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Stress and Strain Relationship for Cylinder Concrete Containing Palm Oil Fuel Ash (POFA) and Expanded Polystyrene (EPS)

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Abstract: In this world, concrete is the most important component for building construction. The purpose of the concrete has remained constant across time, but the component of the concrete has changed. As a result, various innovative ideas and a revolution in modified concrete have been implemented. This will help to reduce the use of natural resources such as gravel and river sand in concrete mixes. In this study, Palm Oil Fuel Ash (POFA) will be implemented as a cement replacement, while Expanded Polystyrene (EPS) will be applied as a fine aggregate replacement in the concrete mixture. This research analyses the stress and strain of a concrete cylinder containing POFA and EPS with replacement percentages of 0.00 % (control sample), 10.00 %, and 20.00 %. The objective of this research is to study the relationship of stress and strain for concrete containing EPS and POFA, to compare the exile comprehensive strength of concrete containing EPS and POFA with normal, and to establish the elasticity value of EPS and POFA containing concrete. This research's methodology must be carried out in accordance with the procedures in order to obtain actual data, whether in theory or in practice. During the test, the concrete sample with more replacement material produces more faults before failing. The test concluded that 10.00 % POFA and 10.00 % of EPS is the optimum value to be as a replacement material as the strength and the strain of the concrete were relatively close to the normal concrete.

Keywords: Concrete, POFA, EPS, Cement, Compression

1. Introduction

Concrete is a building material or mixture made up of cement, fine aggregates (sand), coarse aggregates, and water with proper ratio. The purpose of concrete has not changed over time, but the components of concrete have. As for today, the elements for making the concrete are cement, aggregate and water and the with right ratio and practical uses of these elements, a good concrete can be made.

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However, different types and ratios of the concrete mixtures will be obtained different strengths [1]. The compressive strength of a solid cube or cylindrical specimen is used to determine the value of concrete strength. Different concrete compressive strengths served different purposes. Nowadays, there have been numerous studies on low density concrete made from recycled materials that have achieved a certain level of workability and strength. As a result, ordinary concrete can be replaced with low density and long-lasting concrete. Furthermore, in order to achieve a balanced development and in accordance with current technology, recyclable materials have been widely used in concrete construction [2]. As stated in the project's scope, the goal is to develop a strong concrete that can withstand the load in a building construction by using POFA as a binding component and replacing concrete.

1.1 Palm Oil Fuel Oil (POFA)

Palm oil fuel ash (POFA) and expanded polystyrene (EPS) are two examples of waste materials that are capable of producing low density concrete with comparable performance. POFA is a significant by-product of the palm oil industry and can be visually inspected as greyish in color [3].

1.2 Expanded polystyrene (EPS)

There has been a surge in interest in the use of expanded polystyrene (EPS) in the construction industry in recent years. Researchers have previously conducted research on the performance of EPS in concrete. In order to produce lightweight concrete, EPS can be partially replaced with fine aggregate [4].

2. Materials and Methods

This chapter discusses about each part of the project in detail. Palm oil fuel-ash (POFA) and Expanded Polystyrene (EPS) are the key components of this plant, which replace the cement. Most previous research has only looked at Expanded Polystyrene (EPS) as a concrete aggregate. As an alternative to concrete development and as a sustainable solution, this project brings POFA and EPS together in front.

2.1 Material preparation

In this project there will be a sample of concrete cylinder where 42 of the sample each contain different ratio of EPS and POFA as shown in Table 1. The concrete sample that contains 0.00 % POFA and EPS will be kept as a control sample and will be treated as normal concrete with full cement. The concrete cylinder will be 100 mm x 200 mm in size, and a suitable cylinder mould will be used to create the sample. After 7 & 28 days, a concrete test will be conducted, including a slump test for fresh concrete mix and compressive strength and density. While, Figure 1 shows the whole process of this study has been carried out.

Table 1: Sample of concrete containing percentage of POFA and EPS

POFA(%) / EPS (%)		0	10	20
0	No. of Sample	7	7	7
10		7	7	7

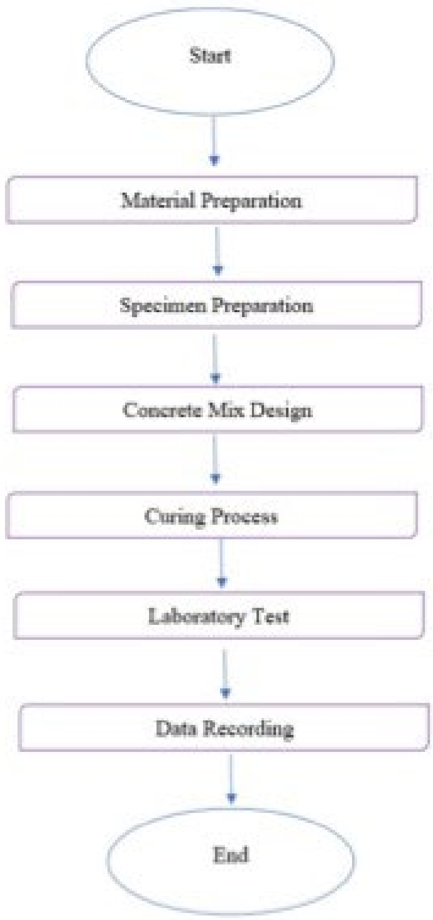

Figure 1: Methodology Flow Chart

Palm Oil Fuel-Ash (POFA) is a waste product formed when palm oil husk or fibre and palm kernel shell are burned as fuel in a palm oil mill burner [5]. Malaysia is the second largest palm oil producing country in the world. In Malaysia, there are around 200 mills producing roughly 100 tonnes of POFA per year. By replacing concrete with POFA as a binding component, a strong concrete that can withstand the load in a building construction can be developed, giving rise to the phrase "green concrete".

Polystyrene in raw beads that has expanded after being steam heated is known as expanded polystyrene (EPS) [6]. EPS is light, has strong energy absorbing properties, and is a good thermal insulator. EPS was used to replace the aggregate in this project at a rate of 0.00 %, and 10.00 %.

2.2 Laboratory test

Two tests will be conducted in the laboratory for this project. Figure 2 shows the laboratory flow that will be carried out. The slump test is conducted in accordance with BS EN 12350-2 (Testing fresh concrete: Slump test), which is used to determine the fresh concrete's workability. The purpose of the test was to ensure that the concrete mixed properly and that the required amount of water was supplied to the mix. Then the most important test for concrete is the compression test, which determines the concrete's characteristics. This test will be carried out after the concrete cylinder has been cured for 7 days and 28 days.

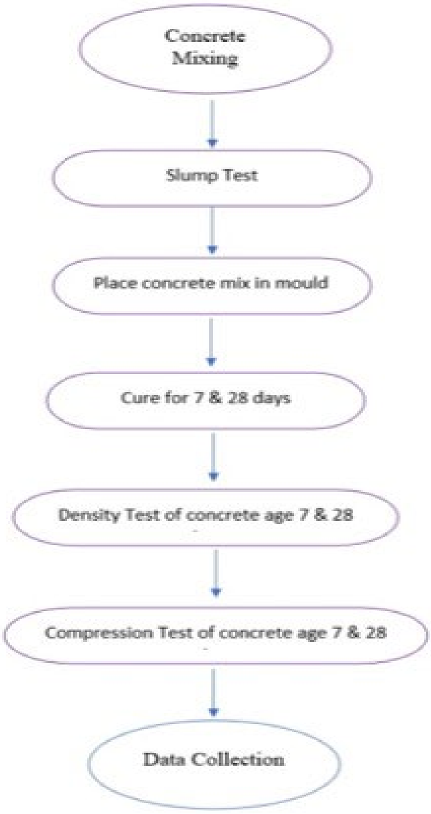

Figure 2: Flow Chart of laboratory test

2.3 Testing of Sample

2.3.1 Compressive Strength Test

The most important test for concrete is the compression test, which determines the concrete's characteristics. This test will be carried out after the concrete cylinder has been cured for 7 days and 28 days. The purpose of this test is to use a concrete compression machine to determine the compressive strength of each cylinder mixture. This test will also provide strain data by connecting a strain gauge to the cylinder during compression testing, as shown in the Figure 3 below. The concrete cylinder will be tested respectively with reference to ASTM C39 (Concrete Cylinders Compression Testing)

Figure 3: Strain gauge on Concrete Cylinder

2.3.2 Splitting Test

A concrete cylinder is loaded along its diameter and put horizontally between loading surfaces in this test. The cylinder receives lateral tensile stress because of this loading, and it breaks in tension along its diameter as shown in Figure 4 below. This test will also provide strain data by connecting a strain gauge to the cylinder during compression testing, as shown in the Figure 5 below. Refer ASTM C 496 for the split cylinder test procedure.

Figure 4: Splitting test on Concrete Cylinder

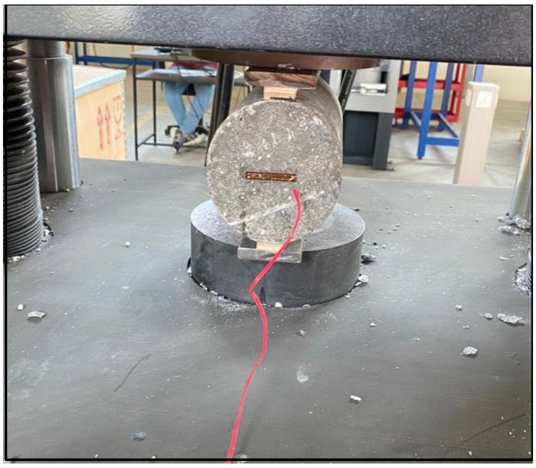

Figure 5: Split cylinder test with strain gauge

3. Results and Discussion

The results of the tests on concrete samples were discussed in this chapter. Slump tests, compression tests, stress and strain tests, and modulus elasticity of concrete are all included. The findings were analysed in order to determine the study's objective.

3.1 Slump Test

The test is conducted in accordance with BS EN 12350-2 (Testing fresh concrete: Slump test), which is used to determine the fresh concrete's workability. The purpose of the test was to ensure that the concrete mixed properly and that the required amount of water was supplied to the mix. The slump test works on the premise of compacting fresh concrete into a cone-shaped mould. The collapse height of the slump in each sample containing Palm Oil Fuel Ash and Expanded Polystyrene is shown in Table 2. According to Table 3, there are slightly decreasing number of collapse height of the slump of the samples when the number of POFA and EPS increases. The range was roughly 3.00 to 19.00 mm, which was not significantly different from the control samples, indicating that the workability of the concrete samples containing POFA and EPS was not significantly different from that of normal concrete. All of the slump values acquired were acceptable because they met the criteria for slump values.

Table 2: Slump Test Result

Palm Oil Fuel Ash (%)	Expanded Polystyrene (%)	Collapse Height(mm)
	0	47
	10	44
0		
	0	35
10	10	32
	0	30
20	10	28

3.2 Compression Test

The test referred to ASTM C39 (Concrete Cylinders Compression Testing) done on the concrete cylinder sample with 100.00 mm diameter and 200.00 mm height. This test conducted after all the samples have been cured for 7 and 28 days. Each percentage of POFA and EPS had 3 samples to determine the average compressive strength of each sample percentage mix.

Based on the Figure 6 below, the strength of the concrete samples decreases as the number of POFA and EPS increase. For instance, the normal concrete in 7 Days and 28 Days having a strength of 21.65 MPa and 22.21 MPa respectively meanwhile the concrete that contain 0.00 % of POFA and 10.00 % of EPS having 18.59 MPa and 18.85 MPa. The design mix for the study is 20 MPa with the replacement materials that has been stated earlier. For concrete containing 0.00 % POFA with EPS 10.00 % the strength value is near the normal concrete strength value, and this is because the bonding between the cement with the EPS were disturbed. Therefore, the strength of the concrete slightly reduces. Based on the findings, it was discovered that the higher the percentage of POFA and EPS in a concrete, the lower its strength and workability. This is due to the fact that when additional replacement materials are introduced, the concrete bond becomes weaker. Although the replacement materials impair workability, minor differences can be overlooked because they can aid in the long-term sustainability and affordability of concrete production. 10.00 % POFA is an ideal percentage for replacement material because it only loses a small amount of strength while still being able to bear weight. More replacement material was not recommended since it would weaken the concrete and make it less workable.

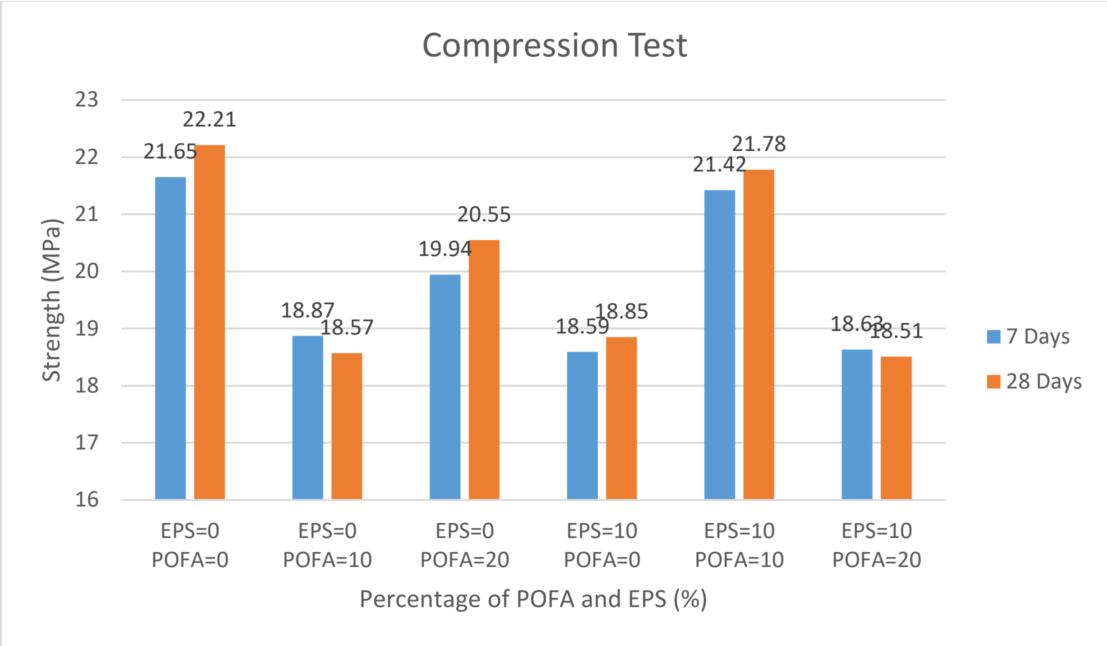

Figure 6: Compressive Strength of Sample

3.3 Splitting Test

The test referred to ASTM C 496 for the split cylinder test procedure done on the concrete cylinder sample with 100.00 mm diameter and 200.00 mm height. This test conducted after all the samples have been cured for 7 days. Each percentage of POFA and EPS had 1 sample to determine the average compressive strength of each sample percentage mix. Table 3 shows the tensile strength of the samples. As a result, the tensile strength it shown decrease due to the concrete mix if the replacement material as POFA and EPS that has been used in the project increases.

Table 3: Tensile strength of the samples

POFA Percentage (%)	EPS Percentage (%)	Tensile strength (Mpa)
	0	25.21
0	10	22.17
	0	24.12
10	10	25.05
	0	18.98
20	10	15.10

3.4 Stress and Strain of Cylinder Concrete

The compression test was conducted simultaneously with the strain measurement. Strain data was gathered using a strain gauge attached to a data logger for reading and recording strain measurements. The strain gauge is affixed to the sample, as indicated in the previous chapter. During the compression test, only two out of three samples had their strain recorded. The results of stress and strain of concrete with different ratios of POFA and EPS are illustrated in Figure 7, 8 and 9 below.

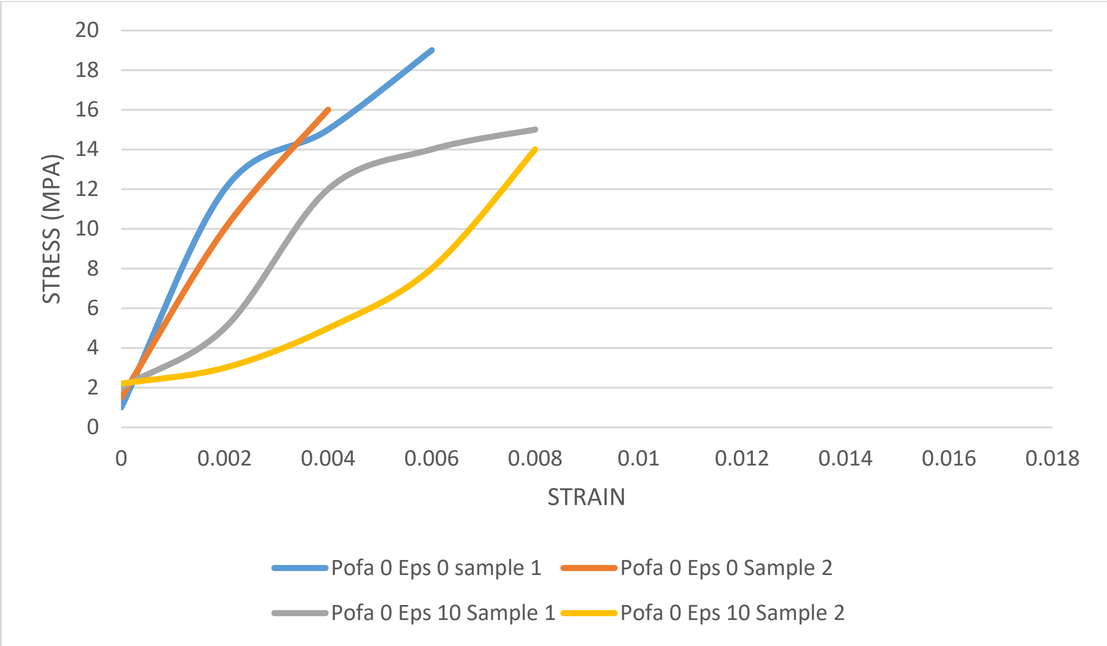

Figure 7: Stress and Strain of concrete contain 0.00 % POFA 0.00 % EPS and 0.00 %POFA 10.00 % EPS

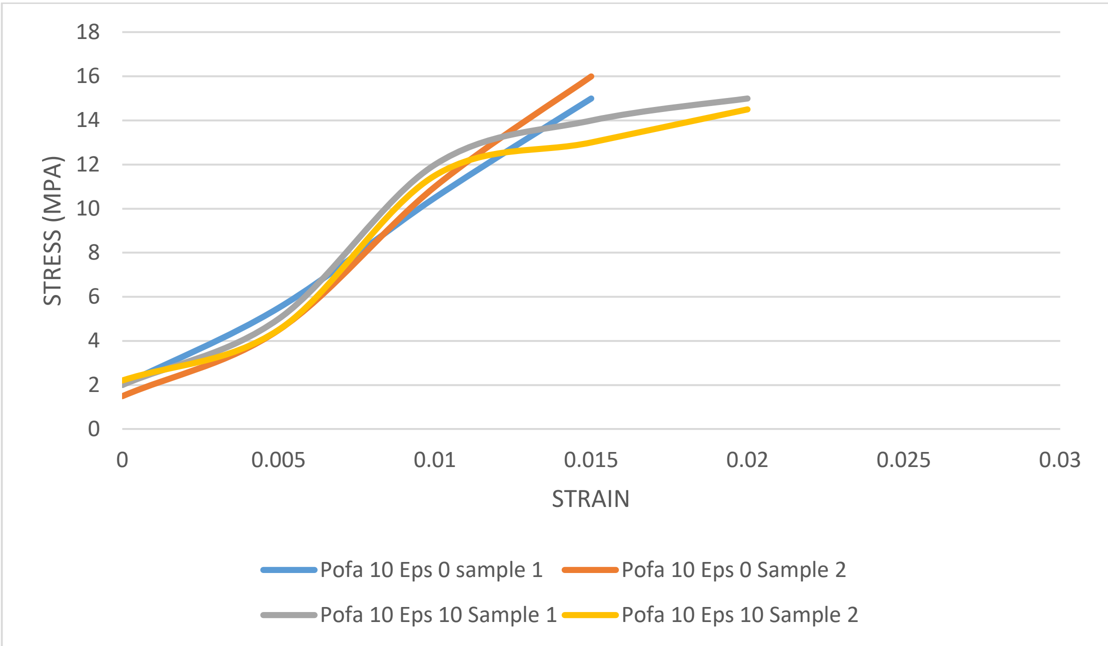

Figure 8: Stress and Strain of concrete contain 10.00 % POFA 0.00 % EPS and 10.00 %POFA 10.00 % EPS

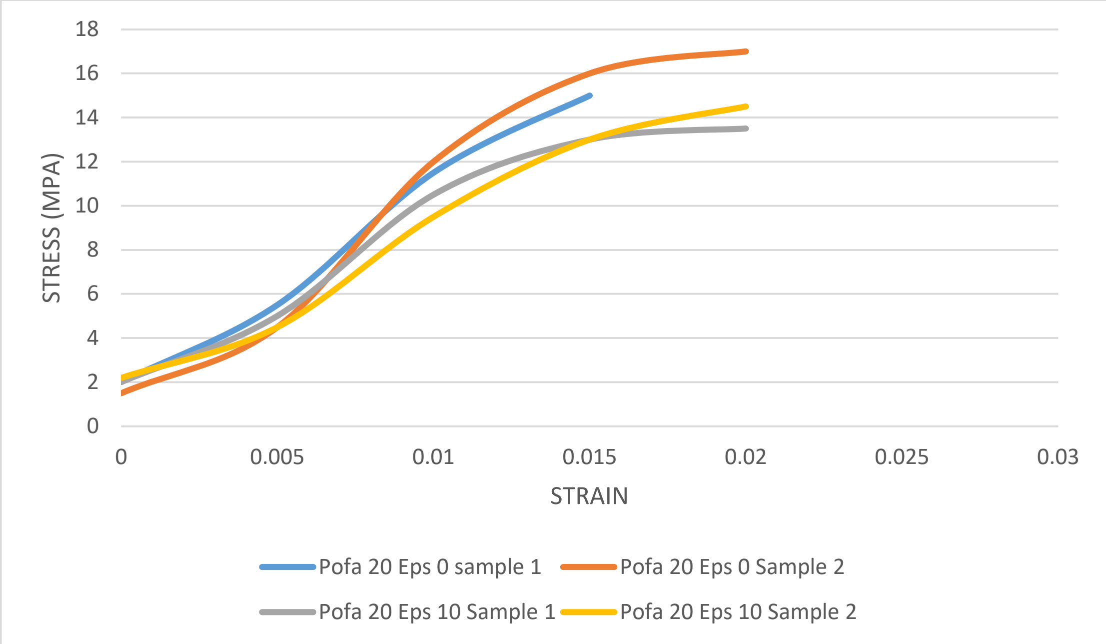

Figure 9: Stress and Strain of concrete contain 20.00 % POFA 0.00 % EPS and 20.00 % POFA 10.00 % EPS

Figure 9 illustrates that as the amount of replacement materials increases, the strain grows as well. Until the concrete collapses, the control sample shows stiff strain values. Meanwhile, when the amount of POFA and EPS added to the concrete samples grows, other samples show a higher number of strain values. It can be shown that the presence of POFA and EPS, which were employed in this study, made concrete expansion simpler.

There were certain limitations in this study's test that must be noted. Because it was connected directly to the concrete surface, the strain gauge was delicate and easily shattered. The strain data of the concrete was only collected in the research until the concrete failed the compression test. The strain gauge did not fully work above the peak value of the concrete's compressive strength due to the existence of a tiny fracture in the concrete failure. Because it is connected to the surface that is cracking, the strain gauge can be pulled away, and the data logger shows no value for the strain data. So, in this study the strain data that were obtained perpendicular when it achieves the maximum stress or cracking surface where strain gauge attached.

3.4 Modulus of Elasticity

The modulus of elasticity of the samples are calculated through the stress and strain data. The data can be obtained by calculate the gradient on stress and strain curve that has been recorded from the previous test. This test was to determine the deformation or the elasticity of the concrete that contain POFA and EPS compare with the normal concrete.

The Table 4 below shows the Modulus of Elasticity of the concrete sample containing percentage of POFA and EPS.

Table 4: Modulus of Elasticity

POFA Percentage (%)	EPS Percentage (%)	Modulus of Elasticity
0	0	9750
	10	7520
10	0	7150
	10	6510

20	0	6250
	10	5500

Higher elastic modulus means that a greater percentage of deformation must occur before the concrete fails, and higher elastic modulus means that a greater force is required to produce a given deformation. The elasticity of the sample with more replacement material tends to be lower. For example, as compared to regular concrete, a sample with 10.00 % POFA and 20.00 % EPS has a significantly lower elasticity value. This is due to a weak and unstable bond between the cement and the EPS. During the test, the concrete sample with more replacement material produces more faults before failing.

4. Conclusion

The test concluded that 10.00 % POFA and 10.00 % of EPS is the optimum value to be as a replacement material as the strength and the strain of the concrete were relatively close to the normal concrete. This can be used to solve a cost problem in the sector, such as a shortage of cement supply, or to create cost-cutting programmes. In conclusion, the goal of this study was met when the compressive and density strengths of concrete were determined. In addition, the value of the modulus of elasticity was established.

Acknowledgement

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