrete strength but also supports environmental sustainability by reducing industrial waste and minimizing the need for natural sand.

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