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Flexural Performance of RC Beam with the Partial Replacement of Cement with Egg Shell Powder (ESP)

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Abstract: It's a renowned fact that concrete used around the globe is second only to water. The cement industries have been categorized as highly polluting industries by the Central Pollution Control Board (CPCB). The production of ordinary Portland cement contributes 5-7% of total greenhouse gas emission and also consumes large amount of energy, hence it is crucial to discover substitute to cement. Eggshell is a waste material that can be obtained from restaurants, bakeries and households. Eggshell powder (ESP) has high amounts of calcium and can be combined with pozzolanic materials, such as fly ash, which have low calcium content. If effective uses for eggshell can be found, it would create an opportunity for a sustainable solution. Eggshell waste is among the most abundant agro-waste material discharged from food processing industries. Despite the exceptional properties and several applications, eggshell is castoff in huge quantity without any further use. This review paper focuses on appraising the potential uses of eggshell waste as a feedstock for production of sustainable construction materials. The emphasis is on the need to exploit extensively eggshell waste as a partial cement replacement material in cement-based construction materials. This study focuses on the viability of using calcined eggshells (CES) as a partial replacement of cement by analysing early age performance. Compressive, Flexural and Split Tensile Strength of concrete with 10%, 15%, 20% cement replacement with eggshell powder. The utilization of PES which offers a low-cost and energy-efficient resource for construction.

I. INTRODUCTION

The use of eggshell powder as a partial replacement for cement in concrete production is a topic of interest in the construction industry due to its potential environmental and economic benefits. Eggshells contain calcium carbonate, which is a major component of cement, making them a possible alternative to traditional cement. The incorporation of eggshell powder into concrete mixtures can improve the mechanical properties of the resulting concrete, including compressive strength, workability, and durability. This is because the calcium carbonate in the eggshells reacts with other components in the mix, leading to the formation of calcium silicate hydrate (c-s-h), which is the main component of cement. To use eggshell powder as a cement substitute, it is typically added in a ratio of 5-15% by weight of the cement. The eggshells should be cleaned, dried, and ground into a fine powder before use. The eggshell powder can then be added to the concrete mix during the mixing process.However, there are some potential drawbacks to the use of eggshell powder as a partial replacement for cement. The strength and durability of the resulting concrete may be affected if the eggshell powder is not ground finely enough or if the ratio of eggshell powder to cement is too high. The setting time of the concrete may also be affected. This project report aims to explore the use of eggshell powder as a partial replacement for cement in concrete production. The report will include a review of relevant literature on the topic, an overview of the experimental methodology, and a discussion of the results. The report will also examine the economic and environmental benefits of using eggshell powder in concrete production, as well as any potential drawbacks. Overall, this project aims to contribute to the growing body of research on sustainable and eco- friendly construction materials.

II. OBJECTIVES

1) To determine Flexural Strength of normal RC Beam.
2) To determine Flexural Strength of RC Beams with partial replacement of cement with different percentage of Eggshell Powder (ESP).

3) Comparative study of Flexural Performance of Normal RC Beams and RC Beams with partial replacement of cement with different percentage of Eggshell Powder (ESP).
4) To reduce the environmental impact of cement production: Cement production is a significant source of carbon emissions and other environmental impacts. By using eggshell powder as a partial replacement for cement, the amount of cement required can be reduced, resulting in lower carbon emissions and environmental impact.
5) To utilize a waste material: Eggshell powder is a waste product that is usually discarded by the food industry. By using it as a partial replacement for cement in concrete, it can be repurposed and put to good use, reducing waste and improving sustainability.
6) To improve the strength and durability of concrete: Studies have shown that adding eggshell powder to concrete can increase its compressive strength, making it more resistant to compression and improving its durability over time.
7) To improve the workability of concrete: Eggshell powder has a slightly finer particle size than cement, which can help improve the workability of the concrete mixture. This can make it easier to mix, pour, and place the concrete, resulting in a more uniform and consistent finished product.
8) To improve the thermal insulation of buildings: Eggshell powder has insulating properties, which can help improve the thermal insulation of the concrete. This can help reduce energy consumption in buildings by improving their energy efficiency.
9) Overall, the objectives of using eggshell powder as a partial replacement for cement in concrete are to reduce the environmental impact of cement production, utilize a waste material, improve the strength and durability of concrete, improve the workability of concrete, and improve the thermal insulation of buildings.

III. LITERATURE REVIEW

1) *K. Nandhini, J. Karthikeyan (Sustainable and greener concrete production by utilizing waste eggshell powder as cementitious material – A review)*

The development of infrastructure projects requires the use of innovative, cost-effective, and environmentally sustainable materials. The manufacturing process of cement involves the use of non-renewable resources, which poses significant environmental risks. To address these concerns, recyclable materials could be used as substitutes for cement. In this context, a comprehensive review was conducted to assess the potential of waste eggshells for use in construction. The study investigated the physical, chemical, and morphological characteristics of powdered eggshells (PES), as well as the fresh and hardened properties of concrete blended with PES. Results showed that a 10–15% PES substitution for cement resulted in improved strength and performance of concrete. Therefore, PES could offer a low-cost and energy-efficient resource for construction.

2) *Hussein M. Hamada, Bassam A. Tayeh, Alyaa Al-Attar, Fadzil M. Yahaya, Khairunisa Muthuswamy, Ali M. Humada (The present state of the use of eggshell powder in concrete: A review)*

Eggshell waste is a by-product generated by bakeries and fast-food restaurants. This waste material is usually disposed of in landfills, causing environmental pollution and health hazards. Eggshell powder (ESP) contains high amounts of calcium and can be used in combination with pozzolanic materials like fly ash, which have low calcium content. This paper presents the latest studies on the utilization of ESP as a filler, cement replacement, and fine aggregate. The chemical composition, physical properties, and fresh and hardened properties of ESP concrete at different proportions are also discussed. Results indicate the potential of using ESP with other pozzolanic materials to improve concrete properties and reduce cement production, thus minimizing environmental pollution. The compressive, flexural, and tensile strengths have also been improved with the use of some materials with ESP as cement replacement. However, some studies reported a reduction in strength when cement is replaced with high percentages of ESP, particularly those larger than 10%. Moreover, the modulus of elasticity decreases with high levels of replacement. The specific gravity of ESP was found to be lower than that of cement. The durability and water absorption of concrete were reduced with the addition of ESP.Processing of Eggshell, Calcination – 900 Degree Celsius for 2 Hr, Particle Size – Less than 300um

Split tensile and flexural strength and the modulus of elasticity decreases with ESP content by more than 10%.

ESP has a negative effect on concrete durability mainly because it increases the water absorption of concrete.

3) *Navaratnarajah Sathiparan (Utilization prospects of eggshell powder in sustainable construction material – A review)*

As infrastructure development continues to grow at a rapid pace, so does the demand for construction materials, with cement being one of the most commonly used materials worldwide. However, the use of nonrenewable resources in cement production and the resulting CO_2 emissions have created significant environmental problems. One practical solution is to partially or fully replace cement with waste materials, which can reduce the environmental impact caused by the dumping of waste.

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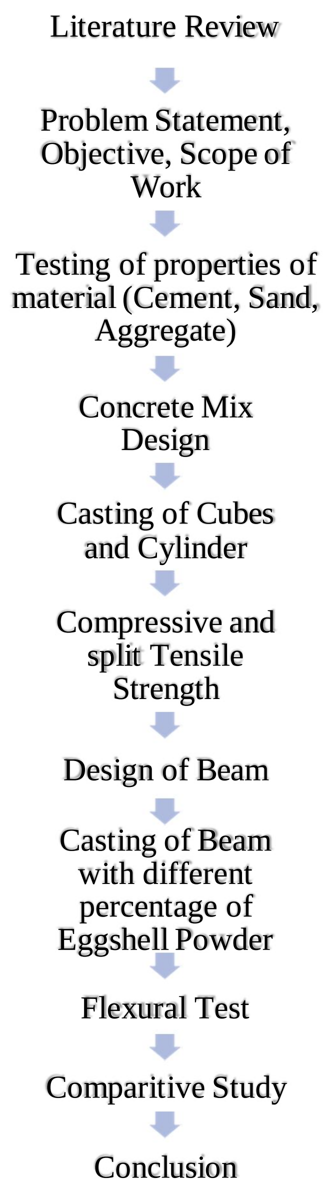
Eggshell waste can be obtained from households, bakeries, and restaurants, and if it can be effectively utilized, it presents a sustainable solution. This report presents the latest studies on the use of eggshell powder in various construction materials, such as concrete, cement mortar, brick, alkali-activated binder, and soil stabilizer. The physical and chemical properties of eggshell powder and the factors that influence its characteristics were also analyzed. The results indicate that eggshell powder can improve the characteristics of cementitious materials. Specifically, replacing 10-15% of cement with eggshell powder results in strength development comparable to the control. Several studies have also shown the potential of using eggshell powder as a soil stabilizer and for improving the mechanical properties of bricks. Therefore, eggshell powder is an energy and cost-effective solution for creating sustainable construction materials.

IV. METHODOLOGY

A. Methodology Flowchart

The whole project is based on laboratory experiment so the approach of the research adopted here is Experimental Research. The following flow chart illustrates the methodology of the study.



V. RESULT AND ANALYSIS

A. *Summary of Results*

Sr no.	Replacement in (%)	Compressive strength (N/mm^2)	Split Tensile	Load at peak	Flexural strength
1	0%	30.17	3.75	104.87	24.93
2	5%	26.8	3.1	86.64	22.74
3	10%	25.99	2.7	80.8	21.21
4	15%	24.2	2.51	74.84	19.64

B. *Results*

1) *Compression Test Result*

a) *0% Replacement*

Table 19 0% Compression Test results

Sr. no.	Identification mark	Size of specimen(mm)	No. of curing days	Maximum load (KN)	Compressive strength (N/mm^2)
1.	M25	150*150*150	7	388.25	17.25
2.	M25	150*150*150	28	678.90	30.17

b) *5% replacement: -*

Table 20 5% compression Test Results

Sr. no.	Identification mark	Size of specimen(mm)	No. of curing days	Maximum load (KN)	Compressive strength (N/mm^2)
1.	M25	150*150*150	7	345.87	15.37
2.	M25	150*150*150	28	603.40	26.8

c) *10% Replacement*

Table 21 10% Compression Test Results

Sr. no.	Identification mark	Size of specimen(mm)	No. of curing days	Maximum load (KN)	Compressive strength (N/mm^2)
1.	M25	150*150*150	7	320.40	14.24
2.	M25	150*150*150	28	584.9	25.99

d) *15% Replacement*

Table 22 15% Compression Test Results

Sr. no.	Identification mark	Size of specimen(mm)	No. of curing days	Maximum load (KN)	Compressive strength (N/mm^2)
1.	M25	150*150*150	7	276.7	12.29
2.	M25	150*150*150	28	544.86	24.2

2) Split tensile Test Result

a) 0% Replacement

Table 23 0% Split Tensile Test Result

Sr. no.	Identification mark	Size of specimen(mm)	No. of curing days	Maximum load (KN)	Compressive strength (N/mm^2)
1.	M25	Diameter 150cm, length 300cm	7	129.8	1.8
2.	M25	Diameter 150cm, length 300cm	28	264.90	3.75

b) 5% Replacement

Table 24 5% Split Tensile Test Result

Sr. no.	Identification mark	Size of specimen(mm)	No. of curing days	Maximum load (KN)	Compressive strength (N/mm^2)
1.	M25	Diameter 150cm, length 300cm	7	117.8	1.6
2.	M25	Diameter 150cm, length 300cm	28	221.9	3.1

c) 10% Replacement

Table 25 10% Split Tensile Test Result

Sr. no.	Identification mark	Size of specimen(mm)	No. of curing days	Maximum load (KN)	Compressive strength (N/mm^2)
1.	M25	Diameter 150cm, length 300cm	7	102.3	1.44
2.	M25	Diameter 150cm, length 300cm	28	194.87	2.7

d) 15% Replacement

Table 26 15% Split Tensile Test Result

Sr. no.	Identification mark	Size of specimen (mm)	No. of curing days	Maximum load (KN)	Compressive strength (N/mm^2)
1.	M25	Diameter 150cm, length 300cm	7	92.9	1.3
2.	M25	Diameter 150cm, length 300cm	28	177.4	2.51

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3) Results of beam

a) Normal Beam

Figure 13 Testing of Normal Beam

Table 27 Normal Beam Load and Deflection Readings

0% Replacement		
Load (kN)	Deflection (mm)	
	Centre	Side
0	0	0
10	1.42	1.27
20	2.17	1.95
30	2.81	2.5
40	3.48	3.13
50	4.38	3.9
60	5.56	5
70	10.14	9.12
76.63	14.56	13.1

b) 5% Replacement Beam

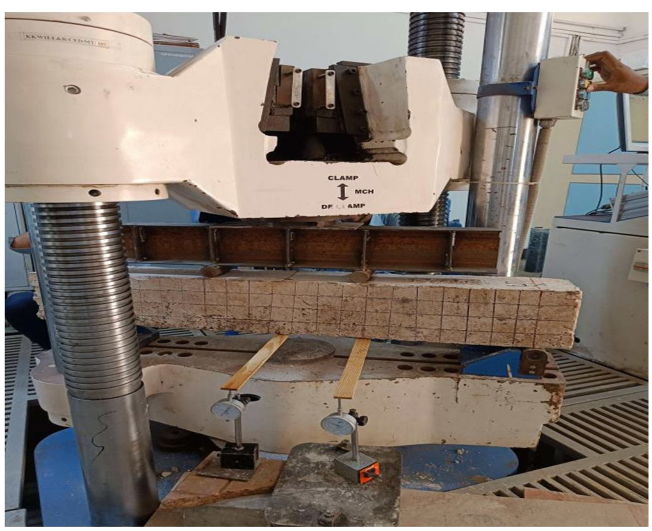

Figure 15 Flexural Test for 5% Replacement Beam

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Table 28 5% Load and Deflection Readings

5% Replacement		
Load (kN)	Centre	Side
0	0	0
10	0	0
20	0	0
30	0.81	0.5
40	1.55	1.1
50	2.9	1.25
60	3.98	1.4
70	5.07	1.45
80	7.69	1.7
81	9.14	1.71
83	11.07	1.9

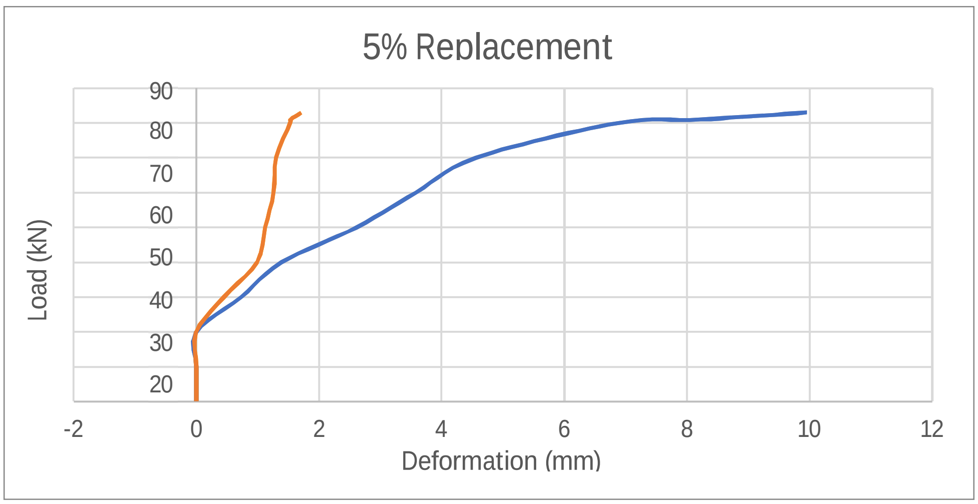

Figure 16 Load v/s Deflection Graph for 5% Replacement Beam

c) *10% Replacement Beam*

Figure 18 Flexural Test of 10% Replacement Beam

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Table 29 10% Load and Deflection Reading

10% Replacement		
Load (kN)	Deflection (mm)	
	Centre	Side
0	0	0
10	0	0
20	0	0
30	0.79	0.48
40	1.33	1.08
50	2.84	1.55
60	3.67	1.99
70	6.89	2.03
80	7.23	2.54

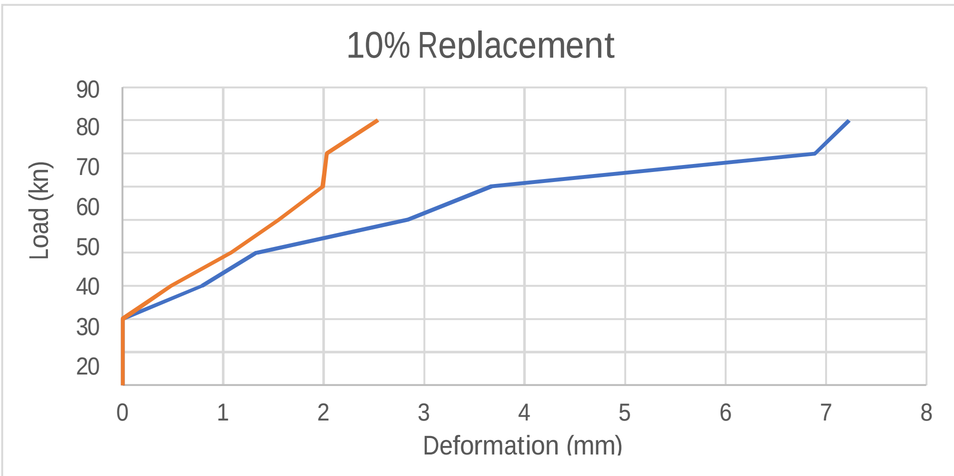

Figure 19 Load v/s Deflection Graph for 10% Replacement

d) 15% Replacement Beam

Figure 20 Flexural Test of 15% Replacement Beam

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Table 30 15% Load and Deflection Readings

15% Replacement		
Load (kN)	Deflection (mm)	
	Centre	Side
0	0	0
10	0	0
20	0	0
30	0.95	0.6
40	1.66	1.16
50	3.35	1.87
60	4.89	2.13
70	8.15	2.28
73	14.51	2.78

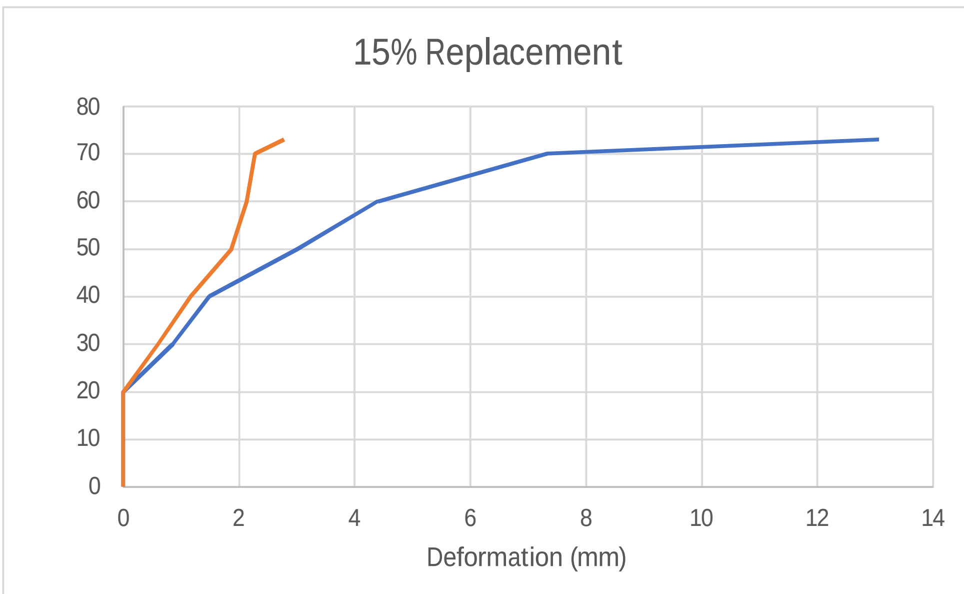

Figure 21 Load v/s Deflection Graph for 15% Replacement Beam

VI. CONCLUSION

After conducting flexural test on five beam specimens the conclusions of the work are as follows:

1) From test results it is observed that flexural strength of 5% beam is decreased as compared to conventional beam by 8.78%.

2) Replacement of ESP by 10% in Beam has significantly decreased the flexural strength by 14.92 %.

3) Replacement of ESP by 15% in Beam has significantly decreased the flexural strength by 21.22 %.

From above it seems that the addition of ESP in beam has decreased the flexural strength at 5%,10% and 15% replacement.

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