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An investigation study on pulverized egg shell as a partial replacement of cement for non-load bearing concrete hollow blocks

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ABSTRACT

In order to minimize the problem and develop a useful, practical, and affordable construction material, the researchers discovered the use of waste materials. Because of the scarcity, the researchers are motivated to utilize the solid waste generated by households and companies that use eggs in their production of goods. The researchers propose using Egg Shells to develop an alternative cement for the concrete mixture. The study has three main objectives: (1) to determine the 7-day, 14-day, and 28-day compressive strengths of concrete when pulverized egg shells are used as a partial replacement for cement; (2) to determine the water absorption percentage of the concrete when pulverized egg shell is used as a partial replacement for cement in concrete; and (3) to perform a cost analysis in the preparation of a concrete mix with pulverized egg shell as compared to the standard concrete mixture. The study involves cost analysis and two tests: compressive strength and water absorption. To achieve the result from the compressive test, the researchers made CHB specimens consisting of nine for each experimental (5%, 10%, and 15% cement partial replacement) setup and nine standard concrete mixtures for each different curing age (7, 14, and 28 days). Based on the analysis of the findings, the researchers conclude that egg shell can be a partial replacement for cement for non-load bearing concrete hollow

blocks. The samples were tested using the Universal Testing Machine (UTM), and the results show that the concrete samples with 10% replacement of PES have higher compressive strength than the standard concrete samples, all of the specimens have passed the ASTM C129 standards in both the compressive strength test and the water absorption test. Also, using pulverized egg shells can reduce the cost of the project. However, only a 10% replacement of egg shell is highly recommended.

Keywords: Waste Materials, Concrete Mixture, Compressive Strength, Water Absorption, Cost Analysis, Pulverized Egg Shell, Universal Testing Machine

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1. INTRODUCTION

Concrete Masonry Units (CMU) are primarily used to construct internal and external partition walls. According to the National Concrete Masonry Association (NCMA, 2017), CMU is a standardized rectangular block that is manufactured in a variety of sizes, shapes, colors, and textures to provide a variety of finishes and uses. These are classified into two types: hollow and solid. Concrete hollow blocks (CHB) are extensively used for masonry work in the Philippines. There are two varieties of concrete hollow block (CHB): load-bearing and non-load-bearing blocks. Non-load-bearing blocks have a thickness of 7 to 10 centimeters and are intended for usage as partitions, fences, dividers, and walls (Fajardo, 2000).

Sand, cement, and water in accordance with Item 900, Reinforced Concrete Specifications, mixed in a ratio of one (1) part cement to three (3) parts sand by volume, and enough water to achieve the desired consistency, make up mortar for concrete hollow blocks and louver blocks (Department of Public Ways and Highways, 2018). Concrete Hollow Block (CHB) is a compressed mixture of screened sand and cement (Fajardo, 2000). These blocks do not bear any gravity loads from the building and do not accept any weight other than their own. A non-load-bearing partition wall divides any interior space (Pitroda, 2016).

According to the study of Allie and Firdous (2018), a number of waste products in India are produced by different manufacturing companies, thermal power factories, external solid wastes, and other wastes. Solid as well as liquid waste operations are one of the biggest problems in the world. During the manufacturing of one ton of ordinary Portland cement (OPC), we need about 1.1 tons of earth coffers. Furthermore, during the manufacturing of one ton of cement, an equal quantum of carbon dioxide is released into the atmosphere, which acts as a silent killer in the terrain as colorful forms.

2. BACKGROUND OF THE STUDY

Concrete is the most significant construction material, and it is in high demand. Portland cement is a major constituent in the production of concrete. However, the price of cement is rising over time; this spike in price is a challenge in the construction industry, and there is a desire to develop alternative ecologically acceptable cement replacement materials without sacrificing the mechanical qualities of structural concrete (Teshome, 2019). The world's biggest environmental challenge is thought to be climate change. Technology development has led to the fact that, relative to the past, cement manufacturing enterprises are now able to generate bigger volumes. However, increased manufacturing has also been identified as the main source of pollution (Zimwara et al., 2012).

The garbage produced by industries nowadays is a major worry for the environment, human health, and the need for land filling. Recycling these wastes and using them as building materials appears to be a workable solution to the pollution issue as well as a cost-effective choice for construction (Agrawal et al., 2014). Waste is a significant environmental issue and a hazard to the ecosystem. Reusing and discarding these resources are essential. Reusing and recycling garbage are two ways that it could be put to use in the construction industry (processing waste into raw materials used in the production of building materials) (Dachowski & Kostrzewa, 2016). Egg shells are agricultural waste products made in bakeries, fast food restaurants, chick hatcheries, and other agricultural facilities. Because they can harm the environment, egg shells contain environmental contaminants that require proper handling. When left in the trash for a prolonged period of time, eggshells can potentially cause allergies. Cement use can be reduced, natural lime can be conserved, and waste material can be used if egg shell waste is used in place of natural lime to replace cement in concrete. The main components of an egg shell are calcium, magnesium carbonate, and protein. Before use with concrete or mortar, pulverized egg shell is a fine-grained powder with the proper proportions that has been sieved to the necessary size (Basit et al., 2019).

Yerramala (2014) studied the properties of concrete with eggshell powder as a cement replacement. This paper describes research into the use of poultry waste in concrete through the development of concrete incorporating egg shell powder (PES). Different PES concretes were developed by replacing 5–15% of PES with cement. The results indicated that PES can successfully be used as a partial replacement for cement in concrete production. The data presented covers strength development and transport properties. With respect to the results, at 5% PES replacement, the strengths were higher than control concrete, indicating that 5% PES is an optimum content for maximum compressive strength. The strengths were higher than control concrete for 5% PES replacement at 7 and 28 days of curing. PES replacements greater than 10% had lower strength than control concrete.

3. BRIEF DISCUSSION OF MATERIALS USED

Egg shells are waste products from the poultry industry and are particularly common in fast food establishments, restaurants, and homes. Due to their environmental inconvenience, these residues increase the cost of managing disposal sites, produce an offensive odor, and attract flies in areas where they are abundant. The shells of chicken eggs make up roughly 11% of the egg's overall weight (Murakami et al., 2007). OPC is produced from naturally available components, including clay and limestone (Prabhu et al., 2013). In the studies of Hassan et al. (2012) and Dhaliwal et al. (2013), egg shells show high calcium contents of 94% to 98%, while the remainder contains other trace elements, including minute amounts of sodium, magnesium, phosphorus, boron, and carbon. In 2011, King'ori reaffirmed that eggshell calcium is more easily absorbed than that found in other food sources (Adogla et al., 2015).

Eggshells offer a wide range of applications in varied sectors, such as nutrition, art, construction, fertilizers, and medicine. It is speculated to be a better source of calcium than limestone. Eggshells have been reported as an alternative source for soil stabilizing agents. It is used as a fertilizer supply for calcium, and the acidity of soil can be reduced with the utilization of calcium from egg shell. The waste egg shells were reported to be a good adsorbent of humidity. Calcium oxide (CaO) was produced when the egg shells were heated at 1300 ^{o}C for four hours. The difference in hydration rate of CaO produced from heating duck and chicken egg shells was investigated, where duck egg shells showed higher absorption of humidity (Poornima et al., 2017).

Concrete is one of the most significant natural resource products. The use of concrete in the modern era was the foundation of the nation's construction industry. The local construction industry's growth requires a greater quantity of concrete, which indirectly increases the need for a greater supply of natural resources for concrete production. A change in cement can be obtained on the market, and each type is used under persuaded illness owing to its unique characteristics, such as cement color and different ways of arrangement. In recent years, there has been a general trend towards reducing the use of natural resources and the reuse of waste products (Tan et al., 2017).

4. OBJECTIVES OF THE STUDY

4.1 **General Objective**

The general objective of this study is to determine the suitability of pulverized egg shell as a partial replacement for cement, especially in the production of concrete products such as non-load-bearing blocks. Hence, it aims to determine the compressive strength and water absorption percentage of the concrete product, as well as the cost analysis of the standard sample compared to the simulated sample.

4.2 Specific Objectives

1. Determine the compressive strength for 7-day, 14-day, and 28-day non-load-bearing concrete hollow blocks when PES was used as a partial replacement for cement.

2. Determine the water absorption percentage for the 7-day, 14-day, and 28-day non-load-bearing concrete hollow blocks when PES was used as a partial replacement for cement.

3. Determine the cost analysis of the standard concrete hollow blocks compared to the simulated non-load-bearing concrete hollow blocks with PES.

5. SIGNIFICANCE OF THE STUDY

The significance of the study will focus on the following stakeholders who will benefit from it. Also, this study will provide significant information and knowledge, especially on the premise of pulverized egg shell (PES) as a partial replacement for cement in non-load-bearing concrete hollow block production.

The Construction Industry. This study will provide knowledge and information to different construction companies specifically, which will serve as their guide in innovating the concrete products used in construction, especially CHB. Also, this study will give ideas to the construction industry on how to make concrete products affordable and, at the same time, environmentally friendly.

The Environment. This study will be beneficial to the environment by minimizing the waste product of egg shells by producing non-load-bearing concrete hollow blocks. The researchers will collect egg shells from different food establishments and the like that use eggs as one of their primary ingredients in producing their products. It will lessen the waste in the environment, which can help in the protection and conservation of the environment and its natural resources.

The Future Researchers. This study will be beneficial to future researchers as a reference for providing the information and ideas that they need to develop similar studies.

6. SCOPE AND LIMITATIONS

This study only focuses on using pulverized egg shell (PES) as a partial replacement for cement in concrete hollow blocks (CHB). The researchers gathered data by testing the proposed product to assure that PES is a suitable partial replacement for cement in producing non-load-bearing concrete hollow blocks. In addition, the researchers gathered the data needed by testing the Standard Concrete Mixture and PES Concrete Mixture in terms of compressive strength. This study also compared the commercially available concrete hollow blocks to determine if pulverized egg shell is a suitable replacement for cement. Furthermore, the specimens will be tested in the compressive strength test and the water absorption test. The collection of egg shells used in the experiment came from households and small businesses that used eggs in their production of goods.

7. REVIEW OF RELATED LITERATURES

Numerous researchers have attempted to improve the mechanical properties of concrete and reduce waste disposal issues by using waste products. Until now, fly ash, silica fumes, quartz sand, and egg shell powder have been the main waste products used. It is claimed that disposing of egg shells contributes to and creates unpleasant odors that are upsetting and have an impact on people's health (Vasudevan & Chan Wei, 2020).

7.1 Component of Egg Shell that is Similar to Cement

The main substance in egg shells is calcium carbonate ($CaCO_3$). The shell's actual composition is 95% $CaCO_3$, with the remainder being made up of magnesium, aluminum, phosphorous, salt, sulfur, mercury, iron, salt, ironic acid, and silica acid. Due to their cellulosic structure and amino acid content, egg shells can serve as a beneficial bio-sorbent. Alkali-silica and sulfate expansions can be decreased by using egg shell (Vasudevan & Chan Wei, 2020).

Egg shell powder is a new Supplementary Cementitious Material (SCM) and a source of calcium carbonate in the form of pure calcite. The activity test has shown that egg shells are of high quality for reacting with other materials. The addition of egg shell powder to Portland cement speeds the hydration reaction by reacting with tri-calcium silicate (C_3S) and alters the hydration product of cement paste by supplying nucleation sites (Shiferaw et al, 2019).

Egg shell is almost entirely composed of calcium carbonate ($CaCO_3$) crystals, which can act as limestone. Egg shells contain 96-97% $CaCO_3$, with organic material accounting for 3-4%. (Intharapat & Kongnoo, 2013). According to some sources, egg shell's general chemical makeup is comparable to that of limestone. $CaCO_3$ is an interesting one of the four main basic elements used to make cement (Chandrasekaran, 2018). In contrast to limestone, which may contain impurities like sand, clay, and other minerals, egg shells have calcite, a pure and more stable form of $CaCO_3$. When limestone is ground into powder, it can be utilized for a variety of tasks, including the removal of heavy metals from water and as a filler in cement, concrete, and bricks (Pliya & Cree, 2015).

7.2 Egg Shell as a Waste Product

Solid waste management is one of the challenging issues that rising nations encounter. In developing countries, managing waste generation and disposal is essential. This greater expansion in production is mostly due to the rise in domestic consumption. This may lead to a higher generation of solid waste. To avoid these issues, egg shells could be employed successfully in cementitious blends during the production of concrete (Nandhini & Karthikeyan, 2022). Global egg consumption is highly significant, and with it comes a huge amount of egg shell waste. Egg shell wastes were simply converted to low or high-purity calcium carbonate grades by washing, crushing, and drying to use as raw materials for manufacturing highly valued calcium phosphate products in order to reduce and utilize these wastes (Laohavisuti et al, 2021). Around 83 million tons of eggs were produced worldwide in 2018, which naturally resulted in a large number of leftover egg shells. Eggs, including those from chicken, duck, ostrich, turkeys, geese, and quail, are frequently utilized as food on daily menus. (Oliveira et al, 2013). One of the waste products that could be used to partially replace cement is egg shell. Although complete cement substitution is now impossible, replacing 15% of the cement in the world may drastically reduce CO_2 emissions by up to 250 million tons (Naik et al, 2005).

7.3 Pulverized Egg Shell as Partial Replacement of Cement in Concrete

Egg shell may also be a helpful accelerator since it adds more calcium oxide, which speeds up both the early setting and the final setting of concrete (Mtallib & Rabiu, 2009). Construction projects may frequently be stopped during extended periods of severe rain, so it is preferable to keep the stabilized matrix's setting time as short as possible. The performance of concrete employing egg shell powder as a partial cement replacement at volumes of 5%, 10%, 15%, and 20% is the main subject of this study. The features of egg shell powder, the mechanical characteristics of egg shell concrete, and the performance of egg shell concrete in terms of durability were the three categories into which the examination of egg shell concrete was split.

According to the study of Mahmood et al (2022), replacing cement with pulverized egg shell increased compressive strength at curing ages of 7 and 28 days compared to the comparable control mix up to 10% substitution, thereafter the trend declined. According to the study of Parthasarathi et al (2017), when pulverized egg shell is used as a cement substitute instead of silica fume, the compressive strength of the concrete rises by up to 15%.

8. METHODOLOGY

This chapter includes the methods applied and utilized by the researchers, such as the research design, the instrument, the materials used, the data gathering procedure and data analysis technique, and the statistical treatment of the data. Furthermore, this chapter provided information on the different parts and their importance to the problem of the study.

8.1 Research Design

The study is experimental research, which utilized experimental research design methodology. Experimental design involves establishing a cause-and-effect relationship between different variables. Research papers, works, articles, books, and other studies having context pertaining to or concerning the proposed topic fall under this category, but they are not limited to it. A mixture of standard concrete hollow blocks and a mixture of concrete hollow blocks with PES were used in the study's testing and comparison to ensure the accuracy of the findings.

The researchers gathered egg shells from the household sector as well as from different food businesses such as cakes and pastries stores, restaurants, etc., as these egg shells served as the main subject of the study. Once enough had been gathered, the eggshells were heated and ground into a powder. Then, the PES were added in different ratios as a partial replacement for cement in the concrete hollow block specimens. Lastly, the specimens are set in a curing state for 7, 14, and 28 days.

8.2 Research Methodology

8.2.1 Material Collection. In the material collection, the researchers collected the egg shells by asking for the consent of the owner. The following are the places where the researchers obtained waste egg shells:

8.2.1.1 Household. The researchers collected waste egg shells from different households. Since eggs are often consumed at home, where their shells are thrown away as garbage.
8.2.1.2 Restaurants. The researchers collected egg shell waste in restaurants, where eggs are frequently used as one of their primary ingredients in preparing food.
8.2.1.3 Bakeries. The researchers gathered egg shell scraps in bakeries since eggs are frequently used in baking.

8.2.2 Location of the Simulated Experiment Specimens. The researchers made the specimens in a conducive area located at JV Construction, Bulaon, City of San Fernando, Pampanga.

8.2.3 Testing Laboratory. The researchers visited the Unified Geotest Laboratory at Unit C & D Ground Floor UB Building, MacArthur Highway, Barangay Saguin, City of San Fernando, Pampanga, Philippines, to assess the compressive strength and water absorption percentage of the concrete hollow blocks with PES.

8.4 Procedures in the Production of Simulated Sample

8.4.1 Collecting of Egg Shell

According to Abdulrahman et al. (2014), egg shell is a type of agricultural waste that is often disregarded as useless and dumped because it causes pollution, which is why the researchers came up with the study of PES as a partial replacement of cement in concrete. The researchers collected egg shell waste from households, restaurants, and bakeries inside Pampanga.

8.4.2 Heating of The Collected Egg Shell

After collecting, the egg shell was cleaned to get rid of extra debris. Then, the researchers adapted the technique of heating described by Shiferaw et al. (2019), where the egg shells were heated at 120°C for about 2 hours and then crushed into powder.

8.4.3 Preparation of the Simulated Specimens

The following procedures for making and curing the concrete specimens were all based on ASTM C129, also known as "**Standard Specification for Non-Load Bearing Concrete Masonry Units”**.

8.4.4 Preparation of Mixture for Non-Load Bearing Concrete Hollow Blocks

Table – 1: Raw Materials Used for each Specimen

PES-CHB	MATERIALS			TOTAL (kg)
	CEMENT (kg)	PES (kg)	SAND (kg)	
Control Sample	3	0	9	12
Experimental Setup A – 5%	2.85	0.15	9	12
Experimental Setup B – 10%	2.7	0.3	9	12
Experimental Setup C – 15%	2.55	0.45	9	12

In this study, the researchers adapted the designed proportional mixtures 1:3 for Pulverized Egg Shell (PES), cement and sand respectively and these are:

a. 0% of PES, 25% of Cement and 75% of Sand
b. 1.25% of PES, 23.75% of Cement and 75% of Sand
c. 2.5% of PES, 22.5% of Cement and 75% of Sand
d. 3.75% of PES, 21.25% of Cement and 75% of Sand

Table – 2: Raw Materials Used for the Total *Specimens*

PES-CHB	MATERIALS		
	CEMENT (kg)	PES (kg)	SAND (kg)
Control Sample	54	0	162
Experimental Setup A – 5%	51.3	2.7	162
Experimental Setup B – 10%	48.6	5.4	162
Experimental Setup C – 15%	45.9	8.1	162
TOTAL	199.8	16.2	648

Table 2 shows the number of raw materials used by the researchers for all specimens required for the compressive strength and water absorption tests, such as cement, pulverized egg shell, and sand.

8.4.5 Forming the Simulated Sample

8.4.5.1 Making of Standard Concrete Hollow Blocks Control Sample

1. In this study, the proportion of cement and sand is 1:3. All the materials are mixed thoroughly until the correct consistency of the mixture was acquired and it produced blocks with a dimension of 400 mm x 200 mm x 4 in.
2. The mixture is poured in a hollow block molder, and to get a clean and level top, the extra concrete mixture is then scraped off using a flat, even metal piece.
3. Lastly for 7, 14, and 28 days for the concrete hollow blocks to cure.

8.4.5.2 Making of Standard Concrete Hollow Blocks with Partially Replaced Pulverized Egg Shell Sample

1. Use a blender to crush the collected eggshells until they become fine and pulverized, then sieve them with a strainer to achieve the desired size of PES.
2. The concrete mix for the control setup was composed of 1 part cement and 3 parts fine aggregates. For the experimental setup, the specimen was partially replaced at a percentage of 5%, 10%, and 15% of the total weight of the cement, which is in kilograms. For the whole production of specimens, the researchers produced a total of 16.2 kilograms of PES for the experiment. The concrete component was mixed manually until the right consistency was achieved.
3. After achieving the proper mixture for the concrete hollow blocks, the mixture is then poured into the molds. Each block will be marked with the sample's date, indication, and number.
4. Lastly, the concrete hollow block specimens are to be cured for 28 days. The concrete specimens were kept for 7 days, 14 days, and 28 days for testing in terms of their compressive strength.

9. RESEARCH TESTING

All the specimens, including the control and simulated specimens, were tested in the Universal Testing Machine (UTM) or compression machine to obtain their respective compressive strengths. Furthermore, the two mentioned tests were used to determine the properties and behavior of concrete mix. The data gathered for testing were used to compare each specimen, and the results of the comparison served as the determining factor if there was a significant effect of change in the compressive properties of CHB with PES.

9.1 Compressive Strength Test

The higher the compressive strength of the CHB with PES, the better it is. This is one of the most considered properties of CHB used for masonry materials. The compressive strength test is an important test to assure the quality of CHB that conforms to the standard specifications of ASTM C129, or the "Standard Specification for Non-Load-Bearing Concrete Masonry Units".

In this study, the sample specimen was set to obtain its compressive strength after 7 days, 14 days, and 28 days of curing. To achieve the first objective of this study, the compressive strength of the samples at 7 days, 14 days, and 28 days was tested. Then, the obtained results were compared to the standard compressive strength of a non-load-bearing block, which specifies that the average minimum strength should be 4.14 MPa.

Table – 3: Average Compressive Strength of the Hollow Blocks

PES - CHB	DAYS	Average Value	STANDARDS ASTM C129 (MPa)	REMARKS
CS	7	7.87	4.14	PASSED
	14	8.59		PASSED
	28	9.31		PASSED
5%	7	6.50		PASSED
	14	8.58		PASSED
	28	8.72		PASSED
10%	7	6.69		PASSED
	14	7.14		PASSED
	28	9.87		PASSED
15%	7	6.78		PASSED
	14	7.00		PASSED
	28	9.15		PASSED

In Table 7, all samples passed the ASTM standard compressive strength for Non-Load-Bearing Hollow Blocks. The table above shows the average value of compressive strength in MPa for each mix proportion percentage on the 7^{th}, 14^{th} and 28^{th} day.

9.2 Water Absorption Test

The water absorption test was carried out in accordance to ASTM C 129 standard for Testing Concrete Masonry Units. The water absorption of Concrete Mixture with PES will be compared to the standard concrete mixture with 0% mixture of PES. To obtain water absorption percentage, the researchers will use the equation:

$$W = \frac{Ww}{Ws} \times 100\%$$

Where:

W = Moisture Content Percentage
Ww = Weight of Water
Ws = Weight of Solid

Table – 4: Water Absorption Data of the Hollow Blocks

Water Absorption	PES - CHB Average %			
	CS	5%	10%	15%
7th Day	8.42%	7.96%	7.2A%	8.56%
14th Day	7.31%	8.87%	8.64%	9.24%
28th Day	7.22%	8.35%	6.27%	7.67%
ASTM STANDARD maximum %	24.01%			
Remarks	PASSED	PASSED	PASSED	PASSED

Table 10 shows the result of the water absorption test and the impact of PES replacement in concrete hollow blocks after 7, 14, and 28 days. According to ASTM C129, the water absorption must be less than the permitted maximum. A final water absorption of 24.01% or less indicates that the block can be used as a non-load-bearing block, and it was met by all specimens.

9.3 Cost Analysis

A breakdown of the concrete mixture components for the control and experimental setups was prepared. Then, the regular costs for each material or component were obtained. The total cost of 400 mm by 200 mm by 4 in concrete hollow blocks was obtained for the control setup (standard concrete hollow block mixture) and the experimental setup (concrete hollow block mixture with PES as a partial replacement for cement). The weight of the materials was specified in kilograms.

Table – 5: Computed Cost per Setup

MATERIALS	CONTROL SAMPLE	EXPERIMENTAL SETUP A	EXPERIMENTAL SETUP B	EXPERIMENTAL SETUP C
CEMENT	PHP 240.00 (1 BAG)	PHP 228 (0.95 BAG)	PHP 216.00 (0.90 BAG)	PHP 204.00 (0.85 BAG)
FINE AGGREGATES	PHP 210.00 (3 BAGS)	PHP 210.00 (3 BAGS)	PHP 210.00 (3 BAGS)	PHP 210.00 (3 BAGS)
TOTAL	PHP 450.00	PHP 438.00	PHP 426.00	PHP 414.00

Table 11 shows the cost estimates for the control sample and the experimental setup with pulverized egg shell (PES) partially replacing cement. As indicated in Table 11, the Experimental Setup C with 15% partially replaced pulverized (PES) cement is the most cost-effective, costing only PHP 414.00, whereas the Control Sample costs PHP 450.00.

The experimental setup B is highly recommended as an alternative to the standard concrete hollow block mixture. In the control sample, the estimated cost was PHP 450, while in the experimental setup B, it was PHP 438. There was a PHP 12.00 difference between the two setups. Therefore, there is a significant difference in the cost of preparing a concrete hollow block mixture with partially replaced pulverized egg shell (PES) in cement compared to the standard concrete hollow block mixture.

10. CONCLUSION

1. On the 7th and 14th day, none of the experimental setup surpassed the control setup. On the 28th day, the 10% PES-CHB achieved the highest compressive strength with a value of 9.87 MPa and surpassed the control setup. Following that were 15% PES-CHB with a compressive strength of 9.15 MPa and 5% PES-CHB with a compressive strength of only 8.72 MPa.

2. In terms of compressive strength tests, water absorption tests, and the cost of specimens. 10% PES-CHB is the most recommended to use since it surpassed the control setup, achieved the optimum compressive strength, has the lowest water absorption percentage, and is more cost-efficient compared to the control setup.

3. All of the PES-CHB did meet the minimum compressive strength requirement of ASTM C129, meaning they can still be used as non-load-bearing blocks.

4. The 10% PES-CHB (in the 28th day) obtained the lowest value for absorption with 6.27%, while the 5% PES-CHB obtained the highest value with 35%. All the CHB passed the ASTM C129 standard, which has 24.01% for maximum water absorption.

5. Using pulverized egg shell can reduce the cost of the project. Concrete samples with 10% pulverized egg shell cost PHP 426.00, and standard concrete samples cost an estimated PHP 450.00.

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