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POWDERED EGG AND SNAIL SHELLS AS CEMENT ALTERNATIVE IN MAKING PAVERS

Rea Obbamen, Lea Grace T. Daraway, Julie Ann Dela Peña, Joemel M. Estabillo
College of Teacher Education, Cagayan State University Piat Campus, Philippines
0009-0009-2189-1539
estabillojoemel@csu.edu.ph

ABSTRACT

This study explored the use of powdered snail shell and eggshell as partial cement alternatives in paver production. The main goal was to evaluate how these alternative binders affect slump, compressive strength, and flexural strength, and to compare their performance against traditional cement-based pavers. Results from the slump test showed that mixtures with pure eggshell had the highest workability, indicating better flow characteristics. Compressive strength tests over 3, 8, and 15 days revealed that while pavers made with 100% eggshell or snail shell had very low strength, partial replacements slightly improved this property. Eggshell demonstrated pozzolanic activity, contributing positively to compressive strength, whereas snail shell showed limited effectiveness. Overall, pavers with alternative binders had lower compressive and flexural strengths compared to those made entirely of cement. The study found that cement-based pavers remain superior in durability and strength, while eggshell mixtures offer better workability but insufficient strength. Recommendations include adjusting the cement-to-eggshell or snail shell ratios to optimize performance, extending curing periods to better assess strength development, and exploring additives to enhance mixture properties. Furthermore, additional testing on durability, environmental resistance, split tensile strength, and water absorption is suggested for a comprehensive evaluation of alternative binders. In summary, powdered eggshell and snail shell show promise as sustainable cement substitutes, but significant further research is necessary to improve their effectiveness and ensure they meet industry standards for paver production.

Keywords: Aggregates, Cement, Eggshell, Pavers, Snail shell

INTRODUCTION

The construction industry has played a major role in uplifting the socio-economic development globally (Sohu et al., 2018), driving urbanization and infrastructure growth. Most of the concrete's infrastructures are constructed using concrete, which is the most preferred construction and building material in the construction industry (Lakhiar et al., 2018). However, the production of concrete's key component, cement is not without environmental consequences.

The popularity of concrete has increased due to its availability, flexibility and durability (Memon et al., 2018), that is why concrete has been utilized in vast civil engineering applications ranging from the construction of foundations, retaining walls to bridges and dams (Sandhu et al., 2019). Concrete is a man-made construction and building material which is comprised of binder (cement), aggregates (fine and coarse) and water. It has been estimated in a report that the concrete industry utilizes 1.5 billion, 20 billion and 0.8 billion tons of cement, aggregates and water respectively every year (Kubissa et al., 2015).

Cement manufacture contributes greenhouse gases both directly through the production of carbon dioxide when calcium carbonate is thermally decomposed, producing lime and carbon dioxide and also through the use of energy, particularly from the combustion of fossil fuels (Walton, H.V et al., 1973). There is a growing interest in reducing carbon emission related to cement production from both academic and industrial sectors. Though cement plays a vital role in the manufacturing of concrete, it has risen environmental concerns. According

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to the report of Benhelal et al. (2013), the cement industry contributed to approximately 7% of the total global Carbon Dioxide (CO2) gas emissions.

Furthermore, production of one ton of cement emits approximately equal amount of CO2. Another concern is the number of raw materials required for production of cement. According to Naik and Moriconi (2005), to produce 1.6 billion tons of cement, 2.5 billion tons of raw natural resources such as limestone and clay are required. Each year, the demand for concrete is increasing and as such the production of cement is also on the rise. The nonstop production of cement is consuming natural resources at an alarming rate.

Therefore, to reduce the dependency on cement as a binder in the manufacturing of concrete, research studies have been done to find an alternative binder material which can substitute cement and reduce the natural resources depletion. The waste materials can be potential Supplementary cementitious materials (SCMs). Eggshell is one such waste material which could be used as partial cement replacement. Though full replacement of cement cannot be done at present, replacing 15% of cement worldwide can significantly reduce the CO2 emissions up to 250 million tons (Naik and Moriconi, 2005).

Nowadays, the construction industry is trying to achieve sustainability, in which the development of current infrastructures satisfies the present requirements without limiting the possibilities of fulfilling the needs in the future (Kubissa et al., 2015).

Reducing the utilization of natural resources and energy, decreasing of greenhouse gases emission has become a necessity as volume of cement and concrete production is projected to continuously increase over the years (Kubissa et al., 2015). Recycling of waste components contributes to energy savings in cement production, to conservation of natural resources and to protection of the environment (Kuma, S., 2014). Research have shown that it is possible to use recycled materials to replace some of the traditional mixture components in concrete products and produce a more sustainable building material (Amarnath Yerramala., 2014). One of these materials that can be recycled and have the possibility of use in the sand concrete block production is waste eggshell.

On the other hand, Accordingly, to become a "Green," environmentally conscious society, current and future generations have to make a commitment to actively reuse, reduce, recycle, rethink, redesign, and re-imagine the way they live and produce things in order to cultivate change. It is now the time that learning communities can take the lead to educate communities on ways to "Go Green" in order to limit the impacts of waste and pollution in the environment and the quality of life for all humans (International Technology and Engineering Educators Association, 2010).

Among the common wastes that can be possibly used for green technology are the aquatic animal shell wastes (World Organization for Animal Health, 2010). These wastes include shells that are disposed from households, markets and farms.

In Harrisburg, Texas alone, up to 20,000 tons of shells is stored in limestone-capped stockpiles at the Cape Foulwind quarry for QA between four and six months (New York Times, 2008). As reported by Mazik, Burdon & Elliott (2005), during the Seafood-waste disposal at sea – a scientific review at the University of Hull, Cottingham Road Hull HU6 7RX, United Kingdom, the disposal of seafood processing waste including shells is a worldwide problem.

In the Philippines, several coastal islands produce most of the different types of shell wastes that are disposed from households, seashores, markets and farms. It includes shells of Tahong {Perna viridis) or mussel shell, Kuhol ((Helix pomatia) or mollusk shell, and Talaba (Crassostrea gigas) or oyster shell are considered wastes and are normally dumped in open garbage areas or back to the aquatic system. As the waste shells are being reused / recycled, waste materials in the environment are decreased. Vectors of diseases that swarm waste areas will be diminished and thus safeguard public health (Solidum, J.N., et al, 2011).

In other countries, seashell is a common alternative to crushed limestone in coastal areas. They can be easily crushed or ground into gravel for walkways, aggregate in concrete mixes or drainage bases under masonry or other construction.

Bivalves and gastropods, commonly known as mollusk shellfish, contribute significantly to the global aquaculture industry, with bivalves alone representing around 87% of molluscan aquaculture. This sector accounts for approximately 22% of total global aquaculture production. The abundance of seashells in coastal regions worldwide suggests their potential as secondary sources of cement for concrete production.

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Shell waste poses a considerable financial and operational challenge to the primary processing industry. The need for simple, cost-effective outlets for shell disposal has been emphasized by industry experts. Utilizing shells as aggregates offers a range of applications, from low-value bulk products to high-value niche products, albeit requiring significant product development.

Studies by Orlando Ketebu et al. (2017), N. Devendran (2017), Syed Talha Zaid et al. (2014), and Othman et al. (2013) have explored the use of various seashell ashes as partial replacements for cement in concrete. These studies have shown promising results, with maximum compressive strengths achieved at specific replacement percentages. However, compressive strength tends to decrease with higher percentages of shell ash replacement, highlighting the importance of optimizing ash content for desired concrete properties.

Arroyo et al. (2005) investigated the feasibility of using mollusk shell-based adhesives as substitutes for traditional mortar, demonstrating the potential for shell-based materials in construction applications. Similarly, research conducted in the southern coast of Korea explored the use of crushed oyster shells as construction materials, highlighting their effectiveness in replacing sand.

The chemical composition of seashells, particularly calcium oxide (CaO) and silicon dioxide (SiO_2), varies depending on shell type, cleaning methods, and burning temperatures. Seashells typically contain high percentages of CaO and SiO_2, making them potentially pozzolanic and suitable for cement replacement. Additionally, seashell powders have been found to contain essential metals and can enhance product hardness and resistance to weathering.

Today, blended hydraulic cements are one of the technologies being used in the construction by intimately blending two or more types of cementitious material. Primary blending materials are Portland cement, ground granulated blast-furnace slag, fly ash, natural pozzolan, and silica fume. These cements are commonly used in the same manner as Portland cements. Blended hydraulic cements conform to the requirements of American Society for Testing and Materials (ASTM) C595 or C1157.

Hence, in response to these environmental challenges, researchers have explored alternative binder materials to reduce reliance on cement in concrete production. Waste materials such as powdered eggshells and snail shells, have emerged as promising supplementary cementitious materials. While full cement replacement remains a distant prospect, incorporating even small percentages of these waste materials could yield significant reductions in carbon emissions.

The need of building sustainably emphasizes the necessity of reducing greenhouse gas emissions and resource depletion. Complementing energy conservation, recycling waste components also helps to protect the environment. Incorporating recycled resources into concrete manufacture also provides a route to more environmentally friendly building methods.

In this context, the study aims to assess the feasibility of using powdered egg and snail shells as alternatives to cement in manufacturing pavers. By evaluating the properties and performance of these unconventional materials, the research seeks to contribute to the development of more environmentally friendly construction practices

Objectives of the Study

Generally, this study aimed to develop powdered snail shell and eggshell as cement alternatives in making pavers.

Specifically, the study aimed to:

1. Determine the conglomeration impact of snail shell and eggshell as alternative cement or binding agent, using
   a. Slump test
   b. Compressive Strength
   c. Flexural Strength
2. Determine the significant difference between the qualities and characteristics of pavers out of cement, pavers out of powdered eggshell and snail shell.

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MATERIALS AND METHODS

In this factorial experimental investigation, eggshell and snail shell were the two factors considered. Principal Component Analysis using SPSS was employed in this investigation. The mechanical characteristics of concrete using snail shell and eggshell powder as partial replacements for regular Portland cement were analytically investigated. Nine experimental samples with three curing ages provided the results. The research evaluated regular concrete with 100% cement in the form of control mixtures, 100% ground eggshell powder, and 100% ground snail shell powder. The impact of the eggshell and snail shell powder contents on the concrete was assessed using the control mixes. The number of mechanical and physical characteristics was analyzed through slump, flexural, and compressive strength according to the control samples for the studies.

Materials

The materials that were used in the study were the following:

a. Raw Materials: eggshell, snail shell, cement.
b. Tools: Pale, Paver molder, measuring box/cups, mallet, shovel, skillet
c. Equipment: Blender, Oven, Computer

Experimental work

Before adding the recommended amount of water, the raw materials were thoroughly mixed. The workability of the concrete mix was evaluated using the slump test to examine the effects of different ESP and SSP percentages and fineness on the workability of concrete. After the cubic samples reached the prescribed curing point as per the guidelines, they were tested for compressive strength and flexural strength using hydraulic press machine.

Procurement of Materials

The following mixes were prepared by the researchers before the investigation. The necessary supplies were procured in the neighborhood market.

Experimental Procedures

TREATMENTS	DESCRIPTION	QUANTIFICATION
Treatment 1	Control	1 cup cement+ 1’ 1/8 gravel+ ¼ water (100% cement)
Treatment 2	Eggshell	1 cup egg+ 1’ 1/8 gravel+ ¼ water (100% eggshell)
Treatment 3	Snail Shell	1 cup snail+ 1’ 1/8 gravel+ ¼ water (100% snail shell)
Treatment 4	Eggshell + cement	3/8egg+ 1/8 cement+ 1’ 1/8 gravel+ ¼ water (75% eggshell + 25% cement)
Treatment 5	Snail shell + cement	3/8snail+ 1/8cement+ 1’ 1/8 gravel+ ¼ water (75% snail shell + 25% cement)
Treatment 6	Eggshell + cement	1/8 egg+ 3/8cement+1’ 1/8 gravel+ ¼ water (50% eggshell + 50% cement)
Treatment 7	Snail shell + cement	1/4 snail+ 1/4cement+1’ 1/8 gravel+ ¼ water (50% snail shell + 50% cement)

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Treatment 8	Eggshell + cement	1/8 egg+ 3/8cement+1' 1/8 gravel+ ¼ water (25% snail shell + 75% cement)
Treatment 9	Snail shell + cement	1/8 snail+ 3/8cement+1' 1/8 gravel+ ¼ water (25% snail shell + 75% cement)

Preparation of the Substrate

The materials for growing media preparation are based on the above treatment formulation. Thorough mixing of materials was observed. Also, separate mixing based on the formulation was made to avoid interchanging of materials.

Implementation of the treatments

Procedure (Eggshell)

a) Rinse the eggshells.
b) Boil the eggshells. Boil for 10 minutes to safely remove bacteria and pathogens. While they boil, preheat your oven to 200 degrees Fahrenheit.
c) Drained eggshells. Allow the eggshells to cool.
d) Toast using oven the eggshell in order to crashed it easier.
e) Grind the eggshells using blender, grind the eggshells until they become a fine, white powder.

Procedure (Snail Shell)

a) Wash and rinse the snail shell.
b) Sundry the snail shells
c) Grill the snail shell on flaming.
d) Crash and smash the snail shells turn into powder
e) Strain and put it in a clean container.

Procedure in Making Pavers:

a) Prepare all the materials needed
b) Measure the different mixture
c) Follow the exact proportion for Concrete.
d) Combine all the dry mixture and hollow.
e) Pour the mixture in the moulder.
f) Ensure that the mixture is compacted
g) Remove the moulder and harden the mixture within 12-24 hours
h) Cure the mixture daily

Locale of the Study

The study was conducted at Cagayan State University Piat Campus, BTLED Laboratory for the school year 2023-2024.

Data Gathering Tool

The data needed in the study was obtained from the results of the tests conducted by the N'ris Construction Materials Testing Services-Civil Engineering Laboratory.

Analysis of Data

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The collected data were subjected to weighted arithmetic mean and Microsoft excel using the Principal Component Analysis using SPSS. This means that making the correct decision in the analysis is 95% whether there a relationship of pavers out of cement and pavers out of snail shell and eggshell

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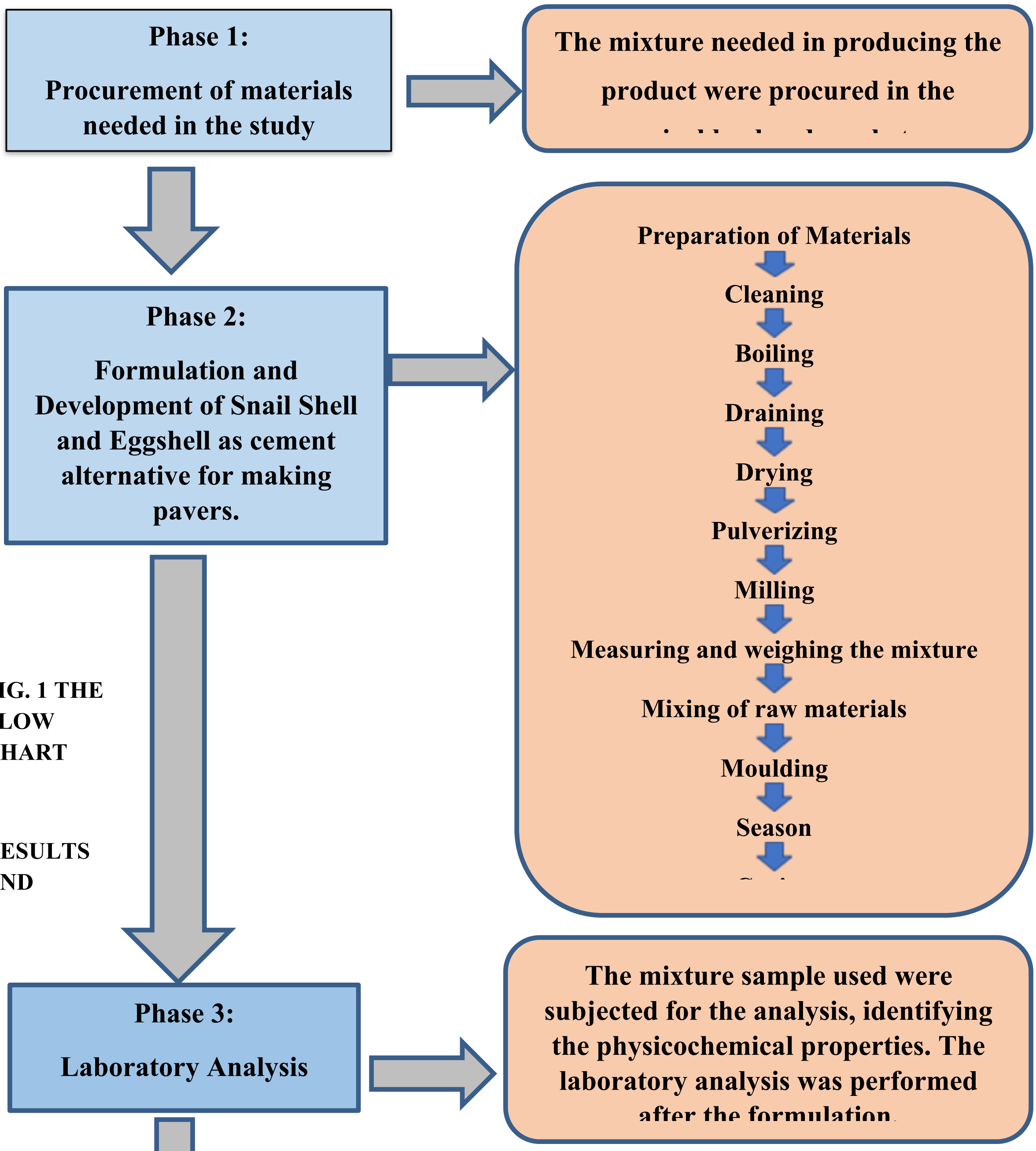

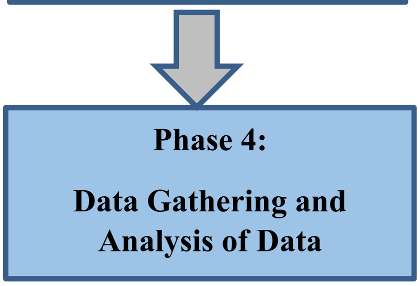

FIG. 1 THE FLOW CHART

RESULTS AND DISCUSSION

1. Conglomeration impact of snail shell and eggshell as alternative cement or binding agent, using the following:

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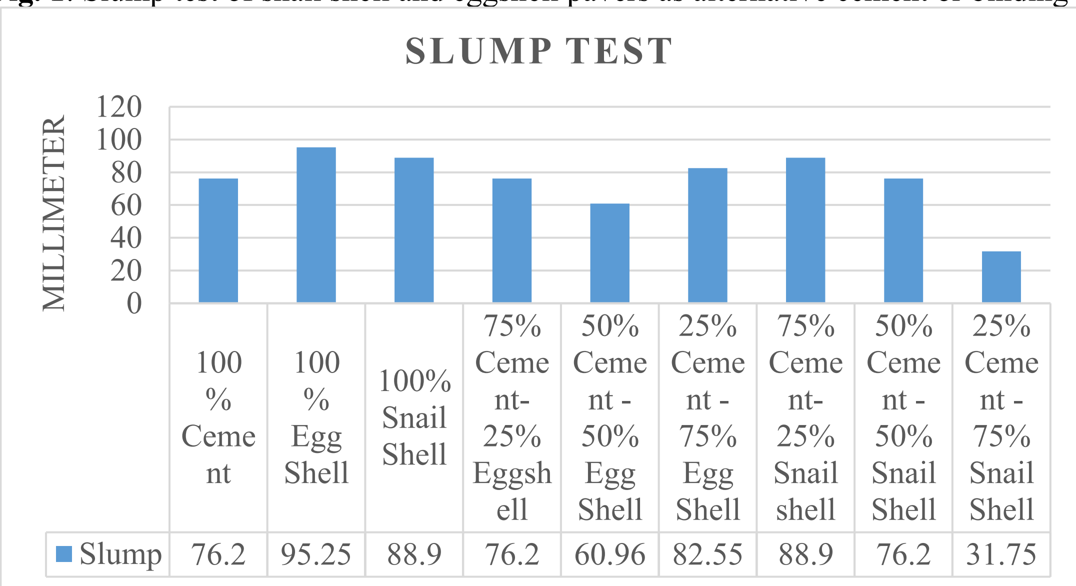
a. Slump Test

Fig. 1: Slump test of snail shell and eggshell pavers as alternative cement or binding agent



Results for Eggshell as Cement Replacement:

In figure 1, the control specimens (T1) with 100% cement displayed a slump of 76.2mm. Treatment 2, with 100% eggshell, exhibited a higher slump of 95.25mm. Interestingly, at 75% cement and 25% eggshell, the slump maintained the same as the control, which is 76.2mm, indicating a balance in workability. Conversely, at 50% cement replacement, the control paver's slump decreased by 15.24mm, corresponding to 50% eggshell replacement. However, at 25% cement replacement, the control paver's increased by 6.35mm, emphasizing the positive impact of a 25% eggshell replacement.

Results for Snail Shell as Cement Replacement:

Figure 1 also presents the workability of cement concrete pavers incorporating snail shell. Similar to the eggshell results, the control specimen (Control 1) with 100% cement displayed a slump of 76.2mm. The pure snail shell as a cement replacement resulted in a higher slump of 88.9mm. At 75% cement replacement, the control paver's slump increased by 12.7mm with a 25% snail shell replacement. At 50% cement replacement, the control paver and the snail shell replacement both displayed a slump of 76.2mm. However, at 25% cement replacement, the control paver's slump decreased by 44.45mm with a 75% snail shell replacement.

The figure suggests that 100% cement or the inclusion of eggshell and snail shell in the mixture has an impact on improving the workability.

b. Compressive Strength

The investigation into the compressive strength of concrete mixtures incorporating alternative binding agents, specifically eggshell and snail shell, presents a nuanced understanding of their impact on the material's performance over curing periods of 3, 8, and 15

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days. The experimental design encompasses a range of compositions, including 100% cement, 100% eggshell, 100% snail shell, and various combinations of eggshell and snail shell with cement.

The control group, comprising 100% cement, demonstrated a predictable trend with a steady increase in compressive strength from 390 Psi at 3 days to 650 Psi at 8 days, followed by a decline to 493.33 Psi at 15 days. In stark contrast, mixtures with 100% eggshell and 100% snail shell exhibited negligible strength throughout the testing period, underscoring the challenges associated with complete substitution of traditional cement.

The study delves into the intricacies of partial replacements, revealing that T1 and T2 demonstrated marginal improvements in strength compared to their 100% counterparts. However, a 50% replacement of cement with eggshell or snail shell yielded varying compressive strength values, indicating a complex interplay between the components.

Of particular interest is the finding that T8 showcased enhanced compressive strength, while T9 displayed inconsistent outcomes. This discrepancy may be attributed to the pozzolanic properties of eggshell, which likely contributed to strength improvement, while snail shell exhibited limited pozzolanic activity, resulting in less consistent outcomes.

The observed variations in compressive strength are elucidated by considering the hydration reactions and interplay between calcium carbonate in shells and cement hydration processes. The pozzolanic activity of eggshell appears to positively influence strength, whereas snail shell's limited activity leads to less consistent outcomes.

Analyzing the data presented in the table, it is evident that alternative mixtures generally exhibit lower compressive strength compared to the 100% cement baseline. Notably, the 75% Eggshell + 25% Cement mixture stands out with the lowest compressive strength values among all mixtures, highlighting the challenges associated with higher proportions of eggshell.

The graphical representation underscores the significant impact of using eggshell or snail shell as partial replacements for cement on compressive strength. The dynamic nature of compressive strength values over time suggests a complex relationship between the alternative binding agents and traditional cement, warranting further investigation into the long-term durability and performance implications.

Thus, the appropriate manipulation of concrete pavers during their pouring into their molds may be responsible for the outcomes. The results demonstrated that the mean compressive strength of each sample varied significantly. As a result, the null hypothesis was rejected on both counts. Based on the findings of Cacho.J.P. and Sampiano.M.D. (2019), the collected data demonstrated that eggshells and snail shells can be used as partial additives in concrete as they increase the compressive strength of standard pavers.

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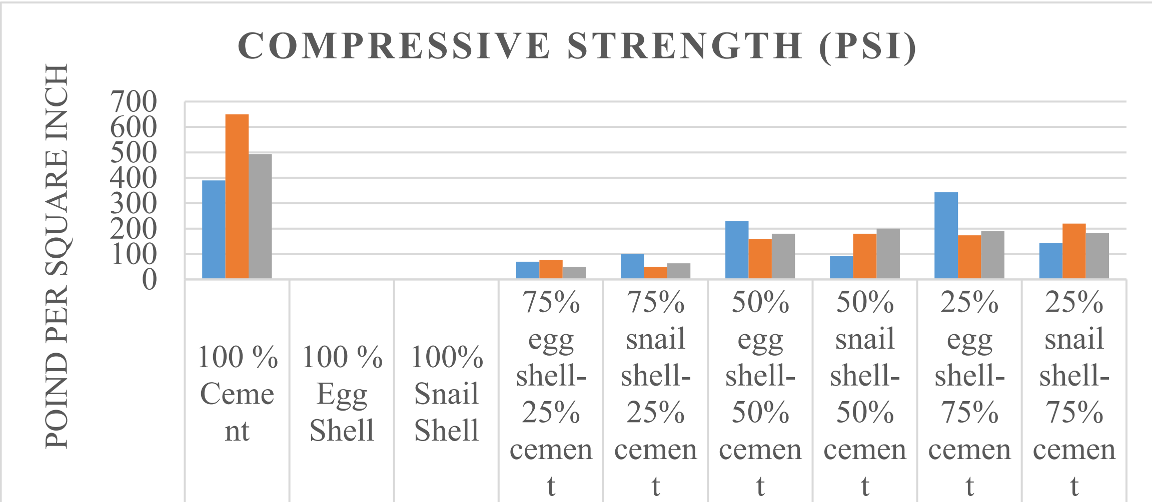

	100 % Cement	100 % Egg Shell	100% Snail Shell	75% egg shell-25% cement	75% snail shell-25% cement	50% egg shell-50% cement	50% snail shell-50% cement	25% egg shell-75% cement	25% snail shell-75% cement
3 days	390	0	0	70	100	230	93.33	343.33	143.33
8 days	650	0	0	76.67	50	160	180	173.33	220
15 days	493.33	0	0	50	63.33	180	200	190	183.33

Fig. 2: Compressive Strength of snail shell and eggshell pavers as alternative cement or binding agent.

d. Flexural Strength

Figure 3 shows the flexural strength, measured in Mega Pascals (Mpa), of various mixtures involving snail shell, eggshell, and cement as alternative binding agents at different curing times (3, 8, and 15 days) for each mixture. Flexural strength is crucial in assessing a material's ability to resist bending or deformation.

Similar to the compressive strength results, the alternative mixtures generally show lower flexural strength compared to the 100% cement baseline. The 75% Eggshell + 25% Cement mixture consistently exhibits the lowest flexural strength values among all mixtures while 25% Eggshell + 75% Cement mixture shows the highest flexural strength at 3 days but decreases at later curing times.

The results also show that employing eggshell or snail shell as partial substitutes for cement did not boost flexural strength when compared to 100% cement.

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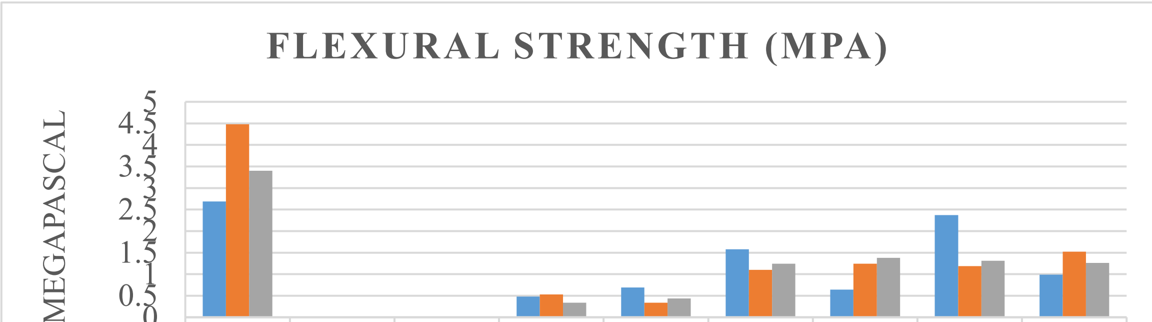

	100 % Cement	100 % Egg Shell	100% Snail Shell	75% eggshell-25% cement	75% snail shell-25% cement	50% egg shell-50% cement	50% snail shell-50% cement	25% egg shell-75% cement	25% snail shell-75% cement
3 days	2.69	0	0	0.48	0.69	1.58	0.64	2.37	0.99
8 days	4.48	0	0	0.53	0.34	1.1	1.24	1.19	1.52
15 days	3.4	0	0	0.34	0.44	1.24	1.38	1.31	1.26

Fig. 3: Flexural strength of snail shell and eggshell pavers as alternative cement or binding agent.

2. The significant difference between the qualities and characteristics of pavers out of cement, pavers out of powdered eggshell and snail shell.

Table 1 provides an analysis of the difference in compressive strength for various mixtures involving snail shell, eggshell, and cement as alternative binding agents with 3-day curing time. The mean compressive strength for 100% cement is significantly different from the alternatives, as indicated by the low p-value (0.013) and the significant decision at a 5% level of significance. 100% cement mixture have significantly higher compressive strength value than the alternative mixtures. This could have practical implications for material selection, as it suggests that the presence of eggshell and snail shell in the mixtures gives noticeable decrease in the compressive strength compared to using 100% cement.

Table 1. Analysis of the Difference of Conglomeration impact of snail shell and eggshell as alternative cement or binding agent using Compressive Strength (3-days).

Trial	Mean	F – Value	P-Value	Decision @ 5% level of significance
100% CEMENT	390.0000	4.161	0.013	Significant
75% EGG SHELL + 25% CEMENT	70.0000			
75% SNAIL SHELL + 25% CEMENT	100.0000			
50% EGG SHELL + 50% CEMENT	230.0000			
50% SNAIL SHELL + 50% CEMENT	93.3333			
25% EGG SHELL + 75% CEMENT	343.3333			

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25% SNAIL SHELL + 75% CEMENT	143.3333			

Table 2 compares the compressive strength of various mixes containing snail shell, eggshell, and cement as alternative binding agents. The analysis focuses on the compressive strength values after eight days. Similar to the 3-day analysis, the results indicate a substantial difference in the mean compressive strength between the 100% cement and the alternative mixtures after 8 days. The findings also imply that the inclusion of egg and snail shell reduces the compressive strength of the mixtures.

Table 2. Analysis of the Difference of Conglomeration impact of snail shell and eggshell as alternative cement or binding agent using Compressive Strength (8-days)

Trial	Mean	F - Value	P-Value	Decision @ 5% level of significance
100% CEMENT	650.00	10.929	00.000	Significant
75% EGG SHELL + 25% CEMENT	76.67			
75% SNAIL SHELL + 25% CEMENT	50.00			
50% EGG SHELL + 50% CEMENT	160.00			
50% SNAIL SHELL + 50% CEMENT	180.00			
25% EGG SHELL + 75% CEMENT	173.33			
25% SNAIL SHELL + 75% CEMENT	220.00			

Table 3 presents the results of an analysis of the compressive strength of different cement mixtures involving snail shell and eggshell as alternative binding agents at 15 – day curing period. Similar to the 3-day and 8-day curing times, there is a substantial difference in compressive strength across the mixtures (p-value=0.000). The results also demonstrate that 100% cement has a much higher compressive strength than other mixtures containing egg and

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snail shell. This also implies that the addition of egg and snail shell in the mixture will not increase its compressive strength.

Table 3. Analysis of the Difference of Conglomeration impact of snail shell and eggshell as alternative cement or binding agent using Compressive Strength(15-days)

Trial	Mean		F - Value	p-value	Decision @ 5% level of significance
100% CEMENT	493.33		9.475	0.000	Significant
75% EGG SHELL + 25% CEMENT	50.00				
75% SNAIL SHELL + 25% CEMENT	63.33				
50% EGG SHELL + 50% CEMENT	180.00				
50% SNAIL SHELL + 50% CEMENT	200.00				
25% EGG SHELL + 75% CEMENT	190.00				
25% SNAIL SHELL + 75% CEMENT	183.33				

Table 4 reveals the analysis of the flexural strength of different cement mixtures involving snail shell and eggshell as alternative binding cured for 3 days. The obtained p-value of 0.013, which is less than the commonly used significance level of 0.05, suggests that there is a statistically significant difference in the flexural strengths of the different mixtures at the 3-day curing period. The flexural strength of the 100% cement mixture is significantly higher than that of the other mixtures. This implies that, at the 3-day curing time, a composition consisting of pure cement is more effective in terms of flexural strength compared to mixtures involving alternative binding agents. The exception is noted for the mixture containing 25% eggshell and 75% cement and 50% eggshell and 50% cement. The flexural strength o f this mixtures is not significantly different from the 100% cement mixture as seen in table 9. This suggests that, in terms of flexural strength, this combination with 25% or 50% eggshell performs similarly to the pure 100% cement mixture.

The results further suggest that for applications where flexural strength is a critical factor, using 100% cement may be the preferable choice. However, the exception for the 25% eggshell + 75% cement and 50% eggshell and 50% cement mixtures indicate that certain alternative compositions might provide comparable performance in specific scenarios.

Table 4. Analysis of the Difference of Conglomeration impact of snail shell and eggshell as alternative cement or binding agent using flexural strength (3-days)

Trial	Mean	F - Value	p-value	Decision @ 5% level of significance
100% CEMENT	2.6867	4.169	0.013	Significant
75% EGG SHELL + 25% CEMENT	.4800			

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75% SNAIL SHELL + 25% CEMENT	.6900			
50% EGG SHELL + 50% CEMENT	1.5833			
50% SNAIL SHELL + 50% CEMENT	.6433			
25% EGG SHELL + 75% CEMENT	2.3667			
25% SNAIL SHELL + 75% CEMENT	.9867			

Table 5 reveals the comparative analysis of the flexural strengths of the different mixtures at 8 days curing time. It can be seen from the table that the obtained p-value of 0.000 is less than 0.050. This result means that there is a significant difference of the flexural strengths of the different mixtures. The result further shows that 100% cement resulted in higher flexural strength compared to other mixtures containing egg and snail shell. This implies that, at the tested time point, a composition consisting of pure cement exhibits superior flexural strength compared to mixtures involving egg and snail shell as alternative binding agents. In practical terms, the higher flexural strength of 100% cement could be crucial in applications where this mechanical property is a critical factor. Industries or projects requiring high early-stage flexural strength may find 100% cement to be the most suitable option based on these results.

Table 5. Analysis of the Difference of Conglomeration impact of snail shell and eggshell as alternative cement or binding agent using flexural strength (8-days)

Trial	Mean	F - Value	p-value	Decision @ 5% level of significance
100% CEMENT	4.4833	10.945	0.000	Significant
75% EGG SHELL + 25% CEMENT	0.5300			
75% SNAIL SHELL + 25% CEMENT	0.3433			
50% EGG SHELL + 50% CEMENT	1.1000			
50% SNAIL SHELL + 50% CEMENT	1.2400			

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25% EGG SHELL + 75% CEMENT	1.1933			
25% SNAIL SHELL + 75% CEMENT	1.5167			

Table 6 shows an analysis of the difference in flexural strengths between the various mixes after 15 days of curing. The obtained p-value is 0.000, which is less than 0.05. This suggests that there is a significant difference in the flexural strengths of the tested mixtures. In addition, the flexural strength of 100% cement is significantly higher than the other mixtures. For applications where flexural strength is a critical factor, these findings imply that choosing 100% cement might be preferable. This has practical implications for engineers, architects, and construction professionals who need to select materials that meet specific performance criteria.

Table 6. Analysis of the Difference of Conglomeration impact of snail shell and eggshell as alternative cement or binding agent using flexural strength (15-days)

Trial	Mean	F - Value	p-value	Decision @ 5% level of significance
100% CEMENT	3.4033	9.484	0.000	Significant
75% EGG SHELL + 25% CEMENT	.3433			
75% SNAIL SHELL + 25% CEMENT	.4367			
50% EGG SHELL + 50% CEMENT	1.2433			
50% SNAIL SHELL + 50% CEMENT	1.3767			
25% EGG SHELL + 75% CEMENT	1.3133			

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25% SNAIL SHELL + 75% CEMENT	1.2633			

CONCLUSIONS

Based on the results of the study, several important conclusions can be drawn. First, pavers made with 100% cement proved to be the strongest in terms of compressive and flexural strength, while those with 100% eggshell mixture showed the highest slump, which means they had the best workability. Second, mixtures with higher cement content produced the most durable pavers, confirming that cement remains the most reliable material for strength and durability. Third, there is a clear difference in the compressive and flexural strengths of pavers made from eggshell, snail shell, and cement mixtures. Because of this, using eggshell or snail shell as complete replacements for cement is not advisable, as they result in weaker performance.

From these findings, several recommendations can be made. Adjusting the ratio of cement to eggshell or snail shell could help achieve a better balance between strength and workability. It is also worth exploring the effect of longer curing periods—beyond 15 days—to see whether mixtures containing eggshell and snail shell could develop greater strength over time. Further studies should also consider the use of additives or alternative binders that may help improve the compressive and flexural strength of these mixtures. In addition, testing should go beyond slump, compressive, and flexural strength to include durability, resistance to environmental conditions, split tensile strength, and water absorption, so that a more complete evaluation of these materials can be achieved.

Finally, this study suggests that mixtures of 50% eggshell with 50% cement and 25% eggshell with 75% cement show promise and should be explored further for practical applications.

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