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Performance Evaluation of Raw and Calcined Eggshell as Alternative Fillers in Cement Mortar

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ABSTRACT

The construction industry significantly contributes to greenhouse gas emissions and natural resource depletion through cement manufacturing and extensive river sand extraction. Meanwhile, abundance amount of chicken eggshells waste was continuously disposed in landfill without any treatment. Incorporating eggshells as a fine filler in cement mortar provides a circular strategy that may enhance product performance while reduce environmental burdens which is in line with Sustainable Development Goals (SDG). This study examines the effect of chicken eggshells filler on the mechanical, durability and microstructural properties of conventional mortar. The mortar mixtures were prepared with 10, 20, and 30% volumetric replacement of fine aggregate by eggshells were tested for compressive strength, carbonation depth, sorptivity, and microstructure. The results showed that mortar containing 20% ground eggshell achieve highest performed in compressive strength, lower sorptivity and lower carbonation depth compared to conventional mortar. This results attributed by improved particle packing, and pore refinement. In contrast, mortars incorporating calcined eggshells exhibited lower compressive strength and poorer durability performance due to high calcium oxide content. The findings demonstrate that raw eggshell waste may utilized as an alternative filler to improve mortar performance while supporting the beneficial reuse of agricultural waste and reducing the demanding of natural resources. This approach provides a practical pathway towards more sustainable and resource efficient cement-based construction.

Keywords: Eggshell waste; sustainable construction; filler material; cement mortar; mechanical; durability

INTRODUCTION

The construction industry significantly contributes to global carbon dioxide emissions through multiple stages of the building process. Emissions arise from energy-intensive production of raw materials, transportation of materials to construction sites, on-site activities such as fuel combustion and equipment operation, extraction of natural resources and the demolition of existing structures. Approximately 90g of CO_2 is emitted during to manufacture of 1000g of cement by calcination process. Globally, building development contributes 33% of greenhouse gas emission (Li et al. 2025; Sizirici et al. 2021). This substantial impact highlights the urgent need for low-carbon strategies, such as using supplementary cementitious materials, adopting energy-efficient construction practices, optimizing material use, and promoting circular approaches like reuse and recycling of construction and demolition waste. These strategies are closely related to Sustainable Development Goals (SDG) that promote climate action, responsible consumption and sustainable cities.

Rapid development has contributed to continuous dependency of natural resources. United Nations Environment Programme (2014) and Bhoopathy & Subramanian (2022) reported that approximately 32 to 50

billion tons of natural river sand was extracted by year globally. Then, this demand is expected to keep growing to 80 billion in year 2060 if current trends continue (Rentier & Cammeraat 2022). Intensive river sand extraction is associated with a range of environmental problems. Numerous pollution issues might arise from extracting river sand such as land lost due to erosion, air pollution, soil contamination, deforestation and more. According to Bendixen et al. (2021), sand mining generates major conflicts with 17 UN SDG indicating that better management strategies and the use of alternative materials are urgently needed to reduce the environmental footprint. Therefore, reducing the dependency of natural aggregates through utilization of waste-derived materials has become an important strategy to support sustainable construction and circular resource management.

Eggshells are a type of agro-industrial waste that is commonly discarded without any treatment or recycling. The food processing industry, which extensively uses eggs as a key ingredient in numerous products, is one of the primary generators of this waste. This improper disposal practice not only represents a loss of potentially valuable resources but also contributes to environmental and solid waste management challenges. According to the Food and Agriculture Organization (FAO), global eggshell production increased dramatically by about 37.3% between 2000 and 2018, reflecting the steady growth in global egg consumption. China remains the leading producer, contributing approximately 38.2% of total egg production, followed by the United States with 7.8% and India with 6.3% (Sathiparan, 2021; FAO, 2020). The FAO further predicts that global egg production will continue to rise, reaching an estimated 90 million tonnes by 2030. In addition, it was reported that around 6.4 million tons of eggshell waste were disposed of in landfills in 2010 alone (Bhagavatheswaran et al. 2019; Bakar & Mohamad, 2022). Every year, several million tons of eggshell waste are produced worldwide, and most of it ends up in landfills (Li, et al. 2025; Ngayakamo & Onwualu 2022). This significant growth not only highlights the rising global demand for eggs but also emphasizes the urgent need to develop sustainable strategies for managing and reusing eggshell waste in various value-added applications. Instead of being disposed to landfills, eggshell waste can be valorized as a construction material, transforming an agriculture waste into a valuable resource while reducing environmental burdens in line with SDG related to climate action, responsible consumption and sustainable cities.

Significant number of studies have investigated proven that appropriate replacement waste-derived materials might improve the fresh and hardened properties of cement-based systems. At optimum dosages additions have been reported to enhance workability (Dawood & Jaber 2022; Nguyen et al. 2022), increase compressive strength (Arif et al. 2021) and carbonation resistance by refining the pore structure (Zhang et al. 2025). Therefore, this study investigated the influence of chicken eggshell waste as filler in mortar to evaluate its effects on the mechanical and durability-related properties of the material.

MATERIALS AND METHODS

In this study, the primary materials utilized were Ordinary Portland Cement, natural river sand, ground eggshell, and distilled water. These components were carefully selected due to their relevance in mortar production and their potential to contribute to sustainable construction practices.

Ordinary Portland cement (OPC) and river sand represent conventional materials, while ground and calcined eggshell was introduced as waste derived filler to mortar. Before use in the experimental procedures, various preparation techniques were employed to ensure the materials met the required specifications. These preparatory methods included drying, boiling, sieving, and calcination, which were essential for achieving uniformity, removing impurities, and enhancing the reactivity of the raw materials.

All experimental procedures were designed and executed in accordance with established international standards, primarily referencing methods from the American Society for Testing and Materials (ASTM) and British Standards (BS), as well as methodologies documented in relevant peer-reviewed journals.

BINDER

The OPC Type I produced by Negeri Sembilan Cement (NSC), was used as the main binder due to its wide availability and reliable performance in construction. This cement type meets the requirements of Malaysian Standard MS EN 197-1:2014 for general-purpose use, ensuring consistent quality for both structural and non-structural applications. Because cement easily absorbs moisture and can harden prematurely when exposed to humidity or water, it was stored carefully to maintain quality. The cement was kept in a sealed bin within a dry, enclosed area, covered with a waterproof tarp, and protected from rain and direct sunlight. These measures were taken to prevent deterioration and ensure consistent results throughout the study. OPC Type I was selected as the control binder to evaluate the effect of eggshell fillers under conventional mortar condition.

Natural river sand with particle sizes between 4.75 mm and 0.425 mm was used as the fine aggregate (BS EN

12620:2013). It was selected for its common use and good compatibility with standard mortar mix designs. The sand mainly comprises silica (over 95% SiO_2), mostly in the form of quartz, which is chemically stable and highly durable. Natural river sand was used as the conventional fine aggregate in all control mixtures.

NATURAL CALCITE

Eggshell waste was collected from local food vendors and processed within 12 hours to prevent decay and microbial growth collection The shells were boiled in water at 100 °C ± 5 °C for 60 minutes with a spoonful of salt to sterilize them and help remove membranes and residual egg material. After boiling, they were brushed clean, rinsed several times under running tap water, and then oven-dried at 105 °C ± 5 °C for about three hours to remove all moisture. The dried shells were ground with an electric grinder for about three minutes to obtain a fine powder, which was stored in a dark, airtight container to protect it from light, moisture, and air and to preserve its quality for further testing. Ground eggshell was used as an alternative filler due its high calcium carbonate ($CaCO_3$) content.

CALCINED EGGSHELLS

The calcination procedure was adapted from Razali et al. (2021) and Tangboriboon et al. (2012). Approximately 20 g of pulverized eggshell powder was placed in a ceramic crucible with a covered top to minimize contamination and material loss during heating. The muffle furnace was preheated and set to a temperature of 900 °C, after which the crucible was positioned at the center of the furnace chamber and maintained at this temperature for 3 hours. This duration and temperature were selected to ensure complete decomposition of $CaCO_3$ in the eggshells to calcium oxide, while promoting a uniform and controlled thermal treatment. Calcined eggshell was prepared to compare the performance with ground eggshell as an alternative filler in mortar.

GRADING PROFILE

The dry sieving method followed the guidelines established in BS EN 13139:2002 (Aggregates for Mortar), which provides a standardized approach for separating and analyzing aggregate particles based on their size distribution. The 300 grams of river sand and ground eggshell were subjected to oven drying at a controlled temperature of 100°C ± 5°C for 24 hours in a ventilated oven (Lu et al. 2022 and Jumadi et al. 2023). This step was essential to ensure complete removal of moisture content before sieving. The sieve analysis setup consisted of a column of standard sieves arranged in descending order by aperture size: 4.75 mm (No. 4), 3.35 mm (No. 6), 2.36 mm (No. 8), 1.18 mm (No. 16), 0.850 mm (No. 20), and 0.425 mm (No. 40), ending with a retaining pan to collect the finest particles. The sieve stack (LAKTAS) was mounted on a mechanical sieve shaker (also LAKTAS brand) and operated for 10 minutes. After shaking, the material retained on each sieve was carefully brushed out and weighed using an analytical weight balance, with a precision of ± 0.05 g.

The ground eggshell was finer, mostly between 1.18 mm and 0.425 mm, while calcined eggshell particles are in the micron or sub-micron range, far smaller than typical sieve apertures and therefore fully passing laboratory sieves into the pan (Hemmami et al. 2024).

MORTAR PREPARATION

The mortar samples were prepared using a binder-to-aggregate ratio of 1:3 by volume was adopted based on the standard mortar proportion specified in BS EN 196-1. In practice, the river sand was first weighed according to binder-to-aggregate ratio and then sieved through 1.18 mm and 0.425 mm sieves to isolate the portions designated for replacement. The removed fractions of river sand were then replaced with an equivalent volume of ground eggshell or calcined ground eggshell, depending on the mix type (see Table 1 below). By referring to ASTM C305 – 14, all dry ingredients were mixed in a Baker Mixer B-10ES (10L) for 30 seconds at 140 ± 5 r/min. Then, water was added in a separate bowl, and the dry mix was slowly introduced. The mixture was then mixed at 285 ± 10 r/min for 30 seconds, paused for 15 seconds to scrape the bowl, and mixed again for 60 seconds.

The mortar was cast in ABS plastic moulds (50 mm × 50 mm × 50 mm) in two equal layers. Each scoop was placed asymmetrically to ensure uniform distribution. Each layer was compacted with 25 strokes using a tamping bar, following BS EN 1015-11:2019, and the mould sides were tapped to eliminate voids.

TABLE 1. Mixing formulations

Samples	Cement (g)	Sand (g)	Water (g)	Materials	
				Ground eggshells (g)	Calcined eggshells (g)
Mc	600.00	1800.00	300.00	-	-
MGES10	600.00	1586.40	300.00	309.00	-
MGES20	600.00	1372.50	300.00	617.50	-
MGES30	600.00	926.00	300.00	321.00	
MCES10	600.00	1586.40	300.00	-	107.00
MCES20	600.00	1372.50	300.00	-	214.00
MCES30	600.00	926.00	300.00	-	321.00

MORTAR PERFORMANCE TESTING

COMPRESSIVE STRENTGTH TEST

The compressive strength test was conducted according to BS EN 12390-3:2021 using an INSTRON Floor-Mounted Material Testing System. On each designated testing day, specimens were removed from the curing tank, and surface moisture was carefully wiped off to ensure accurate results. Each specimen was centered and aligned on the testing machine before loading. Compressive load was then applied at a constant rate until failure, the peak load was recorded, and compressive strength was calculated from the maximum load and cross-sectional area, using the average of three specimens for each testing age.

CARBONATION DEPTH

This test followed BS EN 14630-2006. A 1% phenolphthalein ($C_{20}H_{14}O_4$) solution was sprayed onto a freshly broken mortar surface. The colourless solution acts as a pH indicator, turning pink in the presence of $Ca(OH)_2$ when the pH exceeds 9, indicating uncarbonated (alkaline) regions. Carbonated areas remain colourless, allowing the carbonation front to be visually identified.

Following the method by Saiki et al. (2022), carbonation depth was determined by measuring six points along the interface between carbonated and uncarbonated zones using a digital vernier caliper with 0.01 mm precision. The average carbonation depth was calculated using Equation 1.

$$x = k_c\sqrt{t} \quad (1)$$

Where;
x is average carbonation depth measured in mm
k_c is rate of carbonation in mm/a0.5
$\sqrt{t}$ is effective time in days

SORPTIVITY

The sorptivity test was performed on 7th and 28th days cured specimens according to ASTM C1403 – 15. Referring to Hatungimana et al. (2019), all surfaces of the specimens were coated with epoxy, except for the surface intended to be exposed to water, to ensure that water absorption occurred only on the targeted area. The specimens were dried in a ventilating oven at 105°C ± 5°C for 24 hours to remove excessive moisture attached on the surfaces. Each specimen was then partially immersed and exposed to water (Figure 1) for set times 1, 3, 5, 10, 15, and 30 minutes (Lekshmi et al. 2020; Deng et al. 2022). Then, the differences before and after exposed to water were recorded, and the sorptivity were calculated according to Equation 2 below. The sorptivity experimental set up as shown in Figure 1 below.

$$I = S\sqrt{t} \quad (2)$$

Where;
S is sorptivity
I is the cumulative infiltration (i.e. distance)
t is time

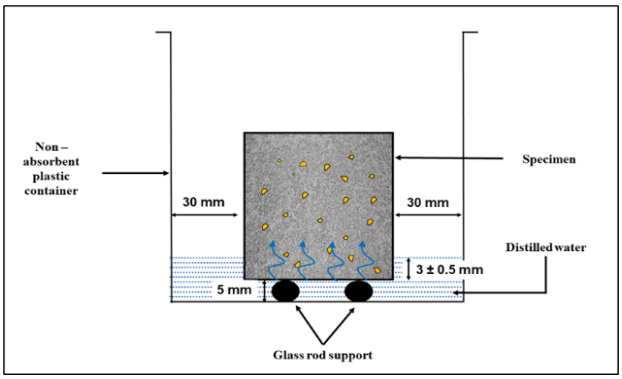


FIGURE 1. Sorptivity experimental setup

MORPHOLOGY

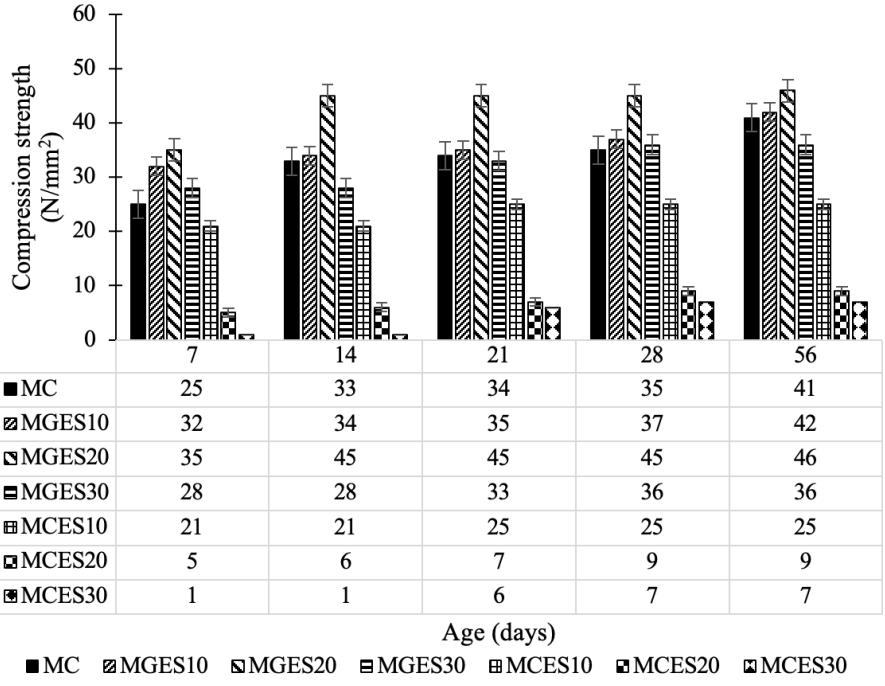
Freshly fractured mortar specimens were examined using an XL30 ESEM with a LaB6 electron source operating in high vacuum at 20 kV to obtain high-resolution images of surface morphology, pores, and hydration products. Samples were broken to size, mounted on 12.5 mm stubs, carbon-coated for conductivity, and imaged at magnifications from ×50 to ×10,000 with a working distance of 10–15 mm.

RESULTS AND DISCUSSION

COMPRESSIVE STRENGTH TEST

The compressive strength results of all mortar specimens showed a consistent increase with extended curing periods. According to Figure 2 below, the control specimen recorded an initial strength of 25 N/mm² on Day 7, gradually increasing to a peak of 41 N/mm² on Day 56. Mortars with 10% ground eggshell (MGES10) demonstrated a similar trend but slightly outperformed the control across all curing days. Notably, MGES20 exhibited the highest performance, reaching 35 N/mm² on Day 7 and peaking at 46 N/mm² by Day 56. Meanwhile, MGES30 also showed strength development over time, although their final values remained below the control specimen. It was observed that the compressive strength of MGES10 and MGES20 on Day 7 nearly matched that of the control on Day 28, suggesting improved early strength. This phenomenon is attributed to the reactivity of $CaCO_3$ in the eggshell, which, according to Shiferaw et al. (2019), reacts with tri-calcium aluminate (C_3A) to form calcium carboaluminate, an early strength-inducing compound in the mortar matrix. Thus, partial replacement of sand with 10–20% ground eggshell enhances strength development, particularly in the early stages, with MGES20 achieving the highest compressive strength overall, though MGES10 remained more efficient than the control.

In contrast, mortars containing calcined ground eggshell displayed different performance characteristics. Among the MCES specimens, only MCES10 exceeded the control on Day 7 with a compressive strength of 32 N/mm², gradually increasing to 35 N/mm² by Day 56. MCES20 and MCGES30 recorded some strength gains, yet their values remained lower than those of the control specimen throughout. As Matalkah et al. (2020) explained, incorporating 5% calcium oxide enhances compressive strength through the formation of C-A-S-H hydrates, increasing alkalinity and reducing water content. However, excessive calcium oxide may disturb the hydration process and microstructure of cement mortar, leading to increased porosity and lower compressive strength. Thus, the findings indicate that the incorporating of 10 – 20% ground eggshell as an alternative filler can improve compressive strength of cement mortar.



	7	14	21	28	56
MC	25	33	34	35	41
MGES10	32	34	35	37	42
MGES20	35	45	45	45	46
MGES30	28	28	33	36	36
MCES10	21	21	25	25	25
MCES20	5	6	7	9	9
MCES30	1	1	6	7	7

FIGURE 2. Compressive strength test

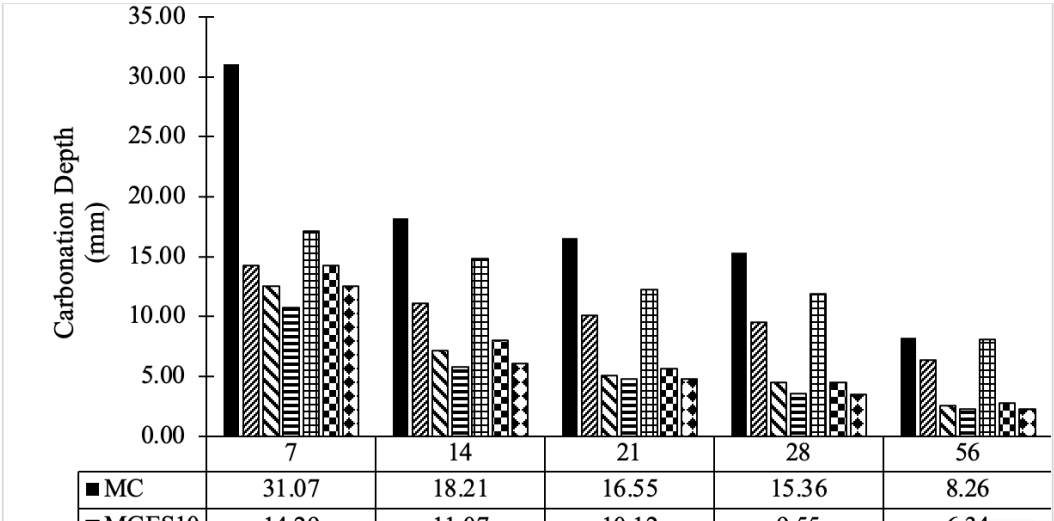
CARBONATION DEPTH

Figure 3 below presents the carbonation rate of mortar specimens over 7, 14, 21, 28, and 56 days, comparing control (MC), ground eggshell (MGES), and calcined ground eggshell (MCES) mixtures. Overall, carbonation was highest on Day 7 and declined with time, reflecting matrix densification and reduced CO_2 permeability. Among MGES samples, MGES30 showed the lowest carbonation depth, while MGES10 had the highest, indicating that higher eggshell replacement enhances the carbonation resistance trend supported by Murthi et al. (2022). Similarly, MCES mixtures revealed that MCES30 performed better than MCES10, and both MCES20 and MCES30 significantly outperformed the control, which showed nearly three times slower carbonation rate. Grain size analysis indicated that ground eggshells were finer than natural sand, while calcined eggshells were uniformly around 0.69 mm. Both materials acted as fillers, reducing the void ratio and pore size, thus slowing CO_2 diffusion and improving durability.

Razali et al. (2023) also demonstrated that smaller pore structures, achieved by using fine fillers, inhibit carbonation due to the restricted movement of CO_2 through the matrix. Similarly, Nivedha et al. (2026) supported this mechanism in their study, stating that fine eggshell particles fill voids, reduce pore size, and consequently delay carbonation. Additionally, Zhang et al. (2024) observed that the refinement of pore structures is directly associated with a reduced carbonation depth, reinforcing the findings of the present study.

The lower carbonation rate observed in mortar containing raw eggshell compared to calcined eggshell is primarily due to the lower reactivity and less effective pore refinement of the raw material. Raw eggshell, composed mainly of $CaCO_3$, lacks the chemical activity and filler efficiency of calcined eggshell, resulting in a more porous microstructure that allows faster CO_2 diffusion (Zhang et al. 2024). In contrast, calcined eggshell contributes to a denser matrix, reducing permeability and slowing the carbonation process (Şenol, 2025).

From a sustainability perspective, the improved carbonation resistance of eggshell-based mortar shows better long-term durability. The lower carbonation rate indicates a denser and more stable mortar structure, which may help to extend the service life of cement-based materials and reduce the need for frequent repair or replacement. Therefore, using eggshell as an alternative filler can improve mortar performance while also promoting the reuse of agricultural waste in construction applications.



	7	14	21	28	56
MC	31.07	18.21	16.55	15.36	8.26
MGES10	14.29	11.07	10.12	9.55	6.34
MGES20	12.50	7.14	5.06	4.51	
MGES30	10.71	5.80	4.76	3.57	2.30
MCES10	17.14	14.82	12.24	11.88	8.11
MCES20	14.29	8.04	5.65	4.51	2.79
MCES30	12.51	6.07	4.76	3.48	2.25

FIGURE 3. Carbonation depth rate of control, MGES and MCES specimens

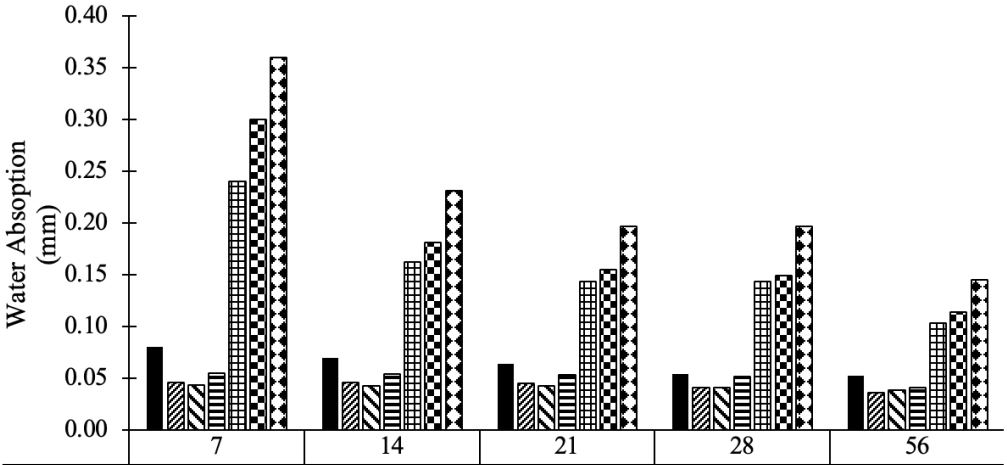
FIGURE 3. Carbonation depth rate of control, MGES and MCES specimens

SORPTIVITY

Figure 4 below illustrates that all of the specimens showed the same absorption trend. The water absorbed decreased gradually while the time increased. Chong et al. (2020a), Jaber et al. (2020), and Nandhini & Karthikeyan (2021) established that the rate of water absorption decreases with the increased percentage of ground eggshells. The smaller particle size of the ground eggshell fills the spaces between the sand and cement particles, strengthening the packing mortar. According to Jaber et al. (2020) and Grzeszczyk et al. (2022), the $CaCO_3$ in ground eggshell speeds up the formation of C-S-H. Water absorption is reduced due to reduced pore size brought on by the growing formation of C-S-H gel. Then, Nandhini & Karthikeyan (2022) revealed in the SEM image that the size of pores containing ground eggshell is smaller due to larger network of C-S-H gel generated.

Based on the graph, the water penetrating the mortar rate is much higher than the control specimen. In addition, Matalkah et al. (2020) established that 5 % of calcium oxide completely reacts with silica to form C-S-H gels. A high calcium oxide content will cause the formation of much ettringite and will cause micro or macro cracks (Jeon et al. 2020). So, in this study, the calcined ground eggshell content in the mortar exceeded the ideal amount, which caused the alkaline carbonate reactivity process.

The lower sorptivity observed in eggshell-based mortar indicates improved resistance against water penetration. Reduced water absorption may limit the movement of harmful substances into the mortar matrix, contributing to better durability and potentially extending the service life of cement-based materials. The use of eggshell as a filler also supports the reuse of agricultural waste and reduces the reliance on conventional filler materials in mortar production.



	7	14	21	28	56
MC	0.080	0.069	0.064	0.054	0.052
MGES10	0.046	0.046	0.045	0.041	0.036
MGES20	0.043	0.042	0.042	0.041	0.038
MGES30	0.055	0.054	0.053	0.051	0.041
MCES10	0.240	0.162	0.143	0.143	0.103
MCES20	0.300	0.181	0.155	0.149	0.114
MCES30	0.360	0.231	0.197	0.197	0.145

FIGURE 4. Water absorption by capillary

MORPHOLOGY

According to the outcomes of the durability testing, the significant result was selected to narrow down our analysis. Sample MGES20 and MCES10 were selected to analyze the morphological characteristics and elemental composition. Figure 6 below illustrates the elemental composition analysis of the MGES20 mortar specimen on the 28th day of curing using Energy-Dispersive X-ray Spectroscopy (EDX). During the EDX examination, three specific areas on the sample surface were analyzed, and the resulting spectra are presented in Figure 5 below. The detected elements include Carbon (C), Oxygen (O), Magnesium (Mg), Aluminium (Al), Silicon (Si), and Sulfur (S), indicating the presence of both cementitious components and additional mineral phases introduced by the ground eggshell. Spectrum 1a revealed round-shaped crystals embedded within the surrounding cement paste,

primarily composed of calcium hydroxide (CH). Spectrum 1b focused on a broader view of the microstructure, while Spectrum 1c provided a magnified image of a selected area from Spectrum 1a and 1b for more detailed observation. Notably, similar round-shaped crystal structures were previously reported by Mahato et al. (2024), who found that both chicken and seabird eggshells exhibit these characteristic morphologies. The EDX spectra from all examined regions (a–c) consistently indicate the dominance of Calcium (Ca) and Oxygen (O), confirming that the primary constituent of the eggshells is $CaCO_3$. This finding aligns with the chemical composition of chicken eggshells reported by Paruthi et al. (2023) and Jin et al. (2024) who also identified high calcium content as the major elemental component in their respective analyses. The EDX data and FESEM micrographs clearly indicate that the raw eggshells largely retain their original morphology after 28 days of curing and exhibit limited chemical interaction with the cement matrix. The high presence of Ca and C supports the identification of $CaCO_3$, which is stable and relatively inert under standard cement hydration conditions.

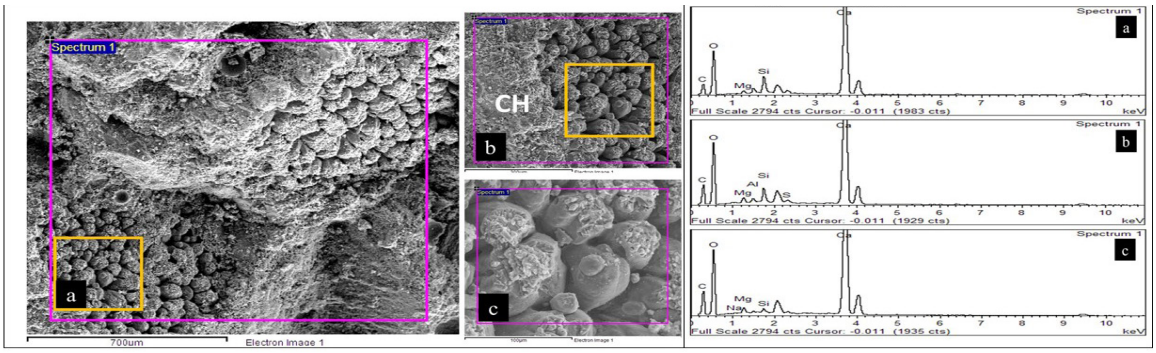


FIGURE 5: Field Emission Scanning Electron Microscopy (FESEM) and Energy Dispersive X-ray Spectroscopy (EDX) of mortar with 20% of ground eggshell (MGES20)

The FESEM images reveal a heterogeneous microstructure consisting of compact regions, porous zones, and crystalline formations (see Figure 6). Notably, fibrous and elongated crystals larger than typical ettringite are observed and are believed to be portlandite ($Ca(OH)_2$). This is supported by EDX spectra, which shows strong peaks of calcium (Ca) and oxygen (O), indicating that the high calcium content from the calcined eggshells has led to the crystallization of portlandite. These findings suggest that calcined eggshells contribute beyond a physical filler effect, where the released calcium oxide may participate in hydration reactions and promote matrix densification. The improved microstructural characteristics may enhance mortar durability, which is relevant for reducing maintenance requirements and extending the service life of cement-based materials. The EDX analysis also identified the presence of elements such as carbon (C), oxygen (O), magnesium (Mg), aluminium (Al), silicon (Si), sulphur (S), sodium (Na), and barium (Ba). The detection of sulphur is most likely due to the presence of sulphate compounds, which are commonly found in natural waters, soil, or cement additives (Zak et al. 2021). Then, Da Silva et al. (2021) claimed that sulphates play a crucial role in early hydration reactions and can contribute to the formation of ettringite. Moreover, the presence of silicon (Si), aluminium (Al), and sulphur (S) indicates the development of hydration products such as C–S–H gels and ettringite, both of which contribute to the strength and stability of the mortar (Poupelloz et al. 2019).

The microstructural findings support the durability results obtained from carbonation and sorptivity tests. The presence of denser hydration products and reduced pore structures explains the improved resistance against water penetration and carbonation in eggshell mortar. The ability of eggshell particles to enhance matrix packing and contribute to mortar durability indicates their potential as a sustainable filler material. By partially replacing conventional filler materials and improving service performance, eggshell utilization may reduce resource consumption and promote the beneficial reuse of agricultural waste in construction applications.

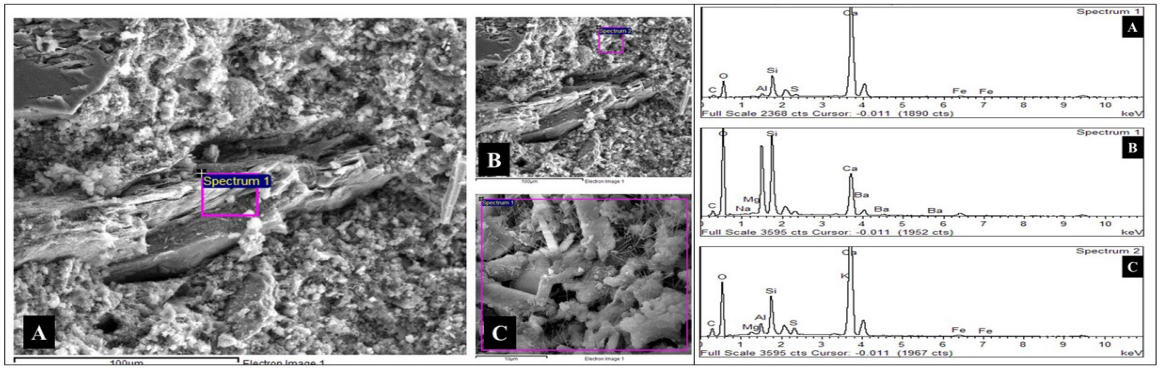


FIGURE 6. Field Emission Scanning Electron Microscopy (FESEM) and Energy Dispersive X-ray Spectroscopy (EDX) of mortar with 20% of ground eggshell (MGES20)

CONCLUSION

The incorporation of eggshells in mortar was found to significantly influence its durability and mechanical performance. The mortar containing eggshells showed lower sorptivity and slower carbonation progression compared to the conventional mortar, alongside improved compressive strength at optimum amount. The microstructural analysis revealed a denser and more compact matrix in the eggshell mortar, while EDX spectra showed a relatively high calcium (Ca) content. This elevated Ca content is believed to promote the formation of $CaCO_3$, which likely contributes to pore filling, densification, and the overall strengthening of the mortar. In contrast, the use of calcined eggshell resulted in different properties. Mortar incorporating calcined eggshell showed significantly lower compressive strength and poor sorptivity performance. Overall, the results show that ground eggshell has potential to be used as an alternative filler in cement mortar by improving its strength and durability performance. The reuse of eggshell waste also helps to reduce the dependence on conventional filler materials and supports sustainable construction practices.

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DECLARATION OF COMPETING INTEREST

None.

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