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Research Article

Analyzing the influence of eggshell powder (ESP) as partial replacement with cement in concrete

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ABSTRACT

Urbanization and growth in infrastructure development have increased the demand for different construction materials. Cement is a significant material of construction and the backbone of infrastructure development. However, cement manufacturing plants are the source of a few harmful compounds like carbon dioxide (CO_2) and are one of the largest contributors to environmental emissions. Eggshell (ES) is a bio-waste material commonly generated from residential areas and restaurants. Typically, this waste is discarded in landfills, posing health risks and contributing to environmental pollution. However, eggshell waste contains valuable organic and inorganic materials that can be composted with other substances to improve their properties. The rising demand has driven the search for alternative raw materials derived from abundant waste products that are both efficient and cost-effective. To mitigate the impact of harmful compounds and protect the environment, eggshell powder is used as a partial replacement for cement. This study examines the effects on concrete properties when cement is replaced with 5%, 7.5%, and 10% eggshell powder. The properties were experimentally assessed based on compressive strength and split tensile strength. These strengths were measured at 7, 14, and 28 days and compared with conventional concrete. The results indicate that 7.5% eggshell powder is the optimal percentage for partial cement replacement. Additionally, the findings of water absorption depicted the decrement at 5% and 7.5% eggshell powder (ESP) replacement but increment at 10% of ESP after 72 hours. In conclusion, eggshell powder could be utilised in future construction materials to reduce carbon dioxide emissions and promote sustainability.

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INTRODUCTION

Concrete is a construction material made from a mixture of sand, cement, coarse aggregates, and water, which hardens over time. Cement is currently the most extensively utilized material in the construction industry. Global cement production has reached 4 billion tonnes, with about half of this quantity used to produce concrete for diverse construction purposes [1]. Global cement production has reached 4 billion tonnes, with nearly half of it being used to make concrete for a wide range of construction purposes. Cement is a fine powder created from a blend of elements such as limestone, shale, and clay. When mixed with water, sand, and gravel, it forms a hard-solid mass known as concrete. However, the environmental impact of concrete is a growing

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global concern, as the cement industry is one of the largest contributors to greenhouse gas emissions [2].

Around 7% of global CO_2 emissions come from the cement industry, with 900 kg of CO_2 released into the atmosphere for every ton of cement produced. Besides being a major source of greenhouse gases, the cement industry significantly contributes to air pollution by emitting particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx), and volatile organic compounds (VOCs) [3]. Dust particles from the cement industry generally range in diameter from 1 to 100 µm. These pollutants can combine to form smog, posing significant risks to the environment and human health [4]. A significant amount of thermal and electrical energy is consumed during cement manufacturing, accounting for 40% of the operational costs [5]. Energy is a crucial factor in a country's growth and development. In India, the current scarcity of non-renewable energy resources combined with the high demand for construction materials makes it essential to explore and adopt alternative methods for cement manufacturing. In 2004, ASTM International C150 allowed the inclusion of up to 5% limestone by mass in Ordinary Portland Cement [6]. One study has recommended incorporating up to 5% limestone, noting that it does not compromise the performance of Portland cement [7]. Additionally, it has been reported that a higher percentage of limestone can be utilized in concrete with lower water-cement ratios. Replacing cement with limestone powder is beneficial, as it saves money and energy and lowers carbon dioxide emissions [8, 9].

However, limestone is a natural mineral resource, and its prolonged quarrying can result in environmental and sustainability challenges. Furthermore, lime production is energy-intensive and consumes significant amounts of water. Therefore, identifying waste materials with similar properties for use in concrete production is a prudent alternative. Eggshells, a poultry waste product, are rich in calcium and have a chemical composition nearly identical to limestone. In 2018, 8.58 million metric tons of eggshell waste were produced globally [10]. India ranks 3rd in egg production globally contributing 7% to global egg production [11], and producing 129.6 billion eggs in the year 2021 [12]. An eggshell contains an average of 2.2 grams of calcium in the form of $CaCO_3$, with approximately 95% of the dry shell composed of $CaCO_3$ and 0.3% each of magnesium and phosphorus. Uronic acid has been studied and compared with the chemical composition of chicken eggshells and has been studied [13]. Scanning electron microscopy (SEM) technique has been utilized and depicted the thickness of the eggshell as less than 50 % before hatching [14].

Several studies have utilized eggshell waste as cement replacement. Amu et al. [15] utilized eggshell powder along with lime to stabilize expansive clayey soil. Othman et al. [16] studied the effect of varying percentages of cement replacement by eggshell and tyre powder. The replacement for both constituents varied between 0%, 5%, 10% and 15%. Tiong et al. [17] studied the effects of partial cement replacement by ESP in lightweight foamed concrete. The replacement percentage was varied between 0%, 2.5%, 5%, 7.5% and 10%. One of the study had done investigation on the effect of partial replacement of cement by nano ESP (NESP) and nano palm oil fuel ash (NPOFA). The replacement percentage of NPOFA was varied between 0%, 10%, 20% and 30% and the replacement percentage of NESP was varied between 0%, 2.5% and 5% [18].

Pillai and Mathew [19], replaced cement with varying percentages of ESP and fine aggregate with varying percentages of granite powder. The eggshells were ground to obtain ESP with 75 µm sized particles and the granite powder passing through 4.75 mm was used. A study has depicted the effect of cement replacement by ESP on water absorption of lightweight foamed concrete [20]. It was observed that at the age of 90 days, all of the ESP concrete mixes had lower water absorption than the control mix, with 7.5% ESP concrete mix having the lowest water absorption. Another study focused on the use of waste materials such as eggshell powder (ESP), ceramic waste powder (CWP), rice husk ash (RHA), and corn cob ash (CCA) as cement substitutes.

This study focuses on using Egg Shell Powder (ESP) in concrete. Given that eggshells are calcium-rich and chemically similar to limestone, they represent a valuable waste material for partial cement replacement. To explore the potential of eggshell waste in concrete, it's essential to understand how ESP affects concrete properties. The primary focus of this research is to evaluate the utilization of ESP in concrete. Systematic evaluations are conducted on the performance of ESP-enriched concrete, focusing on strength properties such as splitting tensile and compressive strength, as well as transport properties like water absorption. Besides, the findings discuss the impact of Eggshell powder replacement and curing age on concrete properties.

Furthermore, the research primarily focuses on replacing cement with eggshell powder up to a specified limit and assessing its impact on fresh and hardened concrete properties. The properties under consideration include density, compressive strength, workability, split tensile strength, and water absorption. However, the main objectives include evaluating the density of concrete containing eggshell powder and determining its workability through slump tests. Additionally, the assessment of water absorption with varying levels of ESP replacement. Measuring the compressive strength of the concrete and evaluating the split tensile strength for different amounts of ESP will be performed.

MATERIALS AND METHODS

Materials

Cement is a binder that sets, hardens, and adheres to other materials, effectively binding them together. When mixed with fine aggregates, it forms mortar for masonry work; when combined with sand (fine aggregate) and gravel (coarse aggregate), it produces concrete. According to IS-4031 (Part 1)-1996, the standard fineness of cement should be less than 10% [21]. The specific gravity of cement is 3.5 (IS-4031 (Part-1), 1988), which is considered standard and suitable for construction purposes [22].

Coarse aggregates (IS:383-1970) are irregular and granular materials such as gravel or crushed stone, commonly used in concrete production [23]. Typically, coarse aggregates are naturally occurring and can be obtained through quarry blasting or manual crushing. These materials are large enough to be retained on a 4.75 mm sieve and can reach a maximum size of 63mm. The size of the coarse aggregate influences the cement-to-water ratio. As per IS: 2386 (Part-III, 1963), the specific gravity of coarse aggregate ranges from 2.5 to 3, while its water absorption varies between 0.1% and 2% [24]. The aggregates less than 4.75 mm but greater than 200 microns in size are called fine aggregates with a specific gravity ranging between 2.65 to 2.67 [24].

Eggshells, a bio-waste material, can support environmental friendly and cost-effective construction. Their high calcium content and overall chemical composition are similar to limestone. Notably, calcium carbonate ($CaCO_3$) is one of the four main raw materials used to produce cement, along with dicalcium silicates (C_2S), tricalcium silicate (C_3S), tricalcium aluminate (C_3A), and tetra-calcium alumino-ferrite (C_4AF). This similarity suggests that eggshells could serve as a partial replacement for cement in concrete. In addition to $CaCO_3$, which makes up over 60% of the eggshell, there are other trace elements present, including boron, copper, iron, manganese, molybdenum, sulfur, magnesium, silicon, and zinc. Table 1 shows the detailed chemical composition of eggshells based on various studies.

The physical properties of eggshells vary depending on their source. The specific gravity of eggshell powder (ESP) is lower than that of cement, which ranges from 3.15 to 3.18 [27, 28]. The values significantly vary depending on the source, preparation method and fineness degree. The specific gravity ranges between 0.85 and 2.66 [29,30]. The bulk density results range between 700 and 2088 kg/m^3 [31, 32], whilst those of cement range between 1000 and 1300 kg/m^3.

Raw eggshells undergo a specific process before they can be used as a cement replacement. First, the eggshells were cleaned with water to remove impurities and the thin membrane. After cleaning, the eggshells were air-dried by leaving them in the sun for one to five days. Further, the dried egg shells were manually crushed and ground into powder with a mortar and pestle. Finally, the eggshell powder was sieved to a micron size and was then ready to be mixed with cement.

Different studies have used various sieve sizes, and in this study, a 90 µm sieve was utilized [33, 34, 35, 36]. Different studies have performed analysis by taking a 75 µm size [37, 38, 39,40], and a bigger size of 2.36 mm [41] has also been attempted with similar results. Additionally, the quality of water used in construction has a direct impact on the strength of cement concrete. It must be free from alkalis, acids, oils, organic materials, and other substances that could harm the concrete. Potable water having pH 6-8 has been considered for concrete mixing.

Methods

The mix proportioning for M20 grade concrete used in this work was designed according to IS 10262-2019 standards [42]. The water-cement ratio for the work was consistently maintained at 0.43 for all the concrete mixes, with the water content set at 191.58 kg/m^3. The density of the concrete was 2495.42 kg/m^3, with a cement content of 445.53 kg/m^3. The mass of fine aggregates (FA) and coarse aggregates (CA) was 661.96 kg/m^3 and 1196.35 kg/m^3, respectively. Table 2 depicts the concrete design mix for different mixes.

Additionally, the proper batching was performed for the materials, including cement, aggregates, and water, with their quantities or proportions measured by volume for the preparation of the concrete mix. After materials were batched, they were introduced into a concrete mixer to produce a uniform and homogeneous concrete mix. The goal of concrete mixing was to achieve a homogeneous and uniform concrete mass in terms of color and consistency. The concrete was mixed for approximately 3 to 4 minutes by adding materials in a specific sequence:

i.Firstly, the coarse aggregate (CA) was placed into the mixer drum.

ii.Secondly, a portion of water needed for concrete mixes was poured into the mixing drum.

iii.Cement and eggshell powder were gently added to the drum, and then spreading the sand over the powder and beginning the mixing process. During this process, the remaining water specified in the mix design was gradually added to the mixer drum to ensure thorough blending of the constituents. Specimens were then prepared and left to set for 24 hours before being de-moulded.

Table 1. Chemical composition of eggshell powder [25, 26]

Composition (% by mass)	OPC*	Eggshell Powder		
Calcium Oxide (CaO)	60.1	52.15	47.49	52.10
Magnesium Oxide (MgO)	2.1	0.60	-	0.06
Silica Dioxide (SiO_2)	21.8	1.22	-	0.58
Alumina (Al_2O_3)	6.6	0.28	0.11	0.06
Ferric Oxide (Fe_2O_3)	4.1	0.16	-	0.02
Chloride (Cl)	-	0.011	-	-
Sulphur Trioxide (SO_3)	2.2	-	0.38	0.62
Potassium Oxide (K_2O)	0.4	-	-	0.25
Sodium Oxide (Na_2O)	0.4	-	0.14	0.15
Loss on ignition (LOI)	2.4	-	-	45.42

***OPC:** Ordinary Portland Cement

Table 2. Concrete mix design of different mixes.

Concrete Mix	Cement Kg/m³	ESP Kg/m³	CA Kg/m³	FA Kg/m³	Water/Cement Ratio
M1	445.53	0	1196.35	661.96	0.43
M2	429.53	16	1196.35	661.96	0.43
M3	421.53	24	1196.35	661.96	0.43
M4	413.53	32	1196.35	661.96	0.43

Preparation of Sample for Compressive Strength Test

For the testing, different equipment for making the concrete cubes included a sample tray, a trowel, a compacting bar, a sample, moulds of 150 mm size, a curing tank, a bucket for transporting samples, a spanner scoop, and rags. Initially, the concrete sample for the test was taken from the mixer. However, an additional sample was collected from the mixer during placing. This sample was mixed on a non-absorbent base with a shovel until it achieved a uniform appearance. In addition to randomly sampling from the mixture in a ghamela during concreting, the concrete was poured into the cube mould in three layers. Each layer was compacted with 35 strokes and tamped with a rod. After compacting the final layer, finishing was done on the top surface with a trowel. After 24 hours, the samples were removed from the mould, avoiding any damage to the edges. The specimens were submerged in clean fresh water until testing. In addition, the testing on three specimens was performed after 7 days of curing and another three after 28 days of curing.

Preparation of Specimen for Split Tensile Strength Test

Concrete was poured into moulds coated with a layer of oil, in layers approximately 5 cm thick. Each layer was compacted using a tamping bar with 30 strokes to ensure uniform distribution, with each stroke penetrating the underlying layer and thoroughly rodding the bottom layer. After compacting the top layer, the surface was levelled with a trowel, and covered with a metal plate to prevent water evaporation. The test samples were stored at a temperature of 27±2 °C for 24 hours before being removed from the moulds and submerged in clean water for curing, which lasted between 7 to 28 days [43, 44].

Density and Workability

The density was determined using a container with a known volume of at least 0.20 cubic feet. First, the weight of the empty container was measured and recorded to the nearest tenth of a pound. After filling the container according to the specified procedures (filling it in three lifts, applying mallet blows, rodding, and striking off with a strike-off plate), the subsequent steps were carried out. There are a few unique procedures listed in the ASTM C-138 to remember. Further, the workability of the concrete mix was assessed using a concrete slump test. Typically, the slump value is used to determine workability, which reflects the water-to-cement ratio.

A concrete mix (M15) with an appropriate water/cement ratio was prepared in the laboratory to cast six cubes after performing a slump test. The internal surface of the mould was cleaned and oiled before placing it on a smooth, horizontal, non-porous base plate. The mould was then filled with the prepared concrete mix in four equal layers, tamping each layer with 25 strokes as shown in Figure 1. Excess concrete was removed, and the surface was levelled with a trowel. The mould was then removed from the concrete immediately and slowly in a vertical direction. The slump was measured as the difference between the height of the mould and the height of the concrete sample being tested. This procedure was carried out in an area free from vibrations or shock and within 2 minutes after sampling. The shapes of the concrete slumps observed during the test are depicted in Figure 2.

Figure 1. Concrete slump test procedure

Figure 2. Measuring slump of concrete

Compressive Strength

According to IS:516-1959, the compressive strength test of concrete cubes provides a comprehensive assessment of concrete characteristics [45]. Various standard codes recommend using either concrete cylinders or cubes as standard test samples. In this study, 15 cm × 15 cm × 15 cm cubical moulds were used, following the American Society for Testing and Materials (ASTM C39/C39M) guidelines, as shown in Figure 3. The concrete was poured into the moulds and tamped to eliminate any voids. After 24 hours, the moulds were removed, and the samples were placed in water for curing, as depicted in Figure 4. The samples were then tested on a compression testing machine at 7 and 28 days of curing, with a gradually applied load of 140 kg/cm² per minute until the samples failed.

Figure 3. Moulds used for concrete cube

Figure 4.De-moulded concrete cubes after 24 hours

Split Tensile Strength

According to IS:5816-1999, tensile strength is a crucial property of concrete because structural loads can lead to tensile cracking [46]. Literature indicates that the tensile strength of concrete is approximately 10% of its compressive strength. The testing was conducted using a compression testing machine, along with two plywood packing strips (each 30 cm long and 12 mm wide), moulds, a steel tamping bar (16 mm in diameter and 60 cm long), a trowel, and a metal plate. After curing, the surface water was removed from the samples, and their dimensions were measured. A plywood strip was placed on the lower plate, and the sample was positioned on top, aligned vertically and centered. The second plywood strip was then placed over the sample, and the upper plate was lowered to make contact with the plywood strip.

Water Absorption

In this testing process, the ASTM (C642-82) standards were adhered to for the cubes [47]. Saturated surface-dry samples were placed in a hot air oven at 105 °C until they reached a constant weight, then allowed to cool to room temperature. The samples were subsequently fully immersed in water, and their weight gain was measured until a constant weight was achieved. The initial surface absorption was recorded after 30 minutes, and the final absorption was noted at 72 hours to assess the quality of the concrete.

RESULTS AND DISCUSSIONS

Table 3 depicts the descriptive statistics analysis of various properties such as density, workability, compressive strength, split tensile strength, and water absorption.

Density

The specific gravity of eggshells is lower than that of cement, resulting in concrete with eggshells having a lower density than normal concrete without eggshells. Table 4 depicts that increasing the percentage of eggshell powder (ESP) in the concrete leads to a decrease in concrete density due to the low specific gravity of ESP. Concrete with a 5% ESP replacement exhibited a significant density, measured at 2350 kg/m^3. In addition, ESP replacement at 7.5% and 10% depicts the lowest values of 2339 kg/m^3 and 2327 kg/m^3, respectively. As we know, the specific gravity of cement is higher than that of ESP, leading to a reduction in concrete density when the proportion of ESP is increased. However, it has also been observed that the dry density of concrete increases as the ESP content rises [48]. A similar study has demonstrated results with a growing percentage above 5 % of eggshell powder [49, 50].

Table 3. Descriptive statistics of different properties of concrete

Descriptive Statistics				
Properties	**N**	**Mean**	**Std. Deviation**	**Variance**
Density	4	2346.50	18.267	333.667
Workability	4	64.50	12.871	165.667
CS* (7 days)	4	20.4375	1.01985	1.040
CS (14 days)	4	24.3300	0.71977	0.518
CS (28 days)	4	27.8950	1.16248	1.351
STS* (7 days)	4	2.2675	0.40672	0.165
STS (14 days)	4	2.6100	0.24235	0.059
STS (28 days)	4	2.8725	0.16780	0.028
WA* (30 hrs)	4	1.2275	0.20646	0.043
WA (48hrs)	4	3.0225	0.70225	0.493
WA (72 hrs)	4	3.3850	0.70995	0.504

Table 2. Concrete mix design of different mixes

Concrete Name	Percentage of ESP (%)	Density (kg/m³)
M1	0	2370
M2	5	2350
M3	7.5	2339
M4	10	2327

CS*: Compressive Strength; STS*: Split Tensile Strength: WA*: Water Absorption

Workability

The workability of eggshell powder concrete is lower than that of conventional cement concrete. Additionally, as the percentage of cement relative to eggshell powder increases, the maneuverability of ESP concrete further decreases. This workability impact is observed in mortar and concrete mixes containing ESP [51]. Figure 5 shows the workability results of fresh concrete using the slump cone method. Each mix ratio and ESP proportion were tested three times, and the average slump loss was recorded for each ESP percentage. For the 1:1.48:2.68 mix ratio with a water-cement (W/C) ratio of 0.43, the initial slump was 81 mm (Figure 5). Replacing 5% of the cement with eggshell powder reduced the slump to 68 mm. With a 7.5% eggshell powder replacement, the slump was 57 mm, and with a 10% replacement, it was 52 mm. These findings suggest that ESP is suitable as a partial cement replacement in concrete due to its non-excessive water absorption property. Further, the replacement of ESP helps to reduce environmental impacts associated with CO_2 emissions and the destruction of ecosystems caused by the production of aggregates [52].

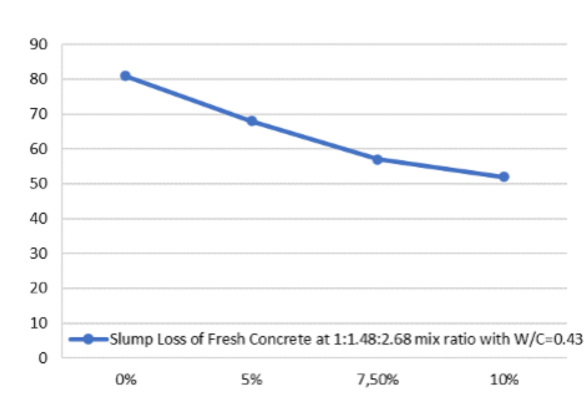

Figure 5. Slump loss of fresh concrete

Compressive Strength

After 7 days, the compressive strength of concrete varied with different percentages of ESP. Figure 6 exhibits normal concrete had a strength of 19.13 MPa with 5% eggshell powder, the strength increased to 20.19 MPa. At 7.5% eggshell powder, it rose to 21.48 MPa, while with 10% eggshell powder, it was 20.95 MPa. Besides, overall outcomes from 7 days of curing with different percentages of ESP exhibited a continuous enhancement in compressive strength up to 7.5% ESP, while, at 10% eggshell powder depicted a decrement.

After 14 days of curing, normal concrete had a compressive strength of 23.43 MPa. Furthermore, adding 5% eggshell powder increased the strength to 24.12 MPa, and with 7.5% eggshell powder, it rose to 25.09 MPa. The aforementioned findings indicated that compressive strength improves with the incorporation of ESP. However, when 10% eggshell powder was utilized, the strength was 24.68 MPa. Thus, while compressive strength increased with up to 7.5% eggshell powder, it decreased at 10% as depicted in Figure 6.

Further, after 28 days of curing, normal concrete achieved a compressive strength of 26.30 MPa. With 5% eggshell powder as a binder, the strength increased to 27.84 MPa. Adding 7.5% eggshell powder further raised the strength to 28.99 MPa. However, with 10% eggshell powder, the strength slightly decreased to 28.45 MPa. These results suggest that eggshell powder can effectively replace part of the cement in concrete production. Specifically, a 7.5% eggshell powder replacement resulted in the highest compressive strength, indicating that 7.5% is the optimal amount for achieving maximum strength, as depicted in Figure 6. In a similar study, a notable increase in compressive strength was observed when cement was replaced with 7% to 9% eggshell powder (ESP). However, in other ESP concrete mixtures, the lowest compressive strength occurred when 1% and 15% of the cement was replaced with ESP [53].

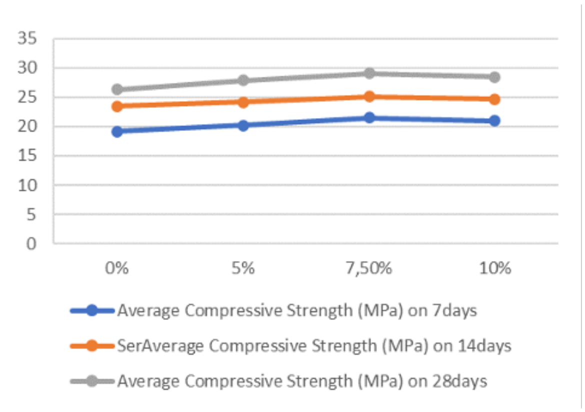

Figure 6. Compressive strength of eggshell concrete on 7, 14 & 28 days

Split Tensile Strength

Figure 7 presents the split tensile strength of eggshell concrete at 7, 14, and 28 days. After 7 days of curing, normal concrete had a split tensile strength of 1.8 MPa. With the addition of 5% eggshell powder, the average tensile strength increased to 2.10 MPa. Further additions of 7.5% and 10% eggshell powder raised the tensile strength to 2.74 MPa and 2.43 MPa, respectively. These results indicate that split tensile strength improved with up to 7.5% eggshell powder but decreased with 10% eggshell powder.

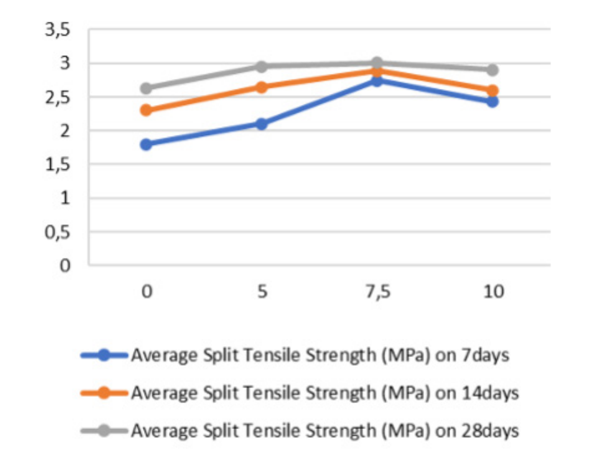

Figure 7. Average values of split tensile strength of Eggshell concrete at 7, 14 & 28 days

Water Absorption

Table 5 depicts the water absorption in concrete changes over time. At 30 minutes, water absorption decreases at 5% and 7.5% eggshell powder (ESP) replacement but increases at 10% of ESP after 72 hours. This pattern continues at 48 and 72 hours and specifically, M2 and M3 mixtures exhibited lower water absorption compared to the control concrete, while M4 concrete has higher absorption than the control concrete. Studies have depicted the test results in which sorptivity, specifically capillary water absorption, decreased with up to 5% replacement but increased at higher replacement ratios of 10%, 15%, and 20% compared to the control concrete [55, 56, 57, 58, 59].

Table 5. Water absorption of eggshell concrete

Concrete Name	Percentage of ESP (%)	Water Absorption (%)		
		30 min	48 hrs	72 hrs
M1	0	1.41	3.97	4.38
M2	5	1.08	2.81	2.99
M3	7.5	1.02	2.29	2.78
M4	10	1.40	3.02	3.39

CONCLUSION

The experiments concluded that Eggshell Powder (ESP) can be effectively used as a partial substitute for cement. ESP concrete demonstrated higher compressive strength compared to control concrete at 5% ESP replacement across 7, 14, and 28 days. However, when the ESP replacement exceeded 10%, the strength decreased compared to the control. Additionally, using ESP significantly reduced initial water absorption, improving the concrete's resistance to water penetration. The optimum replacement level was found to be 7.5%. Thus, ESP holds the potential for use in construction materials, contributing to sustainability by reducing CO_2 emissions. Since eggshells are primarily composed of calcium carbonate ($CaCO_3$), which is similar to limestone, a key ingredient in cement, ESP serves as a viable alternative.

This substitution not only reduces reliance on cement, but plays significant role in mitigating the environmental issue of eggshell disposal in landfills, which poses health risks. Overall, eggshell powder demonstrates significant potential as a sustainable cementitious additive in concrete production, offering an environmentally responsible alternative to conventional materials.

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DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

USE OF AI FOR WRITING ASSISTANCE

Not declared.

ETHICS

There are no ethical issues with the publication of this manuscript.

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