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Experimental Analysis using Egg Shells Powder for making Improvement of Pervious Concrete

Mr. Akshay Dinesh Kadlak [1] Mr. Meghnandan Dattatray Nale [2] Mr. Umesh Ramrao Gatkal [3] Mr. Nagesh Bandu Shinde [4] Prof. Rachana Vaidya [5]
Student, B.E, Dept. of Civil Engineering, Alard College of Engineering and Management, Pune.[1] Professor, Dept. of Civil Engineering, Alard College Of Engineering And Management, Pune.[2]

Abstract - The increasing emphasis on sustainable and environmentally friendly construction materials has encouraged the use of industrial and domestic waste as alternative binders in concrete. This study is focus on the structural behavior of pervious concrete with partial replacement of cement by Egg Shell Powder (ESP). Eggshell powder, is a calcium-rich waste material, offers significant potential as a supplementary cementitious material, thereby reducing environmental waste and the carbon footprint of cement production. In this experimental program, cement will be replaced by ESP at varying proportions of 0%,5%, 10%, 12.5%, 15%, 20%, and 25%. Each mix will be tested to evaluate compressive strength, split tensile strength, flexural strength, and void ratio at different curing days. The investigation will help identify the optimum replacement percentage of ESP that provides a balance between strength and permeability suitable for pervious concrete applications. The expected outcomes will demonstrate that incorporating ESP in pervious concrete can enhance sustainability by utilizing waste materials efficiently, reducing cement consumption, and contributing to eco-friendly construction practices.

Keyword: Egg Shell Powder (ESP), Pervious Concrete, Cement, Sustainable Construction, Compressive Strength, Waste Utilization,

1. INTRODUCTION

In the world, concrete is widely used for the structure of the greatest of the buildings, bridges, etc. Presently, the complete construction industry is in exploration of an appropriate and operative the wasted product that would greatly minimized the use of cement and eventually decrease the manufacturing cost. [1] Therefore, proper alternate is required to manage the wastes in. The goal of this investigation work is to use the egg shell powder as a limited additional of cement. Egg shell powder is replaced by 5%, 10%, 15% and 20% of the weight of cement. An experimental research demonstrates the strength features, such as split tensile strength, compressive strength, and flexural strength, of eggshell-based concrete was investigated. It is found that the strength of the concrete rises with the addition of eggshell powder in concrete.

1.1. Egg Shell Powder

- The eggshell is composed of many mutually developing layers of $CaCO_3$; the innermost layer-maxillary 3 layer grows on the outermost egg membrane and forms the base upon which the palisade layer forms the shell's thickest portion. [14]
- The upper layer is a vertical layer covered by a cuticle made of organic material. Eggshell is primarily composed of calcium, magnesium carbonate (lime), and proteins. In many other nations, it is common practice to dry eggshells and incorporate them into animal feed as a source of calcium.

2. METHODOLOGY

Preliminary investigations such as concrete structures, coarse aggregate, and fine-grained collection, as well as the process of various inspection processes in accordance with IS codes for the detection of these structures and the mixing parameters obtained from compounding, were discussed in this regard.
The experimental work was carried out in a systematic sequence to evaluate the performance of pervious concrete using waste material.

1. **Waste Material Identification:**
   A suitable waste material was identified based on its availability, composition, and potential use in concrete to enhance sustainability.
2. **Waste Material Collection:**
   The selected waste material was collected from local sources, cleaned, dried, and stored properly to ensure uniform quality.
3. **Testing on Material Used:**
   All raw materials, including cement, aggregates, and water, were tested as per IS standards to confirm their suitability for concrete production.
4. **Mix Design:**
   The pervious concrete mix was designed to achieve the desired strength and permeability by optimizing the water-cement ratio and aggregate proportion.
5. **Specimen Preparation:**
   Concrete specimens such as cubes and cylinders were prepared using the designed mix, placed in moulds, and lightly compacted to retain porosity.
6. **Curing:**
   Specimens were water-cured for 7, 14, and 28 days to ensure proper hydration and strength development.
7. **Testing of Specimen:**
   After curing, specimens were tested for compressive strength, permeability, and density to evaluate performance.

2.1. Experimental Investigation

Investigations such as pervious concrete structures, coarse aggregate and Cement collection, as well as the process of various inspection processes in accordance with IS codes for the detection of these structures and mixing parameters acquired from mixing, are included.

2.2 Preparation of ESP

The concretes were mixed in a 100-litre capacity planetary mixer. The mixing duration was kept between three and four minutes. The ingredients were combined in the following order: I coarse aggregate was placed in the mixing drum first; (ii) a portion of the water required for concrete mixes was poured into the mixing drum; (iii) cement and ESP were carefully placed in the drum; and (iv) sand was

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pulverized and mixed. During mixing, the remaining anticipated quantity of water was added to the mixer's drum in order to properly combine the materials. After preparation, the samples were left for 24 hours. After 24 hours, the samples were disassembled and placed in normal water for curing till the test age.

Fig.2 Egg Shell Powder

3. TEST AND RESULT

3.1 Compressive strength of concrete

ESP Replacement (%)	M20-Compressive Strength (MPa)	M25-Compressive Strength (MPa)	M30-Compressive Strength (MPa)
ESP 0% (Conv.)	25	31	35
ESP 5%	27	33	37
ESP 10%	31	36	40
ESP 12.5%	31.9	37.4	42
ESP 15%	30	35	39
ESP 20%	24	29	33
ESP 25%	21	27	31

The sample's heaviest load is noted, and the compressive strength of the template is calculated as follows.

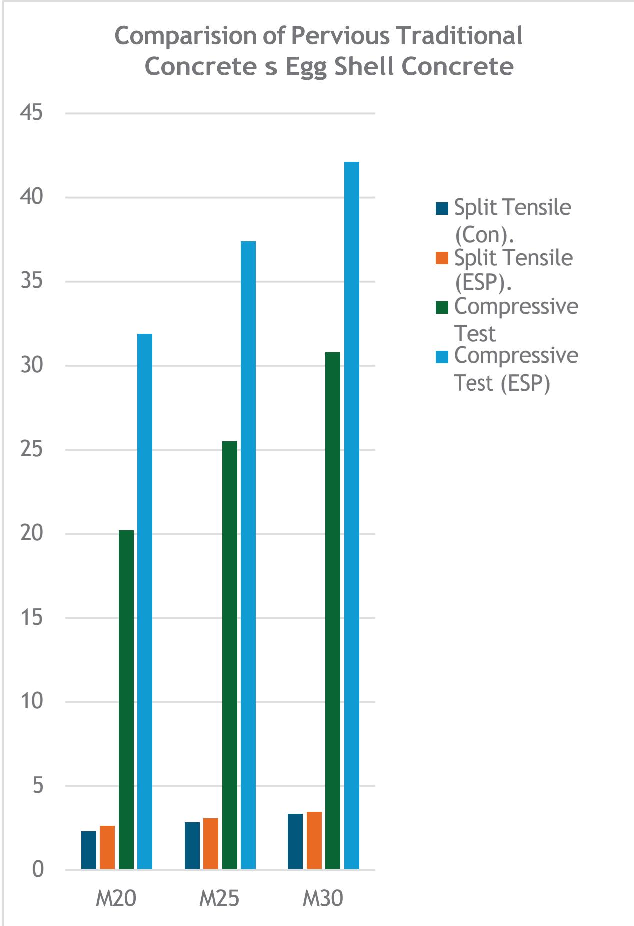
$$Fck = P/A$$

Where, Fig 3 Compressive strength of concrete

P = Maximum load applied on the specimen
A = area of cross-section of the specimen on which the load is applied.
The results show uniform compressive strength values among the three specimens for each mix, indicating good consistency in casting and testing. The compressive strength increases with ESP replacement up to 12.5%. The highest average 7-day strength of 18.33 MPa is observed at 12.5% ESP replacement, followed closely by 10%. Beyond this level, strength decreases gradually due to a reduction in cementitious content and increased porosity of the pervious concrete matrix.

Concrete Grade	Split tensile Strength-(Traditional)	Split tensile Strength- (Egg Shell)	Compressive Strength – (Traditional)	Compressive Strength – (Traditional)

M 20	2.30	2.62	20.20	31.90
M 25	2.85	3.07	25.50	37.40
M 30	3.35	3.45	30.80	42.13



4. APPLICATION

The incorporation of eggshell powder (ESP) into pervious concrete not only reduces the dependency on cement but also promotes eco-friendly construction practices. Its calcium-rich composition contributes to the strength and durability of the concrete. Specific applications where ESP-modified pervious concrete can be effectively used include:

a. **Eco-Friendly Pavements:**

Pervious concrete with eggshell powder can be applied in **pedestrian pavements**, **cycle tracks**, and **low-load driveways** where permeability and moderate strength are essential. The presence of ESP enhances microstructural bonding, improving the overall performance under compressive and flexural loads.

b. **Stormwater Management Structures:**

Structures like **rainwater harvesting beds**, **infiltration trenches**, and **pervious base layers** can utilize ESP-based pervious concrete to filter and recharge groundwater effectively while reducing cement carbon footprint.

c. **Rural and Low-Cost Housing Applications:**

In rural construction, ESP-blended pervious concrete can be used for **courtyards**, **walkways**, and **drainage pavements**, offering a sustainable and economical alternative to conventional materials.

d. **Lightweight Structural Elements:**

Due to its lower density and moderate strength, ESP pervious concrete can be used in **non-load-bearing walls**, **partition panels**,

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and **architectural blocks**, reducing the overall dead load of the structure.

e. **Environmental Restoration Projects:**

Used in **bioswales**, **rain gardens**, and **eco-parks**, this material can assist in controlling soil erosion and maintaining water balance in ecologically sensitive zones.

5. FUTURE SCOPE

The utilization of eggshell powder (ESP) has shown promising results in various industries, especially in construction and environmental applications. However, there is still significant scope for further research and development to enhance its efficiency, applicability, and large-scale implementation.

Future studies can focus on the use of ESP in combination with other supplementary cementitious materials such as fly ash, silica fume, and ground granulated blast furnace slag (GGBS). This can help in developing high-performance and durable concrete with improved mechanical and durability properties. Long-term studies on strength, shrinkage, permeability, and durability of ESP-based concrete are required.

6. CONCLUSION

The partial replacement of cement with eggshell powder (ESP) significantly influences the density and compressive strength of pervious concrete. As the percentage of ESP increases, the density of concrete gradually decreases due to the lower specific gravity of ESP compared to conventional cement. The compressive strength results indicate that ESP contributes positively to strength development up to an optimum replacement level. For M20 grade concrete, the maximum 7-day average compressive strength of 18.33 MPa was achieved at 12.5% ESP replacement, which is higher than the control mix strength of 14.00 MPa. Strength improvement up to 10–12.5% replacement may be attributed to the filler effect and the presence of calcium compounds in ESP, which enhance particle packing and improve the bonding within the cement matrix. Beyond 15% replacement, compressive strength decreases noticeably. At 20% and 25% ESP replacement, the reduction in cementitious material and increased porosity result in lower strength and lighter concrete. The results demonstrate that 12.5% ESP replacement can be considered the optimum percentage for improving early-age compressive strength while maintaining acceptable density in pervious concrete.

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