

Study on Comparison Mechanical Properties of Concrete using Eggshell Powder and Palm Oil Bottom Ash as a Replacement Material in Concrete

Muhammad Firman¹, Mohamad Luthfi Ahmad Jeni^{1*}, Hilmi Kosnin¹

¹ Faculty of Engineering Technology

Universiti Tun Hussein Onn Malaysia, Higher Education Hub, Pagoh, 84600 Johor, MALAYSIA

*Corresponding Author: luthfi@uthm.edu.my

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Abstract

This study focuses on producing Eggshell Powder (ESP) as a substitute for cement and Palm Oil Bottom Ash (POBA) as a replacement for fine aggregate in concrete mixtures. The primary objective is to assess the density and compressive strength of concrete when alternative substances are used as replacements for cement. The second goal is to evaluate the effectiveness of Eggshell Powder (ESP) and Palm Oil Bottom Ash (POBA) as replacement materials for concrete. The design mix is calculated using the Design of Normal Concrete Mix (DOE Method), with replacement percentages of cement and fine aggregate set at 0%, 10%, 20%, and 30%. Density tests, water absorption tests, and compression tests are conducted on 48 concrete cubes at the ages of 7 and 28 days. The experimental results indicate that concrete samples with 30% ESP and POBA exhibit the highest compressive strength and the lowest water absorption ability compared to those with 20% and 30% ESP and POBA. In adhering to a comprehensive dedication to achieving sustainable development goals (SDGs), an innovative approach within the construction domain encompasses the use of environmentally-friendly substitutes in concrete composition

1.1 Introduction

As we know the demand for material such as cement, sand and aggregate are high. The construction industry is become bigger each day, but nowadays the price of material is not cheap like the old days. The price is increase drastically by 30% for the past few years. According to [1], this condition is affecting the price of the construction process and the price of the building that will be sells. This study aims were to reducing the usage of natural fine aggregate and cement in concrete mixture and to achieve most likely equivalent strength of normal concrete mixture. Firstly, the reason why the Eggshell Powder (ESP) as a replacement for cement because Eggshell powder is a waste material generated from the food industry, typically from egg processing plants or household waste. It consists mainly of calcium carbonate (CaCO₃) and contains trace amounts of other minerals such as magnesium, phosphorus, and potassium. Eggshell is one of the waste materials being generated in abundance across the world, especially in Pakistan. The use of eggshell powder in concrete has been studied as a partial replacement for cement or as a fine aggregate. Research has shown that eggshell powder can improve the mechanical properties of concrete, such as compressive strength, flexural strength, and abrasion resistance. Other than that, another reason why the Palm Oil Bottom Ash (POBA) as a replacement for sand aggregate because Bottom ash is a byproduct of coal combustion in power plants and is collected at the bottom of the furnace. It consists of inorganic materials, such as silica, alumina, iron, calcium, and other trace elements.

Bottom ash is typically disposed of in landfills, but research has explored its potential use as a SCM in concrete [2].

2.0 Materials and Method

Eggshell powder contains calcium, zinc, iron, phosphorus, and magnesium. It is also known as a smooth surface that is desirable compared to rough eggshells that fracture more easily. The characteristics of the eggshell are similar to quarried limestone in terms of durability, water absorption and strength. That's why eggshell is selected to replace quarried limestone. Besides, eggshell also has its grade, which is the best quality from commercial layers containing approximately 2.2 grams of calcium in calcium carbonate forms. Many factors affect quality, such as nutrient adequacy, flock health problem, environmental condition and breeding [3]. While, Palm oil bottom ash (POBA) is a waste material generated during the combustion of palm oil industry residues, particularly from the burning of palm kernel shells or empty fruit bunches. It is a byproduct obtained from the bottom of the furnace or boiler after the combustion process. Regarding physical properties, POBA is characterized by a granular and irregular shape. It may contain residual carbon or charred biomass, affecting its colour and porosity.

2.1 Materials

This research utilizes Eggshell Powder as a substitute for cement and Palm Oil Bottom Ash as a replacement for fine aggregate. The composition of the concrete mix adheres to the design specifications, typically consisting of a binder (cement and water) and fillers (fine and coarse aggregate). Consequently, the concrete specimens are shaped as cubes, each side measuring 100mm. The standardized selection of these materials ensures consistency and eliminates any potential discrepancies in the data obtained from each specimen.

2.1.1 Eggshell Powder

Eggshell powder possesses several characteristics that make it a potential replacement for cement in concrete, offering specific benefits. One of its key characteristics is its pozzolanic properties. High levels of calcium carbonate present in eggshells enable the powder to react with calcium hydroxide in the presence of water, forming additional calcium silicate hydrate (C-S-H) gel [4]. This reaction contributes to the strength and durability of the resulting concrete.

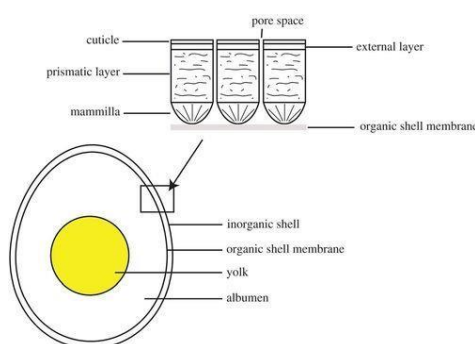


Fig. 1: Part of eggshell

2.1.2 Palm Oil Bottom Ash

Palm oil bottom ash (POBA) possesses distinct characteristics that are significant in evaluating its potential applications. POBA is typically composed of coarse particles with varying sizes, which can influence its suitability for specific uses like concrete or road construction that require particular particle size distributions. Bottom Ash also have angular particles with a very porous surface texture. Bottom ash particles range in size from a fine gravel to a fine sand with very low percentages of silt-clay sized particles.



Fig. 2: Bottom Ash

2.2 Methodology

This chapter emphasizes the method of research that will be executed to achieve the objective of the research. This includes the preparation of sample testing, procedure for testing of sample, apparatus, and materials needed in this research. This chapter will help and guide in understanding the flow of research and will give an early image of how the experiment will be executed. The set of lab testing helps us to achieve the objective of the research which is to know the compressive strength, water absorption, and density of the sample and to know the best replacement portion of eggshell powder (ESP) for cement and bottom ash (POBA) for fine aggregate in concrete mix

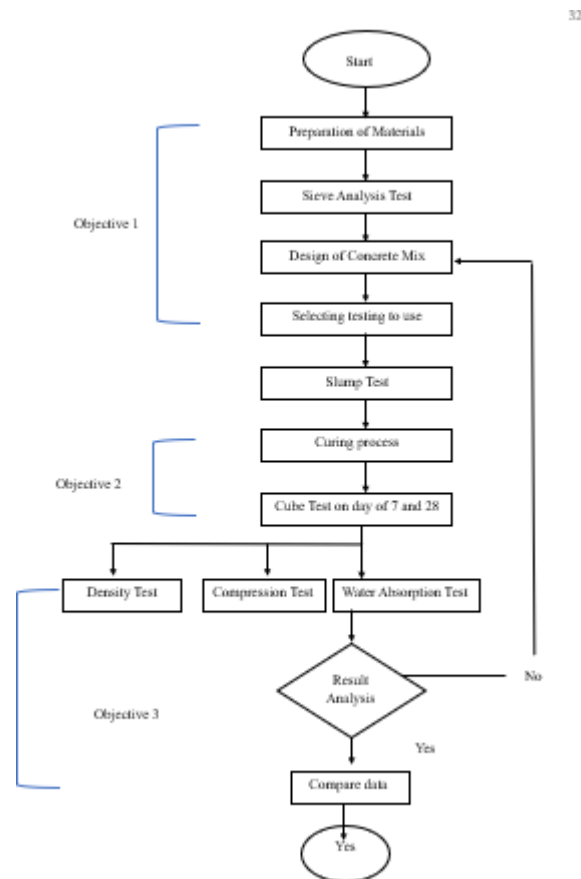


Fig.3: Flowchart Methodology

2.2.1 Preparation Materials

Concrete is a mixture of cement, fine aggregate, coarse aggregate, and water and the proportion of each material controls the strength and quality of the resultant concrete. In this research, two coarse aggregates were used, which are gravel and Palm Oil Bottom Ash (POBA). The artificial replacement coarse aggregate is producing Palm Oil Bottom Ash (POBA) and eggshell powder as a replacement for cement in concrete. The preparation of material is crucial to ensure the experiment will run smoothly

Table 1 The quantity of the material used in concrete mix design (DOE Method)

Quantities	Cement (kg)	Water (kg or l)	Fine Aggregate (kg)	Coarse Aggregate (kg)		
				10mm	20mm	40mm
Per m ³ (to nearest 5kg)	381	210	808	-	1075	-
Per trial mix of 0.012m ³	4.57	2.52	9.70	-	12.85	-

Table 2 Total weight of Bottom Ash (POBA) used as the fine aggregate replacement per trial mix of 0.012m³

Percentage of POBA (%)	Total weight of POBA (kg)	Total weight of Natural Fine Aggregate (kg)
0	0	9.70
10	0.97	8.73
20	1.94	7.76
30	2.91	6.79

Table 3 Total weight of Eggshell Powder (ESP) used to replace the Ordinary Portland Cement (OPC) for per trial mix of 0.012 m³

Percentage of ESP (%)	Total weight of ESP (kg)	Total weight of Ordinary Portland Cement (kg)
0	0	12.85
10	1.28	11.56
20	2.57	10.28
30	3.85	8.99

The control in this study involves the sample with 0% substitution of the ESP and POBA, serving as the reference. The mechanical characteristics of the reference sample are contrasted with those of other concrete cubes, each featuring varying proportions of ESP and POBA replacement in the concrete mixture. All concrete cube specimens undergo a curing period of 7 days and 28 days in the curing tank before laboratory testing is conducted.

2.3 Laboratory Test

For this study on the ESP as replacement material for cement in concrete mix, 48 samples of concrete cubes were prepared for concrete test. The production of concrete cubes was involved in 3 tests, which is each test will use 24 concrete cubes. Except for compression test, the test will use same concrete cubes for the other 2 test as the test only taken the weight and dimension of cubes. The number of concrete cubes used in each test will be distributed based on the age of concrete cube such as 7 and 28 days.

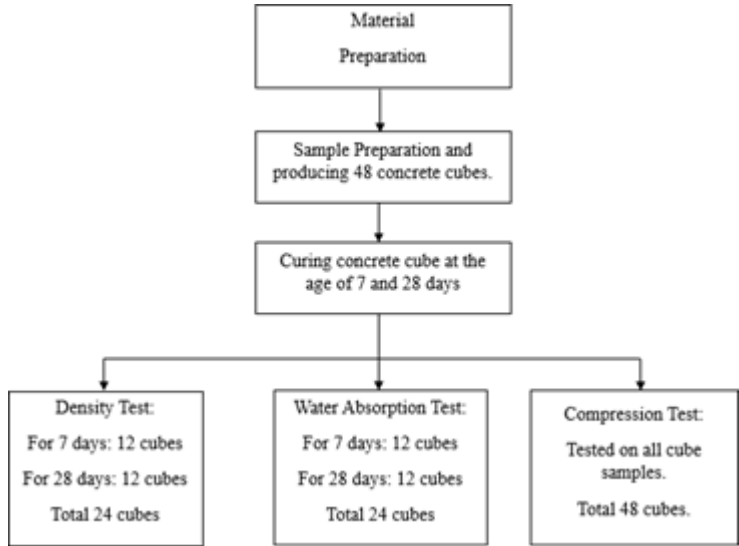


Fig. 4: Laboratory Testing Flowchart

3.0 Result and Analysis

After experimenting on the prepared sample, the subsequent sections involve the analysis of data. The analysis of results entails comparing the experimental findings with the theoretical framework. This study utilizes data obtained from tests such as sieve analysis, slump test, compressive strength test, water absorption test, and concrete density. To enhance comprehension of the data analysis, all gathered information will be presented in both graphical and tabular formats

3.1 Sieve Analysis Test

The assessment of natural fine aggregate is outlined in Figure 5, serving to ascertain its distribution and grade. As per the guidelines provided by [5], it is recommended that the size of fine aggregate does not exceed 5 mm. The grading process, by BS 410:1986 (Specification for Test Sieves), categorizes natural fine aggregate into Zone 2.

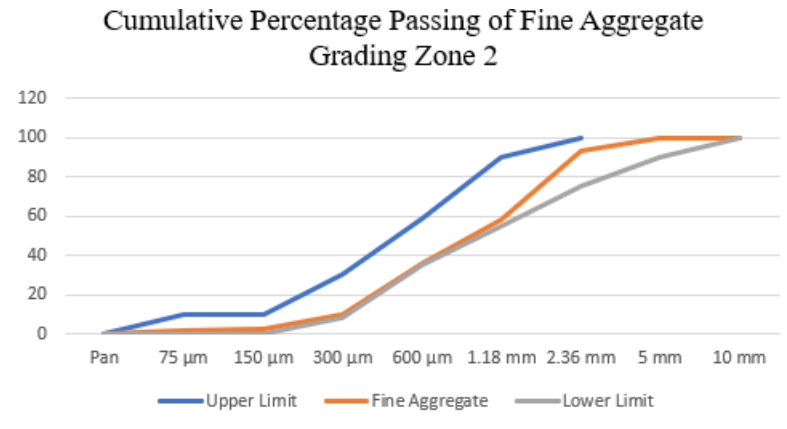


Fig. 5: Cumulative percentage passing of natural fine aggregate within grading Zone 2

3.2 Slump Test

To validate the consistency of the recently developed concrete blend, a slump test was conducted following the guidelines specified in BS EN 12350-2: 2009 (Testing for fresh concrete: Slump test). The outcomes of the slump test can be found in Table 4, while Figure 6 illustrates a graphical representation of the relationship between slump height and the percentage of Eggshell Powder and Bottom Ash Fine Aggregate.

Table 4: Result of Slump Test

Percentage of ESP and POBA (%)	Collapse Height (mm)	Type of Collapse	Degree of Workability
Control	54	True Slump	Medium
10	40	True Slump	Medium
20	45	True Slump	Medium
30	49	True Slump	Medium

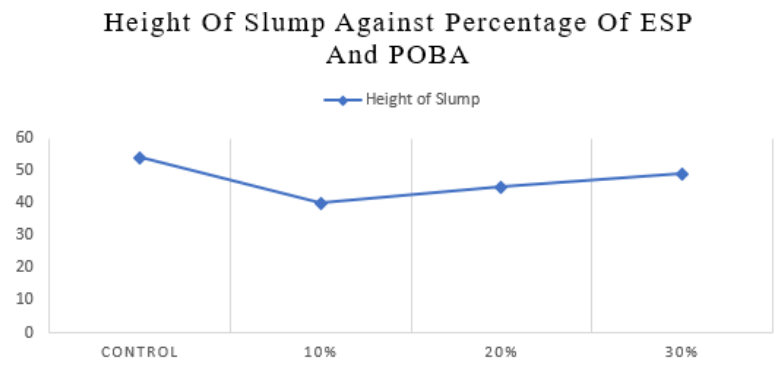


Fig. 6: Graph of height of slump against percentage of Eggshell Powder and Bottom Ash Fine Aggregate

3.2 Compressive Test

The evaluation of compressive strength followed the guidelines outlined in BS EN 12390-3:2009, specifically concentrating on the examination of hardened concrete, particularly in terms of the compressive strength of test specimens. The results of the compressive strength tests conducted at both 7 and 28 days, involving different ratios of ESP and POBA, are presented in Table 5. Figure 7: Result of compressive strength test with different percentage of Eggshell Powder and Bottom Ash Fine Aggregate at the age 7 & 28 days

Table 5 Result of compression test with different percentage of ESP and POBA at the age 7 and 28 days

Percentage of ESP and POBA (%)	Average Strength of Concrete Cube Samples (Mpa)	
	7 Days	28 Days
Control	30	39.8
10	21.5	28.8
20	21.4	29.6
30	23.3	30.8

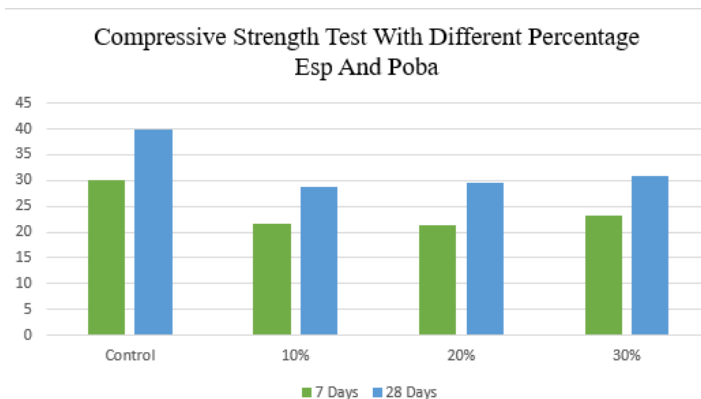


Fig.7: Graph of compressive strength test with different percentage of ESP and POBA at the age 7 and 28 days

3.3 Water Absorption Test

The water absorption test was done according to the BS 1881 - 122: 1983 (Method determination of water absorption). Table 6 shows the result of water absorption test with different percentage of ESP and POBA at the age 7 & 28 days and Figure 8 shows the graph of water absorption test with different percentage of ESP and POBA at the age 7 and 28 days. The result was obtained by taking the average value of 3 cube samples that had been dried in the oven for 72 hours and immersed for 30 minutes.

Table 6 Result of water absorption test with different percentage of ESP and POBA at the age 7 and 28days

Percentage of ESP and POBA (%)	Average Percentage of Water Absorption (%)	
	7 Days	28 Days
Control	1.83	1.35
10	2.19	1.87
20	3.36	2.38
30	4.45	3.27

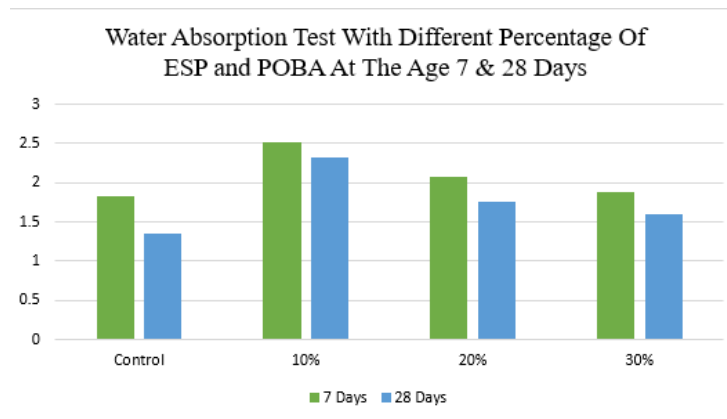


Fig. 8: Graph of water absorption test with different percentage of ESP and POBA at age 7 and 28 days

3.4 Density Test

This sub chapter focuses on how the density of a concrete cube affects its compressive strength and water absorption. The density of a concrete cube was calculated using an average of three cubes aged 7 and 28 days. Table 7 shows the full results of density concrete cubes with different percentages of ESP and POBA for Compressive Strength Tests at 7 and 28 Days.

Table 7 Result of density concrete cube with different percentage of ESP and POBA at the age 7 and 28days

Percentage of ESP and POBA (%)	Average Density (kg/m ³)	
	7 Days	28 Days
Control	2310	2337
10	2128	2210
20	2276	2263
30	2298	2290

4. Conclusion

In conclusion, the result of experimental data in this study has yielded valuable insights and recommendations in line with the specified objectives. The focus of the findings revolves around the effectiveness of incorporating Eggshell Powder (ESP) and Palm Oil Bottom Ash (POBA) as substitutes for cement and fine aggregate in the concrete mix. The study has successfully identified the optimal content of these materials through varying replacement rates of 10%, 20%, and 30% for cement and fine aggregate. The primary objective, evaluating the density and compressive strength of concrete with alternative materials, was met, with concrete featuring a 30% replacement of ESP and POBA demonstrating superior performance in both compressive strength and water absorption tests compared to lower replacement rates. The comparison with standard concrete (grade 30) across density, compressive strength, and water absorption tests revealed its overall dominance, but the concrete sample with a 30% replacement of ESP and POBA emerged as the most effective alternative in this study.

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Author Contribution

*The authors confirm contribution to the paper as follows: **Study on Comparison mechanical properties of concrete using Eggshell Powder and Palm Oil Bottom Ash as a replacement material in concrete: Muhammad Firman Bin Jamaluddin**, **Supervisor: Mohamad Luthfi Bin Ahmad**. All authors reviewed the results and approved the final version of the manuscript*

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