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# Experimental Studies on Concrete using Ceramic Waste and Synthetic Fibres

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***Abstract:***

The construction industry heavily depends on natural coarse aggregates, which are obtained from quarries and riverbeds. Continuous and excessive extraction of these aggregates has led to scarcity of quality natural resources, increased material costs, and adverse environmental impacts. Hence, identifying suitable alternative materials for partial replacement of coarse aggregates has become essential.Ceramic industries generate a substantial amount of waste during manufacturing, transportation, and installation processes. Broken tiles, sanitary ware, and rejected ceramic products are often disposed of in landfills, leading to serious environmental pollution and land degradation. Since ceramic waste is non-biodegradable, its accumulation poses long-term environmental hazards. Utilizing ceramic waste as a partial replacement of coarse aggregate in concrete provides an effective solution for waste management while reducing the burden on natural resources.Moreover, the combined use of ceramic waste aggregate and synthetic fibres contributes to the development of sustainable and eco-friendly concrete. Such concrete minimizes environmental pollution, conserves natural resources, and promotes the recycling of industrial waste materials. The study is therefore necessary to experimentally evaluate the feasibility, strength performance, and practical applicability of M20 grade concrete incorporating ceramic waste as partial coarse aggregate replacement along with the addition of synthetic fibres, ensuring both structural efficiency and environmental sustainability.In the present experimental work, crushed ceramic waste is used as coarse aggregate in manufacturing of M20 grade of concrete. The crushed ceramic waste is partially replaced as coarse aggregates with varying percentages as 0%, 5, 10%, 15% and 20% and also with the addition of constant 1.5% of polypropylene synthetic fibres. The workability, compressive strength, splitting tensile strength and flexural strength of M20 grade of concrete mix are compared with normal concrete (without any replacement).Based on the experimental findings, it can be concluded that the combined use of ceramic waste and synthetic fibres in M20 grade concrete not only improves certain mechanical properties but also contributes to sustainable construction by reducing the consumption of natural aggregates and promoting effective waste utilization.

***Keywords:*** Ceramic Waste

## 1. Introduction

### 1.1 General

Concrete is the most widely used construction material in the world owing to its high compressive strength, durability, adaptability to different environmental conditions and ease of availability of raw materials. It plays a vital role in the development of infrastructure such as buildings, bridges, highways, dams and industrial structures. Conventional concrete primarily consists of cement, fine aggregate, coarse aggregate, and water. Among these constituents, coarse aggregate occupies the largest volume and significantly influences the strength and durability characteristics of concrete.

In recent decades, rapid urbanization, industrialization, and population growth have resulted in a tremendous increase in construction activities. This has led to excessive exploitation of natural resources, particularly natural aggregates obtained from riverbeds and quarries. Continuous extraction of these materials has caused serious environmental issues such as depletion of natural resources, ecological imbalance, erosion, and increased cost of construction materials. Therefore, there is an urgent need to explore alternative and sustainable materials that can partially or fully replace conventional aggregates in concrete production.

### 1.1 Need of the Study

The need for the present study arises from increasing concerns related to sustainability, environmental protection, and the growing demand for durable and economical construction materials. The construction industry heavily depends on natural coarse aggregates, which are obtained from quarries and riverbeds. Continuous and excessive extraction of these aggregates has led to scarcity of quality natural resources, increased material costs, and adverse environmental impacts. Hence, identifying suitable alternative materials for partial replacement of coarse aggregates has become essential.

Ceramic industries generate a substantial amount of waste during manufacturing, transportation, and installation processes. Broken tiles, sanitary ware, and rejected ceramic products are often disposed of in landfills, leading to serious environmental pollution and land degradation. Since ceramic waste is non-biodegradable, its accumulation poses long-term environmental hazards. Utilizing ceramic waste as a partial replacement of coarse aggregate in concrete provides an effective solution for waste management while reducing the burden on natural resources.

### 1.2 Objectives of the Study

The main objectives of the present experimental investigation are formulated to evaluate the feasibility and performance of M20 grade concrete incorporating ceramic waste as partial replacement of coarse aggregate along with the addition of synthetic fibres. The specific objectives of the study are as follows:

The following are the major objectives of the present dissertation work:

1. To utilize crushed ceramic waste as coarse aggregate in manufacturing of M20 grade of concrete.
2. To partially replace crushed ceramic waste as coarse aggregates with varying percentages as 0%, 5, 10%, 15% and 20% and also with the addition of constant 1.5% of polypropylene synthetic fibres.
3. To determine the basic properties of aggregates as water absorption and specific density of crushed ceramic waste.

To determine workability, compressive strength, splitting tensile strength and flexural strength of above mentioned mixes and also to compare with normal concrete (without any replacement).

## 2. Literature Review

### 2.1 General

The detailed review of previous research is essential to understand the behavior of concrete incorporating ceramic waste and synthetic fibres. The following section presents a review of recent and relevant studies related to partial replacement of coarse aggregate with ceramic waste and the use of polypropylene synthetic fibres in concrete. The most recent studies have been discussed first, followed by earlier research works.

**Sahithi et al. (2026)** investigated the mechanical performance of Polypropylene Fiber Reinforced Concrete (PFRC) with partial replacement of cement using ground granulated blast furnace slag (GGBS) and ceramic waste powder (CWP) for rigid pavement of M0 grade concrete. Cement is replaced with GGBS at 5%, 10%, 15%, and 20%, while CWP 10%. Polypropylene fibers and superplasticizer are added at 1% to enhance workability and strength. The mechanical properties as compressive strength, split tensile and flexural strength tests were performed. It was observed that strength and durability due to the pozzolanic and filler effects were enhanced.

**Ngayakamo (2025)** utilised ceramic waste by replacing natural coarse aggregates at 0%, 5%, 10%, 15%, 20%, and 25% by weight. The compressive strength, split tensile strength, water absorption, and bulk density of the concrete were calculated at 7, 14 and 28 days. It was concluded from the tests that ceramic waste up to 20% improves the strength and durability of concrete, making it suitable alternative for sustainable concrete production.

**Amin et al. (2025)** incorporated **s**anitary ceramic waste powder (SCWP) and tiles ceramic waste powder (TCWP), as a substitute for cement to produce high strength concrete. It was observed that with 50% SCWP and TCWP produces a sustainable high strength concrete. and up to 40% cost reduction.

**Marín-Cortés et al. (2024)** studied the recycling of construction and demolition waste (CDW) in ceramic materials using the cold sintering process to promote sustainable and circular construction practices. The research aimed to develop dense ceramic materials with high recycled CDW content while reducing energy consumption during production. Furthermore, the process significantly reduced the conventional sintering temperature, resulting in energy savings and environmental benefits. The researchers concluded that cold sintering of recycled CDW materials can be an effective and sustainable method for manufacturing ceramic tiles and other construction materials while promoting waste recycling and resource conservation.

### 2.2 Summary of Literature Review and Research Gap

A comprehensive review of the available literature reveals that considerable research has been carried out on the utilization of ceramic waste as a partial replacement of natural coarse aggregate in concrete. Most researchers have reported that ceramic waste aggregates possess physical and mechanical properties comparable to conventional aggregates, such as high hardness, angular shape, and rough surface texture. These characteristics enhance mechanical interlocking between the aggregate and cement matrix, leading to satisfactory development of compressive strength. Several studies indicated that ceramic waste can be safely used up to an optimum replacement range of 10% to 20% without adversely affecting the strength characteristics of concrete. Additionally, the particle size distribution, shape, and surface texture of ceramic waste aggregates play a crucial role in workability and compaction of concrete mixes, and proper grading ensures uniform strength development throughout the structure.

## 3.Case and Methodology

### General

In this dissertation work is execute in three stages, initially, the engineering properties of various materials are determined such as water absorption and specific density of crushed ceramic waste. Further, mix design for M20 grade of concrete with partial replacement of ceramic waste with varying percentages as 0%, 5%, 10%, 15%, 20% are investigated and adding 1.5% polypropylene synthetic fibres. Finally the workability, compressive strength, splitting tensile strength and flexural strength of above mentioned mixes are determined and also compared with normal concrete (without any replacement).

### 3.1Basic Ingredients Properties

The materials which are using in the present study are as follows:

1. Cement
2. Fine aggregate
3. Coarse aggregate
4. Water
5. Ceramic waste
6. Polypropylene synthetic fibres


**Fig. 3.1 Typical mix design flow char**

**3.2Experimental Program**

The experimental investigation was conducted according to the following sequence:

3.3.1Material Preparation – Cement, sand, coarse aggregates, ceramic waste, and fibres were prepared and tested for physical properties.

3.3.2Mixing – All materials were weighed and mixed in a mechanical mixer to ensure uniform distribution. Synthetic fibres were gradually added to prevent clumping.

3.3.3Casting – Concrete was cast in moulds for cubes, cylinders, as per required test sizes.

3.3.4Compaction – Each layer of concrete was compacted using standard tamping rods and vibration where necessary.

3.3.5Curing – All specimens were demoulded after 24 hours and cured in water tanks at 27±2°C until testing age (7, and 28 days).

3.3.6Testing –compressive strength, split tensile strength, were conducted as per IS 516:1959 and IS 5816:1999.

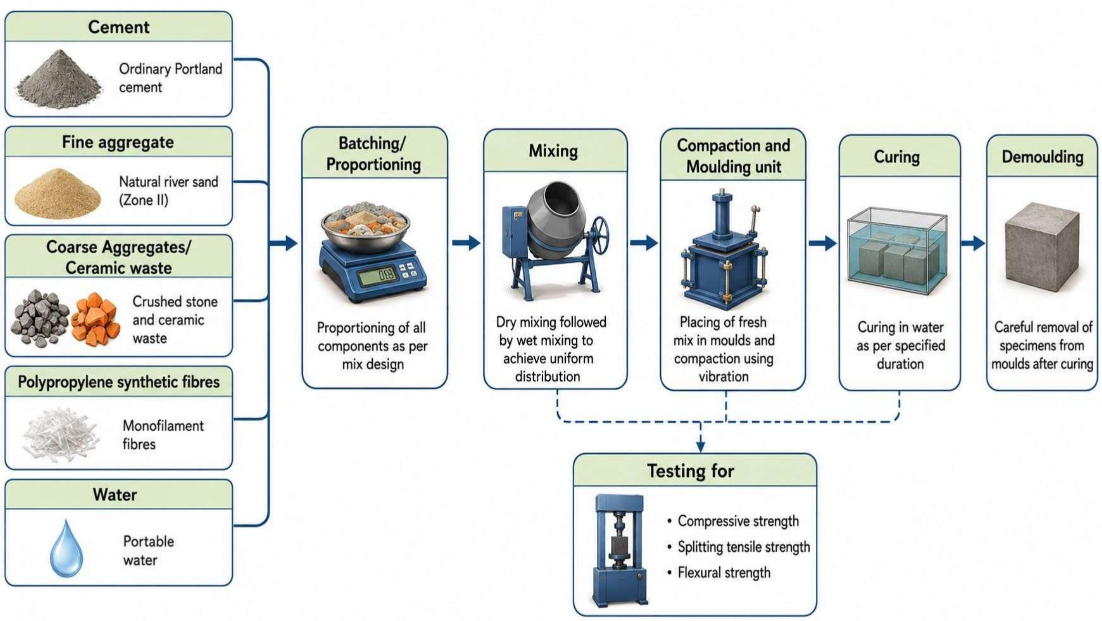


**Fig. 3.2 Present experimental flowchart**

**3.3Tests Conducted**

**2.2.1 Compressive strength**

**2.2.2 Split Tensile Strength**

***2.2.3*** **Flexural Strength**

**4.Results & Analysis**

**4.1General**

In the present experimental work, crushed ceramic waste is used as coarse aggregate in manufacturing of M20 grade of concrete. The crushed ceramic waste is partially replaced as coarse aggregates with varying percentages as 0%, 5, 10%, 15% and 20% and also with the addition of constant 1.5% of polypropylene synthetic fibres. The workability, compressive strength, splitting tensile strength and flexural strength of M20 grade of concrete mix are compared with normal concrete (without any replacement).

| Mix | Cement (kg) | Fine aggregates(kg) | Ceramic waste (kg) | Coarse aggregate (kg) | Water (kg) | % fibers |
|---|---|---|---|---|---|---|
| CM | 9.90 | 19.40 | 0 | 37.13 | 4.75 | 0% |
| CW5 | 9.90 | 19.40 | 1.85 | 35.28 | 4.75 | 1.5% |
| CW10 | 9.90 | 19.40 | 3.71 | 33.42 | 4.75 | 1.5% |
| CW15 | 9.90 | 19.40 | 5.57 | 31.56 | 4.75 | 1.5% |
| CW20 | 9.90 | 19.40 | 7.42 | 29.71 | 4.75 | 1.5% |

Table 4.1: Mix proportion for casting six cubes

**4.3** *Workability of concrete mixes*

As discussed, in this experiment work various concrete mixes of M20 grade concrete are prepared using ceramic waste. The influence of ceramic waste on workability behavior is observed. Workability is basically the property of freshly mixed concrete.

***Slump Cone Test***

This test was conducted for fresh concrete prepared before the molding process. Workability test results obtained from a slump cone test for M20 grade of concrete is given in Table 5.20. Fig. 4.1 shows that workability of concrete using ceramic waste in concrete increase (27.2%)

Table 4.13 Workability of concrete when coarse aggregate is replaced by ceramic waste

| Sn | Mix | Workability (mm) |
|---|---|---|
| 1 | CM | 20 |
| 2 | CW5 | 25 |
| 3 | CW10 | 30 |
| 4 | CW15 | 24 |
| 5 | CW20 | 22 |

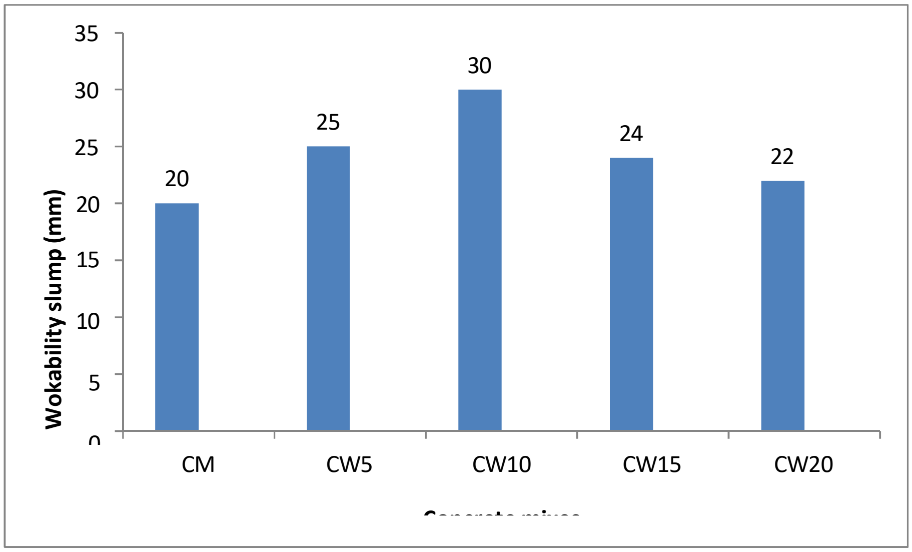


Fig 4.1 Workability of concrete when coarse aggregate is replaced by ceramic waste (Slump cone)

### 4.4 Compressive Strength

The average compressive strength values obtained after 7 days and 28 days are given in Table 4.14

Table 4.14 Average compressive strength at 7 and 28 days

| **Mix** | **7 days average strength (MPa)** | **28 days average strength (MPa)** |
|---|---|---|
| CM | 19.33 | 27.11 |
| CW5 | 23.63 | 26.60 |
| **CW10** | **22.67** | **29.33** |
| CW15 | 20.89 | 28.00 |
| CW20 | 20.22 | 26.50 |

The results indicate that the compressive strength increased significantly at 5% ceramic waste replacement, reaching 23.63 MPa, compared to 19.33 MPa for conventional concrete.

This improvement in strength may be due to:

- Better mechanical interlocking between ceramic waste aggregates and cement paste

- Rough and angular texture of ceramic waste
- Crack arresting action of synthetic fibres
- Improved internal bonding in the concrete matrix

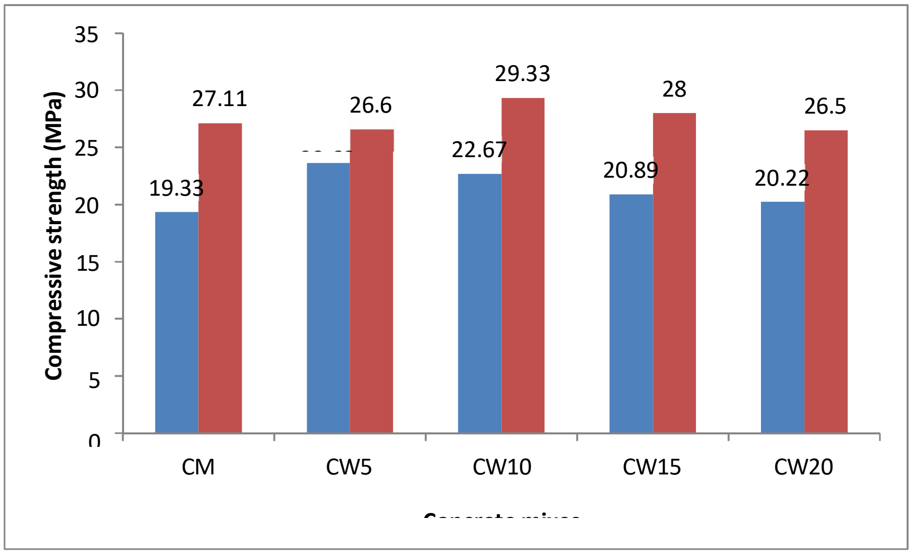


Fig 4.2 Average compressive strength at 7 and 28 days

### 4.3 Split Tensile Strength

Concrete is naturally weak in tension, and therefore split tensile strength is measured to determine its resistance to tensile stresses. Cylindrical specimens of 150 mm diameter and 300 mm height were tested.

Table 4.15 Average splitting tensile strength at 7 and 28 days

| **Mix** | **7 days average strength (MPa)** | **28 days average strength (MPa)** |
|---|---|---|
| CM | 2.18 | 2.38 |
| CW5 | 2.41 | 2.08 |
| CW10 | 2.62 | 2.69 |
| CW15 | 2.44 | 2.51 |
| CW20 | 2.34 | 2.45 |

The split tensile strength increased for all ceramic waste mixes compared to control concrete. The CW10 mix achieved the highest tensile strength of 2.62 MPa, compared to 2.18 MPa for conventional concrete.

The increase is due to:

- Fibre bridging mechanism, which delays crack formation
- Improved bond between cement paste and ceramic aggregate
- Better tensile stress distribution

The CW15 mix showed a slight decrease compared to CW10 but still remained higher than control.

This indicates that ceramic waste along with fibres enhances tensile resistance effectively up to 10% replacement.

The results show that:

- CW10 mix gave the maximum tensile strength of 2.69 MPa
- CW15 mix achieved 2.51 MPa
- CW5 mix showed 2.08 MPa, slightly lower than control mix

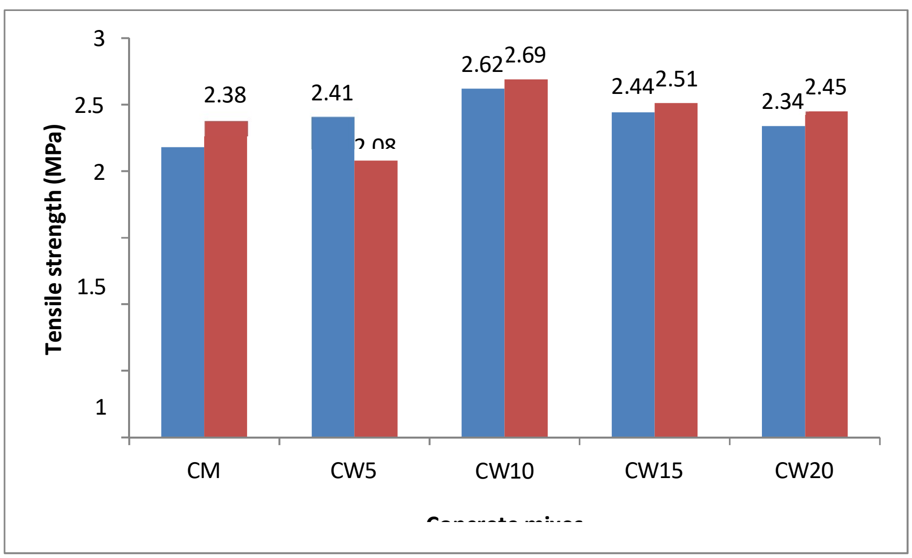


Fig 4.3 Average splitting tensile strength at 7 and 28 days

### 4.5 Flexural Strength

The average flexural tensile strength obtained by testing the beam specimen for M20 grade of concrete to all the mixes designed Table 4.16 and Fig. 4.4. The flexural strength of concrete as per IS 516, IS 5816 and IS 456 is given as:$0.7\sqrt{fck}$.

For M20 grade of concrete its value is 3.13 N/mm$^2$ (approx.). It can be observed from the experimental results that for various replacements considered satisfy the flexural strength requirement.

Table 4.16 Average flexural strength at 7 and 28 days

| **Mix** | **7 days average strength (MPa)** | **28 days average strength (MPa)** |
|---|---|---|
| CM | 2.45 | 4.21 |
| CW5 | 2.24 | 4.32 |
| **CW10** | 2.58 | **5.25** |
| CW15 | 2.34 | 4.65 |
| CW20 | 2.23 | 4.34 |

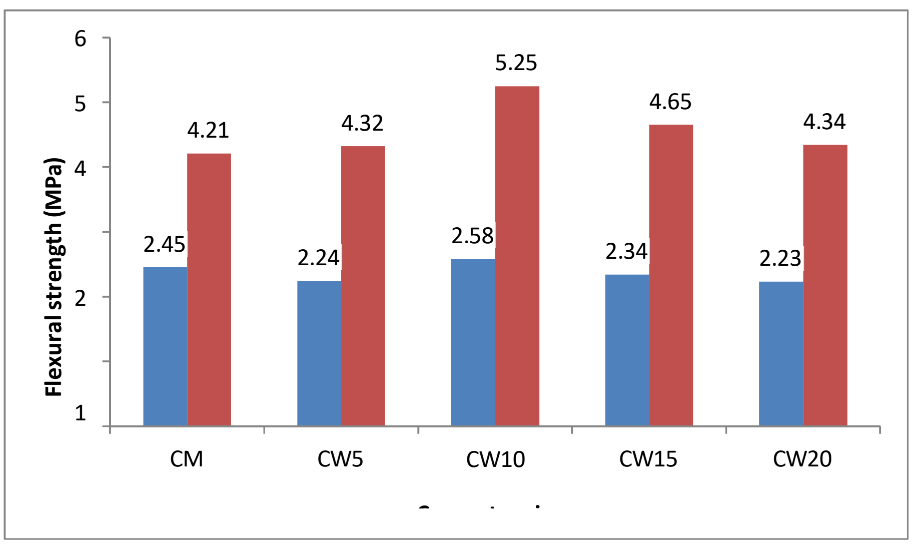


Fig 4.4 Average flexural tensile strength at 7 and 28 days

### 4.2 Conclusions

The following are the conclusions of the present experimental work:

1. Workability increase in case of 10% ceramic waste and compared to normal concrete.
2. The compressive strength improved up to 10% ceramic waste replacement
3. Split tensile strength also improved significantly at 10% when crushed ceramic waste is used as coarse aggregate in manufacturing of M20 grade of concrete.

### 5.1 Future scopes

The following are the future scopes of the present study:

1. The current study was restricted to M20 grade concrete, which is primarily used for general purpose construction. Future research can be extended to higher grades of concrete such as M25, M30, M40, and M50, which are commonly used in high-rise buildings, bridges, and heavy-loaded structures.
2. Also comprehensive durability investigations such as: resistance against acid attack, performance under sulfate exposure, chloride ion penetration and corrosion resistance, water absorption and permeability characteristics, freeze-thaw resistance, abrasion and impact resistance can be further studied.

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