



# EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF EGG SHELL POWDER WITH CEMENT IN CONCRETE

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## ABSTRACT

The eggshell mostly which are waste product is utilized as a substitute of cement as the eggshell consist of Calcium. This research tries to determine the effective utilization of eggshell powder produced by the egg producing company as a partial substitution for the ordinary Portland cement. In this study, 5%, 10%, 15% and 25% of cement is replaced by the eggshell powder by weight. ESP, rich in calcium carbonate, mimics the primary component of cement, potentially enhancing concrete properties. Mechanical and durability characteristics of eggshell powder-based concrete were investigated. Compressive strength test, splitting tensile strength test and sulphate attack test were conducted at curing ages of 7 and 28 days to determine the optimal percentage of replacement by eggshell powder in eggshell powder-based concrete.

Keywords: Eggshell powder, cement replacement, concrete, compressive strength, durability, sulphate attack, sustainability.

## INTRODUCTION

The construction industry, cement in particular, is significant enough to contribute about 5-7% of the CO<sub>2</sub> emissions in the world. And with growing concerns regarding sustainability, there is great interest in finding alternative materials for reducing cement usage while ensuring concrete performance is maintained. One such material could be eggshell powder: the byproduct of poultry and usually discarded as waste. Primarily, eggshells are composed of calcium carbonate and have chemical composition similarities with compounds of calcium in cement; therefore, these are promising candidates

for substitution.

Vast numbers of eggshells are produced globally, while the majority of them never come to utilization and end in pollution. If eggshell powder were included in concrete, such would possibly reduce waste of material as well as further improving properties of the cementitious material. Research proved that the eggshell possesses pozzolanic behavior which would react with a mix containing lime to make other cementitious compounds improving its mechanical as well as the durability character of concrete.

This study aims to investigate partial cement replacement by eggshell powder on concrete's mechanical properties, namely compressive strength, splitting tensile strength, and sulfate resistance. It will be tested at four different levels of substitution, namely 2.5%, 5%, 7.5%, and 10%, with the aim of finding out the optimal percentage for the performance of concrete at 7 and 28 curing days. The aim is to find a suitable replacement that enhances the strength and durability of concrete while reducing its dependency on cement, thus making construction more sustainable and economical.

## OBJECTIVES OF STUDY

This research is designed to examine the potential of eggshell powder as a partial cement replacement in concrete and assess its effect on concrete properties. It aims to investigate the structural behaviour, workability, compressive strength, and durability of ESP-modified concrete and identify the best percentage of ESP replacement that offers maximum strength without sacrificing cost-effectiveness and sustainability. The research also focuses on reducing environmental pollution by utilizing eggshell waste

as a supplementary cementitious material, minimizing landfill waste and decreasing the carbon footprint of concrete production. Furthermore, the study examines the economic feasibility of ESP in large-scale construction projects and explores its potential integration into standard concrete production. Additionally, it assesses the effects of ESP on water absorption, sulphate resistance, and overall performance in varied environmental conditions. Encouraging sustainable construction practices by promoting the use of industrial and agricultural waste materials in the infrastructure sector is another critical objective, contributing to a more environmentally responsible and resource-efficient construction industry.

### Chemical Composition of Eggshell Powder and Cement

The chemical composition of cement plays a crucial role in determining the mechanical properties of concrete. Traditional Portland cement contains various oxides, including calcium oxide (CaO), silicon dioxide (SiO<sub>2</sub>), and aluminium oxide (Al<sub>2</sub>O<sub>3</sub>), which contribute to its strength and durability. Similarly, eggshell powder (ESP), primarily composed of calcium carbonate (CaCO<sub>3</sub>), exhibits a comparable chemical profile, making it a potential alternative as a supplementary cementitious material.

Table 1 presents a comparative analysis of the oxide composition of cement and eggshell powder. Notably, ESP contains a higher percentage of calcium oxide (62.35%) than cement (60.10%), which is advantageous for strength development. It contains much lower levels of silicon dioxide, iron oxide, and aluminium oxide, however, which are necessary for the hydration process and the formation of binding properties in cement.

Table 1: Chemical Composition of Cement and Eggshell Powder

Oxide Group	Cement	Eggshell Powder%
Calcium oxide	60.10	62.35
Sulphur Trioxide	2.50	1.32
Iron Oxide	4.10	0.63
Silicon Dioxide	21.80	0.61
Magnesium Oxide	0.50	0.36

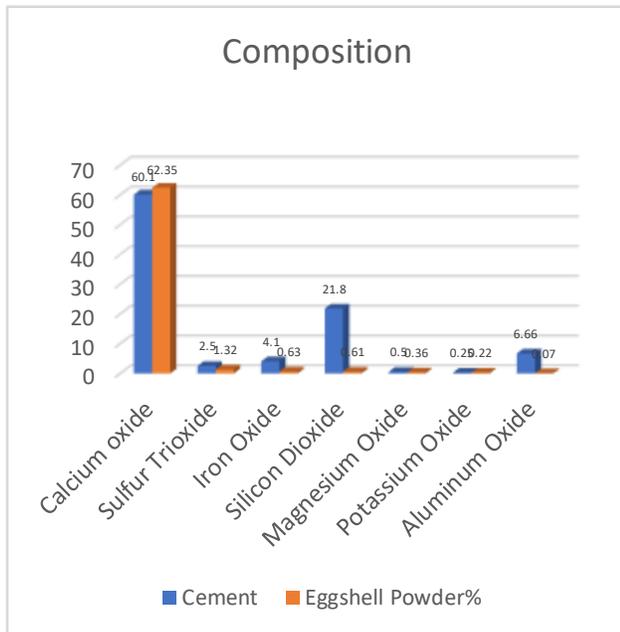
Potassium Oxide	0.25	0.22
Aluminium Oxide	6.66	0.07

### DISCUSSION OF COMPOSITION

The significant presence calcium oxide in ESP suggests that it can contribute to the hydration reaction necessary for cementitious binding. However, the lower levels of silicon dioxide, aluminium oxide, and iron oxide indicate that eggshell powder alone cannot fully replace cement without affecting concrete's structural properties. The reduced amount of sulphur trioxide and magnesium oxide in ESP may lead to improved sulphate resistance, making it suitable for applications in sulphate-rich environments.

Despite its limitations, ESP's high calcium content and environmental benefits make it a promising material for partial cement replacement, reducing the reliance on traditional cement while promoting sustainability in the construction industry. Additional studies can investigate means to improve the binding characteristics of ESP-modified concrete by adding pozzolanic materials like silica fume or fly ash to offset its lower silica and alumina content.

Chart 1: Physical properties of Cement and Egg shell



## EGGSHELL POWDER

### A. GENERAL

Eggshell powder, which contains the high percentages of calcium carbonate, is byproduct material from the poultry industry. Once finely ground, the product reveals pozzolanic characteristics that contribute positively to concrete mechanical and durability features. Replacing some amount of cement in the production with eggshell powder creates environmental value and improves strength in concrete, increasing chemical resistance to attacks.

### B. PROCESSING

Eggshell powder is processed from collecting, cleaning, and drying eggshells then grinding them into a fine powder. Then the powder has to be sieved to acquire uniform particle size for using in concrete.

Fig 2: Eggshell processing



## DESIGN AND TESTS

### A. MIX PROPORTION

Our project focused on M30 grade concrete, with the mix design based on the guidelines provided in IS 10262-1982 and IS 456-2000. The mix proportion was determined accordingly.

Table-2: Mix proportions

Water	Cement	Fine aggregate	Coarse aggregate
191.58	383.16	663.765	1129.702
0.5	1	1.73	2.94

### B. SPECIFIC GRAVITY

Specific gravity refers to the ratio of a substance's density to the density of a standard substance. It can also be defined as the ratio of the mass of a substance to the mass of a standard substance, as long as both have the same volume.

Table-3: Specific gravity

S. No.	Materials	Specific
1	Cement	3.14
2	Egg Shell	1.01

## RESULTS AND DISCUSSION

The aims of all the tests are to determine the mechanical properties of the concrete (Grade M30) with Egg Shell Powder and Silica fume as a cement replacement. The strength properties like compressive strength and split tensile strength test results are given in tabular form and in graphical form for better comprehension. The results are compared between the different mix proportions.

### A. COMPRESSIVE STRENGTH

Compressive strength is a critical parameter in assessing concrete performance. The results indicate that ESP replacement up to 10% improves compressive strength compared to control samples. However, beyond 10%, strength gradually declines due to the reduced cementitious properties of ESP. The lower silicon dioxide and aluminium oxide content in ESP limits the formation of calcium silicate hydrate (CSH), which is essential for strength development. Despite this, the 10% ESP mix shows sufficient strength to be considered for structural applications.

Table-4: Compressive strength

MIX ID (%)	7 Days Curing(N/mm <sup>2</sup> )	28 Days Curing(N/mm <sup>2</sup> )
ESP 0	22.69	34.68
ESP 5	24.35	37
ESP 15	21.34	34.4
ESP 25	20.09	31.53

Chart2: Compressive strength



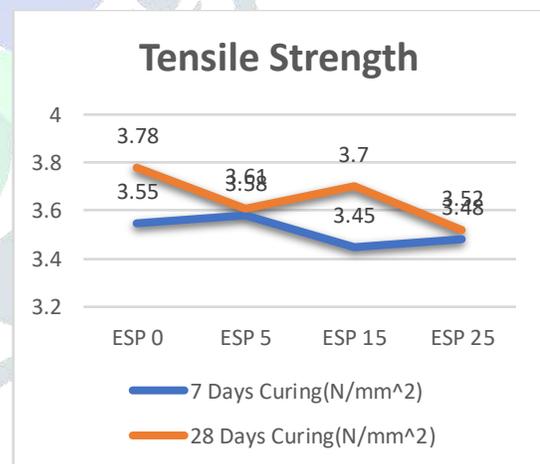
### B. SPLIT TENSILE STRENGTH

Tensile strength is important in evaluating the resistance of concrete to cracking and tension forces. The research discloses that ESP-modified concrete undergoes slight loss of tensile strength as ESP content rises. This decrease is due to the lower binding efficiency of ESP in comparison to cement. However, at 10% replacement, the tensile strength remains within acceptable limits for non-load-bearing structures and minor structural applications. Further research is required to enhance tensile properties, possibly by incorporating Fiber reinforcements.

Table-5: Tensile strength

MIX ID (%)	7 Days Curing(N/mm <sup>2</sup> )	28 Days Curing(N/mm <sup>2</sup> )
ESP 0	3.55	3.78
ESP 5	3.58	3.61
ESP 15	3.45	3.70
ESP 25	3.48	3.52

Chart3: Tensile strength



### C. WORKABILITY

The inclusion of ESP affects the workability of concrete. Workability decreases as the ESP content increases, primarily due to the fineness of the powder and its increased water absorption. A higher ESP content requires additional water to maintain consistency, which may affect the water-cement ratio. To counteract this issue, superplasticizers or water-reducing agents can be incorporated into ESP-modified concrete to improve fluidity without compromising strength.

Fig 2: Slump test for workability



Slump Value: 70 mm

#### D. DENSITY

Concrete density is influenced by the partial replacement of cement with ESP. The trend indicates a decrease in density with rising ESP content. This is due to the lower specific gravity of ESP than that of cement. While lower density can be found to be advantageous in the applications of lightweight concrete, excessive replacement could compromise structural integrity. The 10% ESP mix maintains an acceptable density while reducing overall material weight.

## LITERATURE SURVEY

Workability is a critical property of concrete, reflecting its ease of mixing, placing, and compacting without segregation. Various studies have explored the factors influencing workability with modifications to traditional cementitious materials. Balouch et al. (2017) investigated the impact of incorporating alternative materials into cementitious composites, observing a 5% variation, which led to a reduction in workability. Their research highlights the sensitivity of concrete to minor compositional changes. Similarly, Jhatial

et al. (2019) analyzed the workability of modified concrete and reported a 15% variation, noting a significant decrease in workability, reinforcing the findings of earlier studies regarding the negative effects of material substitution. In contrast, Hordofa (2019) provided a divergent perspective, demonstrating that a 15% variation in material composition could lead to an increase in workability, suggesting that specific additives or changes might enhance flowability under certain conditions. Expanding on these findings, Ishak and Zamani (2020) explored the effects of varying material proportions, with a range of 30–70% variation. Their results indicated a consistent decrease in workability, underlining the importance of maintaining an optimal balance of components in concrete mixtures. Finally, Langah et al. (2020) examined the effects of a 25% variation in material properties on workability. Their study corroborates the findings of Ishak and Zamani, emphasizing the detrimental effects of significant compositional changes.

Compressive strength is crucial for evaluating concrete performance. Studies have examined the effects of material variations. Gowsika (2014) noted a 5% difference in material properties, which led to a reduction in compressive strength. This points out the possible problems involved with slight changes in standard concrete mixes. Contrastingly, Dhanalakshmi (2015) reported a 7.5% increase in compressive strength. This improvement demonstrates the potential for specific substitutions to enhance the mechanical performance of concrete. Further, Tan Yeong Yu et al. (2017) investigated the impact of a 15% variation on compressive strength. Their findings indicated a significant increase, underlining the importance of selecting optimal material proportions to improve concrete properties. Parthasarathi et al. (2017) observed a 15% increase in compressive strength, reinforcing the observations of Tan Yeong Yu et al. However, Amarnath Yeramala (2018) found a dual effect based on the percentage variation. Their study revealed that compressive strength increased up to 10% variation but decreased beyond this threshold. Jhatial et al. (2019) noted a 10% variation that resulted in an increase in compressive strength. This aligns with prior findings that modest material changes can improve the mechanical properties of concrete. In contrast, Ishak and Zamani (2020) reported a significant reduction in compressive strength with variations ranging from 7 days

(41.4%) to 48.18% over extended periods. This emphasizes the importance of maintaining stability in the composition for long-term performance.

The tensile strength of materials has been extensively studied by various researchers. Amarnath Yerramala (2014) reported that the tensile strength of materials increases by 5-15%. Similarly, Vijayarentakesh (2018) found that the tensile strength increases by 20% and 30% after 28 days. Okito et al. (2020) observed that the tensile strength increases by 5-10% but decreases when the variation exceeds 10%. On the other hand, Ishak and Zamani (2020) noted a decrease in tensile strength ranging from 12.7% to 38.1% after 7 days and 13% to 30% after 28 days.

The density of materials has also been a subject of research. Amarnath Yerramala (2014) found that the density decreases by 15%. Conversely, Lau Yih Bling (2019) reported an increase in density by 5%.

## CONCLUSION

The findings of this study confirm that eggshell powder can be effectively used as a partial replacement for cement in concrete, with a 10% replacement yielding the highest compressive strength. Beyond this percentage, a decline in strength is observed, suggesting that careful optimization is necessary. The results also demonstrate improvements in sulphate resistance and workability, highlighting the potential benefits of integrating ESP into sustainable construction practices. By repurposing eggshell waste, this approach not only reduces the environmental impact of cement production but also offers an economically viable alternative. However, further research is needed to explore its long-term durability and large-scale applications. The successful implementation of ESP in the construction industry can significantly contribute to reducing industrial waste and promoting more sustainable infrastructure development.

## REFERENCES

1. Pliya, D., & Cree, D. (2015). Limestone-derived eggshell powder as a replacement in

- Portland cement mortar. *Construction and Building Materials*, 95, 1-9.
2. Meenakshi Dixit, A., Meena, A., Malik, C., & Sundesha, K. (2016). Effect of Using Eggshell Powder and Micro Silica Partially in Place of Cement in M25 Concrete. *SSRG International Journal of Civil Engineering*.
3. Praveen Kumar R., Vijaya Sarathy R., & Jose Ravindraraj B. (2017). Experimental Study on Partial Replacement of Cement with Eggshell Powder. *International Journal of Innovations in Engineering and Technology*.
4. Jhatial, A. A., Sohu, S., & Memon, M. J. (2019). Effect of eggshell powder on concrete properties. *International Journal of Advanced and Applied Sciences*.
5. Yerramala, A. (2018). Compressive and tensile strength analysis of eggshell powder concrete. *Indian Concrete Journal*.
6. Oliko, O. et al. (2020). Performance of Eggshell Powder in Concrete. *Engineering, Technology & Applied Science Research (ETASR)*.
7. Balouch, N., Rashid, K., & Javed, S. (2017). Workability of eggshell powder concrete. *Technical Journal, UET Taxila, Pakistan*.
8. Amarnath Yerramala (2014). The Indian Concrete Journal, Study on Eggshell Powder as Cement Replacement.
9. Hordofa, T. (2019). Addis Abeba Science and Technology University Research on Eggshell Powder in Concrete Applications.