

The Experimental Study on Concrete Using Steel Slag and Ceramic Waste

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Abstract - Nowadays, large amounts of waste materials like steel slag from steel industries and broken ceramic tiles from construction sites are creating serious environmental problems. Instead of dumping these materials, this project studies how they can be reused in concrete.

In this study, steel slag was used to partially replace coarse aggregate, and crushed ceramic waste was used to replace fine aggregate in different percentages. Concrete specimens were prepared and tested for workability, compressive strength, split tensile strength, and flexural strength after proper curing.

The results showed that replacing natural aggregates with steel slag and ceramic waste improved the strength of concrete up to a certain limit. After that limit, the strength started to decrease slightly. The improvement is mainly due to the strong and rough surface of these waste materials, which helps in better bonding inside the concrete. From this study, it is concluded that steel slag and ceramic waste can be safely used in concrete to reduce environmental pollution and save natural resources. This makes concrete more sustainable and economical for construction purposes.

.INTRODUCTION

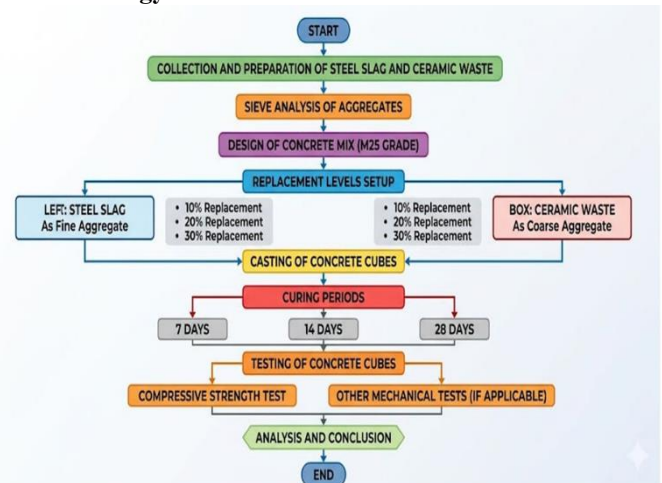
Concrete is one of the most important materials used in construction because of its strength and durability. It is made using cement, sand, coarse aggregate, and water. Normally, natural sand and crushed stones are used as aggregates, but their continuous use is reducing natural resources.

At the same time, industries and construction activities produce large amounts of waste materials such as steel slag and ceramic waste. These materials are often dumped, which creates environmental pollution.

In this project, an attempt is made to use these waste materials in concrete. Steel slag is used instead of fine aggregate, and ceramic waste is used instead of coarse aggregate. Different percentages of replacement are tested to study their effect on concrete properties.

The main aim of this experiment is to check the strength and workability of concrete using these materials and to find the best replacement percentage.

2.1 Meteorology



1. Materials used

1. **Cement** – Ordinary Portland Cement (OPC) 53 grade.
 2. **Fine Aggregate (FA)** – Natural river sand.
 3. **Coarse Aggregate (CA)** – Crushed stone or gravel.
 4. **Steel Slag** – As replacement for fine aggregate (washed and graded).
 5. **Ceramic Waste** – Crushed ceramic tiles as coarse aggregate replacement.
 6. **Water** – water for mixing.
 7. **Admixtures (Optional)** – Superplasticizers if required
1. **Cement**
Type: Ordinary Portland Cement (OPC) 43/53 grade

Property	Typical Value / Standard Requirement
Specific Gravity	3.15
Fineness (by sieve 90 μm)	$\geq 225 \text{ m}^2/\text{kg}$
Standard Consistency	28–32%
Initial Setting Time	$\geq 30 \text{ min}$
Final Setting Time	$\leq 600 \text{ min}$

2. Fine Aggregate (Natural Sand)

Type: Locally available clean and good graded fine aggregate was used after passing through IS sieve 2.36 mm.

Property	Typical Value / Standard Requirement
Particle Size	0.075 – 4.75 mm
Specific Gravity	2.60 – 2.70
Bulk Density	1600 – 1700 kg/m^3
Water Absorption	1 – 2%



3. Coarse Aggregate (Crushed Stone)

The fractions from 80 mm to 4.75 mm are termed as coarse aggregate. 480 is termed as a coarse aggregate. The broken stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having maximum size of 20 mm was used in the present work.

Material = 20 mm Size: 10–20 mm

Property	Typical Value / Standard Requirement
Specific Gravity	2.65 – 2.75
Bulk Density	1500 – 1700 kg/m^3
Water Absorption	0.5 – 1.5%



4. Steel Slag

(Fine Aggregate Replacement) is a by-product generated during the steel-making process, specifically from the separation of molten steel and impurities in a blast furnace or electric arc furnace. Traditionally considered industrial waste, it is now increasingly used in construction applications, particularly as a replacement for natural aggregates in concrete and road construction, due to its mechanical strength and durability.

Property	Typical Value / Notes
Particle Size	0.075 – 4.75 mm (similar to sand)
Specific Gravity	2.9 – 3.3
Bulk Density	1500 – 1650 kg/m^3
Water Absorption	1.0 – 2.5%



5. Ceramic Waste .

(Coarse Aggregate Replacement) is generated from broken or discarded ceramic tiles, sanitary ware, and pottery products during manufacturing, construction, or demolition activities. Instead of being sent to landfills, ceramic waste can be crushed and reused as partial replacement of coarse aggregates in concrete, contributing to sustainable construction practices.

Property	Typical Value / Notes
Particle Size	10 – 20 mm
Specific Gravity	2.3 – 2.6
Bulk Density	1400 – 1600 kg/m ³
Water Absorption	2 – 6%



EXPERIMENTAL ANALYSIS

Mix ID	Cement	Fine Aggregate (Sand)	Steel Slag (Waste)	Coarse Aggregate (Stone)	Ceramic Waste (Waste)
Control (CC)	100%	100%	0%	100%	0%
Mix 1 (M1)	100%	90%	10%	90%	10%
Mix 2 (M2)	100%	80%	20%	80%	20%
Mix 3 (M3)	100%	70%	30%	70%	30%

Total quantity of materials required for M25 grade of concrete

Concrete - M25

Cube: 15 × 15 × 15 cm

Volume:= 0.003375 m³

Material Quantity for M25 per 1 m³

Cement=413kg

Sand=680kg

Aggregate=1150kg

Water = 185 liter.

For 1 Cube

Cement=413×0.003375=1.39kg

Sand=680×0.003375=2.30kg

Aggregate=1150×0.003375=3.88kg

Water = 185 × 0.003375 = 0.62 liter.

EXPERIMENTAL ANALYSIS

The experimental programmed consists of the tests on fresh concrete and hardened concrete. For this purpose, concrete specimens of standard size and according to designed mix proportions were prepared. Then, the experiments are performed on them to check properties like slump, and mechanical properties like compressive strength.

1.2 Tests On Concrete:

- a) Slump cone test
- b) Compressive test

Slump cone test-

This test is extensively used on site. The test is very useful in detecting variations in uniformity of a mix for a given nominal proportion. This test shows of compacted concrete under the action of gravitational field slump occurs due to self weight of concrete there is no external energy supplied for the subsidence of concrete.

Apparatus:

Slump cone (bottom diameter 200 mm, top diameter 100 mm and height 300 mm), standard tamping rod 16 mm in diameter and 600 mm in length along with bullet end.

Procedure:

1. Clean the slump cone and place it on a flat surface.
2. Fill the cone in three layers.
3. Each layer is tamped 25 times using a tamping rod.
4. Level the top surface and remove excess concrete.
5. Lift the cone slowly and measure the slump.

Slump:

The slump shall be recorded in mm of subsidence of the concrete during the test. Any slump in which one half of the cone slides down in an inclined plane is called a shear slump in such case the test shall be repeated if the shear slump persists as may be in the case of harsh mixes this is an indication of lack of cohesion of the mix. If the slump slides evenly on all sides, it is called a true slump In case of concrete mixes with high workability a collapse slump is possible. The values of slump test obtained are interpreted as follows:

Table .5.3.1.1 Slump criteria and its value

Degree of Workability	Slump value in mm	Suitability
Very Low	0-25	Concrete roads.

Low	25-50	Mass concrete foundations, lightly reinforced sections.
Medium	50-100	Manually compacted flat slabs,
High	100-175	For sections with congested sections.

RESULT

- 1) Water cement ratio = 0.43
- 2) Slump measured in mm = 49 mm
- 3) Degree of workability = Low

Casting of Concrete Cube

- 1) The cube mould are of 150mm size confirming to IS: 10086-1982.
- 2) In assembling the mould for use , the joints between the section of mould shall be thinly coated with oil and similar coating of mould oil shall be applied between the contact surface of the bottom of the mould and the base plate in order to ensure that no water escape during the filling.
- 3) The interior surface of the assembled mould shall be thinly coated with mould oil to prevent adhesion of the concrete.
- 4) Compaction of test specimen shall be made as soon as practicable after mixing and in such way as to produce full compaction of the concrete with neither segregation nor excessive laitance.
- 5) The concrete filled into the mould in layers approximately 5 cm deep.
- 6) In placing each scoopful of concrete, the scoop shall be moved around the top edge of the mould as the concrete slides from it, in order to ensure a symmetrical distribution of concrete within the mould.
- 7) Each layer shall be compacted is done by vibrator and by hand, the standard tamping bar shall be used and the strokes of the bar shall be distributed in a uniform manner over the cross section of the mould.
- 8) The 35 number of strokes are given per layer.
- 9) The strokes shall penetrate into the underlying layer and the bottom layer shall be ridded throughout its depth.
- 10) The voids left by the tamping bar, are close by tapping the sides of the mould

Curing:

- AfterCasting**
Concrete is poured into molds (such as cube molds) and compacted properly.

- InitialSetting**

The concrete is allowed to set for about **24 hours** at room temperature.

- Demoulding**

After 24 hours, the concrete specimens are **removed from the molds** carefully.

- Water Curing**

The specimens are then **immersed in clean water** in a curing tank.

- CuringPeriod**

The cubes are kept in water for a specific period, usually **7 days, 14 days, or 28 days** depending on the testing requirement.

- Testing**

After the curing period, the cubes are taken out of water and tested for **compressive strength** using a compression testing machine.

Testing for Compressive Strength on Concrete Cube

The compressive strength test is done to find the maximum load a concrete cube can carry before it breaks. First, concrete is poured into cube molds (usually 150 mm × 150 mm × 150 mm) and properly compacted. The cubes are kept in the molds for 24 hours and then removed and placed in water for curing, usually for 7, 14, or 28 days. After curing, the cube is placed in a Compression Testing Machine (CTM), and load is applied gradually until the cube fails. The maximum load at failure is recorded and used to calculate the compressive strength of the concrete.



Mix replacement	14 Days (N/mm ²)	28 Days (N/mm ²)
0%	21.6	25.9
10%	24.8	28.9
20%	28.9	33.8
30%	23.4	26.6

CONCLUSION

In this experimental study, it is clear that steel slag and ceramic waste can be effectively used in M25 concrete without significantly compromising strength or durability. The concrete shows good compressive, t strength when proper mix proportions are maintained. Using these industrial by-products improves sustainability by reducing cement usage and minimizing landfill waste. Workability can be maintained with careful mix design, and durability properties such as resistance to water and chemicals are enhanced. Overall, concrete with steel slag and ceramic waste is a cost-effective, eco-friendly, and practical alternative to conventional M25 concrete, with potential for wider use in construction.

Steel slag and ceramic waste can safely replace up to 10% 20% 30% of natural aggregates in M25 concrete

Concrete with this replacement is stronger than normal concrete and still workable.

Replacing more than 20% may reduce workability and slightly lower strength.

it makes construction eco-friendlier and more sustainable.

For practical use, a 20% replacement of both fine and coarse aggregates is recommended.

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