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Partial Replacement of Cement by Egg Shell Powder

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Abstract: *The construction industry heavily relies on cement, which is not only costly and resource-intensive but also contributes significantly to CO_2 emissions. Producing one tonne of Ordinary Portland Cement (OPC) consumes around 1.1 tonnes of raw materials and emits a similar amount of CO_2, raising environmental concerns. To address this, our project investigates the partial replacement of cement with 5%, 10%, 15% and 20%eggshell powder—a locally available waste material rich in calcium carbonate ($CaCO_3$).Eggshells, often discarded in large quantities in India, show potential as a sustainable cement alternative due to their chemical composition. In this study, M20 grade concrete (1:1.5:2) was prepared with 10% eggshell powder replacing cement. The mechanical properties such as compressive, split tensile, and flexural strength were tested at 7, 14, and 28 days and compared with conventional concrete. The aim is to produce eco-friendly, cost-effective concrete while reducing cement usage and environmental impact*

Keywords: Exhaustion, Workability, Compressive Strength, declined, sustainable management, effective

I. INTRODUCTION

Using waste products in concrete is good for both construction and the environment. Cement is a key ingredient in concrete, but it uses a lot of natural resources and has a big environmental impact. With more people worrying about this, finding alternative materials—especially recycled ones—has become more important. This study looks at using eggshell powder (ESP) in concrete. Eggshells are full of calcium and are kind of like limestone in terms of chemistry, but they're just thrown away most of the time. The goal was to see how ESP affects concrete properties like strength and water absorption. We tested concrete with 5%, 10%, 15%, and 20% ESP replacements at 1, 7, and 28 days. Making just one tonne of cement takes about 1.1 tonnes of raw materials and releases the same amount of CO_2 into the air. There's a lot of waste from cement production, and while we can recycle some stuff, like plastics, we're still not sure how to deal with solid wastes like eggshells in the best way.

II.OBJECTIVES

1. To reduce the amount of cement used in concrete.
2. To find a useful way to recycle waste eggshells.
3. To make construction more eco-friendly.
4. To lower the cost of concrete by using waste materials.
5. To study the strength of concrete with eggshell powder.
6. To compare normal concrete with eggshell concrete.
7. To check how eggshell powder affects setting time.
8. To reduce CO_2 emissions caused by cement production.
9. To create a sustainable construction material.+
10. To explore new options for green building technology.

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III. EGG SHELL POWDER

Eggshell powder is a fine, white powder made by cleaning, drying, and grinding eggshells, which are typically discarded as kitchen or food industry waste. The main component of eggshell powder is calcium carbonate ($CaCO_3$), which is the same mineral found in limestone — a key ingredient in cement production. Because of this chemical similarity, eggshell powder has gained attention as a potential eco-friendly material for partial replacement of cement in concrete. Using eggshell powder helps reduce the environmental impact of cement manufacturing, lowers carbon emissions, and provides a sustainable way to reuse agricultural waste. When added in small amounts (usually 5–10%), it can maintain or even improve the strength and durability of concrete while promoting greener construction practices**.**

Fig. 1: EGG SHELL POWDER

3.1 Physical properties

MATERIAL	SPECIFIC GRAVITY	COLOUR
EGGSHELL POWDER	2.7	WHITE

IV. METHODOLOGY

The methodology for partial replacement of cement with egg shell powder involves collecting, cleaning, drying, and grinding egg shells into a fine powder. This powder is then used to replace cement in varying percentages (5%, 10%, 15%, and 20%). Concrete is mixed according to standard procedures, ensuring consistent water-cement ratio for all mixes. The concrete specimens (cubes, cylinders, or beams) are cast and cured for 7, 14, and 28 days. Tests such as compressive strength, tensile strength, and flexural strength are conducted to evaluate the impact of egg shell powder on concrete's properties. The results are compared to a control mix to determine the optimal percentage for enhanced performance and sustainability**.**

4.1 MATERIALS SELECTION

1. **Cement:** Ordinary Portland Cement (OPC) of 43 grade conforming to IS: 8112-2013 was used.
2. **Fine Aggregate:** Natural river sand passing through 4.75 mm IS sieve was used as the control fine aggregate.
3. **Egg shell powder:**Egg shell powder is selected as a sustainable material due to its high calcium carbonate content, which can enhance the strength and durability of concrete. It serves as an eco-friendly alternative to cement, reducing waste and promoting sustainability.
4. **Coarse Aggregate:** Crushed angular coarse aggregate of nominal size 20 mm was used.
5. **Water:** Potable water, free from impurities and suitable for mixing and curing, was used throughout the experiment.

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Fig. 2: Coarse aggregate

Fig. 3: Fine aggregate

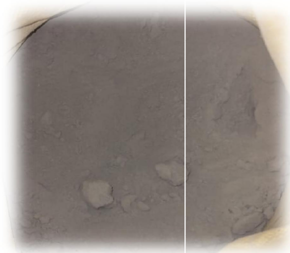

Fig. 4: Cement

Fig. 5: Eggshell powder

4.2 Mix Proportion

. Quantities for 5%, 10%, 15%, and 20% Cement Replacement by Egg Shell Powder

4.2.1.For 5% Cement Replacement:

- Cement = 108g - 5% of 108g = 102.6g
- Egg Shell Powder = 5% of 108g = 5.4g
- Fine Aggregate = 162g
- Coarse Aggregate = 323g
- Water = 54g

4.2.2.For 10% Cement Replacement:

- Cement= 108g - 10% of 108g = 97.2g
- Egg Shell Powder = 10% of 108g = 10.8g
- Fine Aggregate = 162g
- Coarse Aggregate = 323g
- Water = 54g

4.2.3.For 15% Cement Replacement:

- Cement = 108g - 15% of 108g = 91.8g
- Egg Shell Powder = 15% of 108g = 16.2g
- Fine Aggregate = 162g
- Coarse Aggregate = 323g
- Water = 54g

4.2.4For 20% Cement Replacement:

- Cement = 108g - 20% of 108g = 86.4g
- Egg Shell Powder = 20% of 108g = 21.6g
- Fine Aggregate = 162g
- Coarse Aggregate = 323g
- Water = 54g

Material (g)	0% replacement	5% esp	10% esp	15% esp	20% esp
Cement	108	103	96	92	86
Egg shell powder	0	5.4	11	17	22
Fine aggregate	162	162	162	162	162
Coarse aggregate	323	323	323	323	323
Water	54	54	54	54	54

4.3 Specimen Preparation

Concrete cubes of size 150 mm × 150 mm × 150 mm are cast for compressive strength testing. The total number of cubes cast for each mix design will be as follows:

Control Mix: 3 cubes (for 7, 14, and 28 days curing)

Mix 1: 3 cubes (for 7, 14, and 28 days curing)

Mix 2: 3 cubes (for 7, 14, and 28 days curing)

Mix 3: 3 cubes (for 7, 14, and 28 days curing)

Mix 4: 3 cubes (for 7, 14, and 28 days curing)

Each mix is thoroughly mixed using a mechanical mixer to ensure a homogenous blend of materials. The mixture is placed into the molds in layers, compacted using a vibrating table to remove air voids, and leveled to ensure uniformity.

Curing

The concrete cubes are removed from the molds after 24 hours and are then placed in a curing tank for a specified curing period of 7, 14, and 28 days. Curing is performed using water to ensure proper hydration of the cement and development of strength over time.

V. TESTING

5.1 COMPRESSIVE TEST

A set of three cubes were tested for each of the mix for their compressive strengths at 7,14 and 28 days of curing. As expected, the normal weight concrete has more compressive strength at all ages compared to lightweight concrete,

USING THIS FORMULA

Compressive Strength = P/A

P= Maximum load applied (N)

A= Cross-sectional area of the specimen (mm^2)

After curing the concrete specimens for the specified periods (7, 14, and 28 days), the compressive strength test is carried out on the cubes. (CTM) with a capacity of at least 2000 kN. The cubes are

The compressive strength results are calculated for each mix at 7, 14, and 28 days, and the average strength values for each curing period are recorded.

6.TEST RESULT

% ESP	7 Days	14 Days	21 Days	28 Days
0%	23.5	29.4	31.2	33.6
5%	22.7	28.6	30.5	32.8
10%	21.5	27.2	29.1	31.3
15%	19.8	25.4	27.5	29.6
20%	17.6	23.1	25	27.2

Table. 2: load

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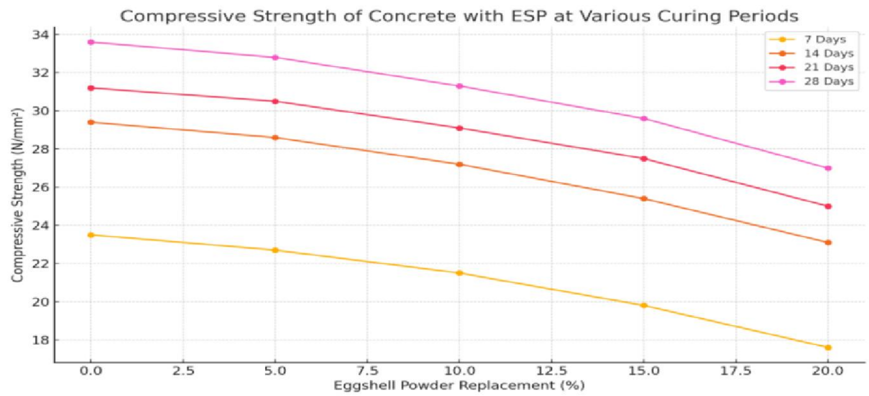

Fig. 6: Compressive strength

5.1Water Absorption Test:

Methodology:

1. After curing (7, 14, 21, 28 days), dry the concrete cubes in an oven at 100–110°C for 24 hours.
2. Record the **dry weight (W1)**.
3. Submerge cubes in water for 24 hours.
4. Take out and record the **wet weight (W2)**.
5. Calculate water absorption using:
6. **Water Absorption (%) = ((W2 − W1) / W1) × 10**

Test Results – Water Absorption (%):

Table 11 Water Absorption (%)

% ESP	7 Days	14 Days	21 Days	28 Days
0%	5.2	4.8	4.5	4.2
5%	5.5	5.1	4.7	4.3
10%	5.8	5.4	5	4.6
15%	6.2	5.7	5.4	5
20%	6.7	6.1	5.8	5.4

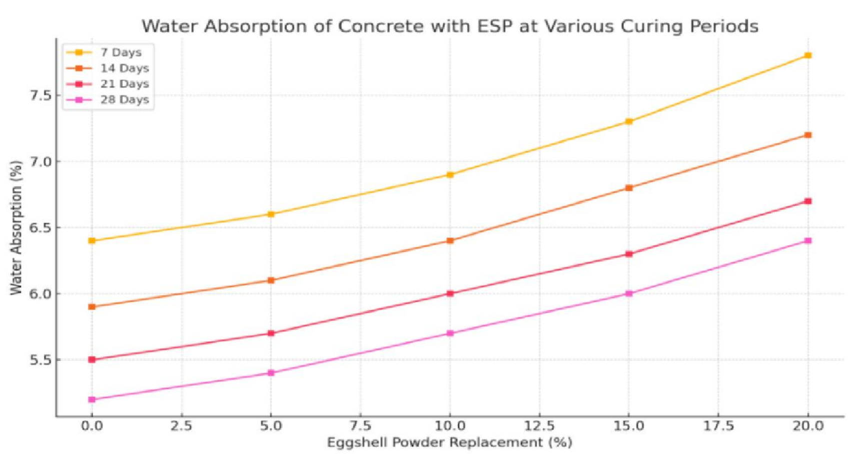

Fig.8 Graph representing waterabsorbing %

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VII. CONCLUSION

Based on the tests conducted, using eggshell powder (ESP) as a partial replacement for cement affects both the strength and water absorption of concrete. The **compressive strength** slightly decreased as ESP percentage increased, but up to **10% replacement**, the strength was still within acceptable limits. This suggests that ESP can be used in moderate amounts without compromising structural performance too much. After 15% and especially 20%, the cubes showed lower strength, maybe because of poor bonding or the ESP not reacting fully like cement does.

In terms of **water absorption**, values increased with more ESP, which means the concrete became a bit more porous. A few errors may have happened like not drying the cubes properly or some inconsistency while casting, which could've affected results. Still, up to 10–15% replacement, the durability was decent. So overall, **ESP up to 10% is a good eco-friendly option**, but beyond that, it might not be reliable without further mix optimization.

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