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Mechanical Properties of Concrete Containing Palm Oil Fuel Ash and Modified Expanded Polystyrene Beads as Replacement Materials Using Finite Element Method

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Abstract: Nowadays, so much waste material was dumped and produced by the industrial sector. In this research, the Palm Oil Fuel Ash (POFA) and Modified Expanded Polystyrene beads (EPS) were used as replacement material. The purpose of this research was to focus on replacement of the modified expanded polystyrene beads (EPS) as a fine aggregate and the palm oil fuel ash (POFA) as a cement in term of mechanical properties of concrete. For Modified EPS will replace with aggregate from 10.0 % and 20.0 % While, for POFA will replace with cement from 10.0 %, 20.0 % and 30.0 %. The data of the material replacement for POFA and Modified EPS will be taken from previous study. Furthermore, the concrete cubes will be analyzed using software called ABAQUS. ABAQUS software is used because this software can measure the concrete cubes in such detail. This test will be performed on a cube that has reached the age of 28 days by following the previous experimental results. In addition, the software can also validate the work for the stress and strain of the graph by analyzing the concrete cubes. Information on Modified EPS and POFA can be filled in this software. Furthermore, it can also analyze mechanical properties of concrete that containing. Modified EPS and POFA. Indirectly, this will help compare the strength of concrete cube that containing of Modified EPS and POFA.

Keywords: POFA , Modified EPS, Abaqus

1. Introduction

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The production of cement was expected increase until the major growth in 2030. So, it can give a negative impact and harmful for ecosystem because the progress of global cement consumption will contribute about 5.0 % - 8.0 % of current global Carbon Dioxide (CO_2) [1]. Expanded polystyrene beads (EPS) also can gave impact to ecosystem such as environment pollutions. This happen because millions of tons of waste EPS are not have enough space for landfilling, the costs for disposal this materials is considerable. Not only that, the production of palm oil fuel ash (POFA) also can make environment pollutions. Meanwhile, in Malaysia the palm oil industry was produced about half of the world palm oil production around 10.8 million tonnes, so this making Malaysia as the largest producer and exporter of palm oil.

1.1 Objective

This study was conducted to produce a lightweight concrete by focusing on replacement of the modified expanded polystyrene beads (EPS) as aggregate and the palm oil fuel ash (POFA). For this study, we use 0.0 %, 10.0 %, 20.0 % and 30.0 % percentage of (POFA) and 20.0 % and 30.0 % percentage for the modified (EPS). The objectives of this study are:

a) To analyses concrete cube using finite element method called ABAQUS subjected to surface load and to verify the experimental work result.
b) To compare the relationship of stress and strain for concrete cube that containing Modified EPS and POFA as replacement materials.
c) To verify the performances of mechanical properties of concrete that containing 0.0 %, 10.0 %, 20 0%, 30.0 % of POFA and 20.0 %, 30.0 % of Modified EPS with simulation model by using finite element method based on previous experimental.

1.2 Scope of Study

This concrete was analysed using finite element analysis software that called ABAQUS. The main focus by using this software was to analyze the strength of concrete by compress the cube by using finite element method. The results was the benchmark for reliability of the materials to be used as replacement.

Therefore, expanded polystyrene beads (EPS) as aggregate and palm oil fuel ash (POFA) as a cement in term of mechanical properties will solve the problem. The percentage of modified EPS is 20.0 % and 30.0 % while POFA is 0.0 % to 30.0 % as shown in the Table 1 below.

Table 1: The percentage of replacement materials

Percentage of Modified EPS (%)	Percentage of POFA (%)
20	**0**
30	**10**
	20
	30

2. Materials and Methods

This section will discuss and focus on the previous research, it shows that many attempts have been made in the construction industry to convert various waste in the production of concrete. Besides that, this section also will explain about material and method that were used in production of concrete.

2.1 Materials

2.1.1 Lightweight Concrete

Lightweight concrete has extreme importance to the construction industry. Most of current concrete research focuses on high-performance concrete, by which is meant a cost-effective material that satisfies demanding performance requirements, including durability. Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities such as lessened the dead weight [2]. It is lighter than the conventional concrete. Lightweight concrete mixture is made with a lightweight coarse aggregate and sometimes a portion or entire fine aggregates may be lightweight instead of normal aggregates. Lightweight density on (1440 to 1840 kg/m^3) [3].

2.1.2 Expanded Polystyrene Beads (EPS)

Expanded polystyrene beads was cellweight cellular plastics materials that produce from polystyrene. The materials has been modified by the addition of flame retardant additives [4]. Expanded polystyrene beads (EPS) was a specific name for geofoam. Geofoam was a new geosynthetic product that was proposed in 1992. It encompasses polymeric and non-polymeric foams. Geofoams can perform functions that traditional geosynthetics product cannot perform. Furthermore, geofoams also can be used to complement or enhance the function of other geosynthetics. Indirectly, expanded polystyrene beads was the most widely used geofoam material.

Expanded polystyrene beads are produce by heated and expand from the polystyrene materials. Polystyrene is a vinyl polymer which is a long hydrocarbon chain with a phenyl group attached to every often carbon atom. Besides that, it also produced by free radical vinyl polymerization from monomer styrene. Expanded polystyrene beads are often used as the basic of packaging material and this leads to a large amount of waste material which is not biodegradable [5]. Besides that, [1] reported the polystyrene also can be translated as polymerized styrene. That is the single styrene molecules are chemically joined together to form a large molecule which is called polymer. While, styrene was produced from benzene and ethylene and polymerization is accomplished in the presence of catalysts, usually organic peroxides. The expanded polystyrene beads form is produced as small beads containing a blowing agent.

2.1.3 Palm Oil Fuel Ash (POFA)

Malaysia was considered as the second largest producer and trading exporter of palm oil with approximate amount 50.0 % of the world share production and 61.0 % of exports [6]. In addition, the expansion of palm oil plantings in Malaysia during the past 41 years has been phenomenal and remarkable. From 55,000 hectares in 1960, the oil palm planted area had expanded to 3.5 million hectares by 2001, occupying 60.0 % of the agricultural land in the country. The rapid expansion in oil palm cultivation resulted in a corresponding increase in palm oil production from less than 100,000 tons in 1960 to 11.8 million tons in 2001.

While, in 2005 the total area of palm cultivation was 4 million hectares. From the European report of palm oil statistics, the oil palm plantation area in Malaysia reached 5 million hectares an increase of 3.0 % from 4.85 million hectares in 2011 [7]. From the huge palm oil industries in Malaysia it will produce the waste generated from the oil production. The waste generated from oil production can have several forms and types based on the level of temperature implied and (POFA) is an ash generated in the mill in the form of dust or ash. The huge quantity production of (POFA) will affect the environment if disposed in landfills. Furthermore, [8] reported the process of the production is initially from the burning of oil shells in the boiler factories. While [9] reported it is approximately that, 5.0 % of the waste is considered as POFA. It was stated that, in every 100 tons of fresh oil fruit, approximately 7 tons of fiber are produced and 20 tons of nut shells are generated. In Malaysia 60 millions of tons the total solid wastes were generated annually.

2.2 Methodology

2.2.1 Methodology Flow Chart

Flow chart acts as indicator in the planning that was proposed for early stage of the project or that will be used to identify the progress of work. Figure 1 illustrates the research flowchart.

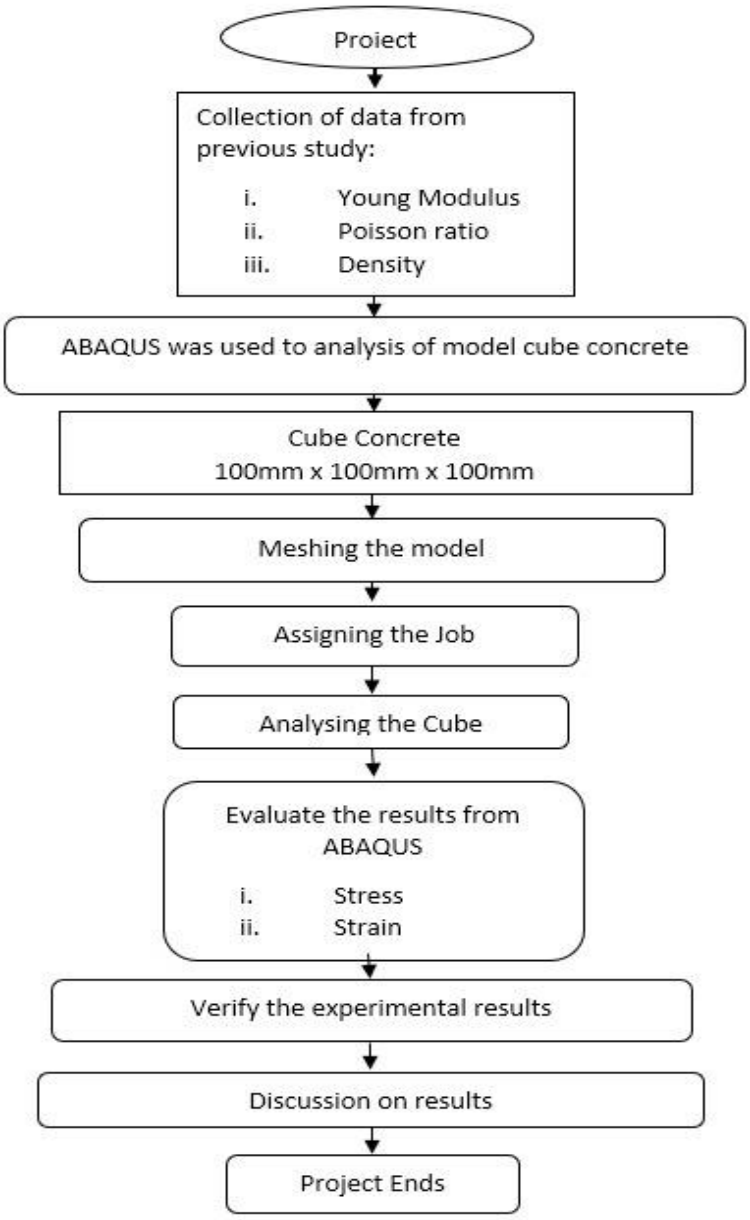

Figure 1: Methodology flowchart

2.2.2 ABAQUS

Generally, finite element analysis has three phase of process which includes pre-processing, solution, and post-processing. For the ABAQUS method that were used for this specimen concrete cube are state as follows :

i. Create a Cube of Concrete
ii. Apply the Section Assignment to the Sample
iii. Application of Assembly to the Sample
iv. Step Module and Boundary Condition
v. Meshing Elements using Abaqus

vi. Job Application using ABAQUS Job Module
vii. Export the Graph in Abaqus to Excel

3. Result and Discussions

This section will be describes more detail about the results and analysis of a study on concrete cube that collected from previous study and experimental. The data was gathered from Abaqus using Finite Element Method (FEM). There are 6 models that were created and meshed in Abaqus. Where, 4 models are for Palm Oil Fuel Ash and 2 model for Modified EPS.

3.1 ABAQUS Data

Simulation ABAQUS was based on result from previous study where the result of young modulus, density and Poisson's ratio was used. Based on result research by [10] [11], [12], [13] as Table 2 and Table 3 below:

Table 2: Concrete in Properties for POFA 0.0 %, 10.0 %, 20.0 % and 30.0 %.

POFA (%)	Density (kg/m^3)	Young Modulus (GPa)	Poisson's Ratio
0	2347	26.17	0.3
10	2328	27.41	
20	2320	28.20	
30	2317	26.99	

Table 3: Concrete in Properties for Modified EPS 20.0 % and 30.0 %.

Modified EPS (%)	Density (kg/m^3)	Young Modulus (GPa)	Poisson's Ratio
0	1970	26.17	0.2
10	1750	27.41	

3.2 ABAQUS Result

This result is conducted by Abaqus using Finite Element Method (FEM). The data that were collected from previous study were fill in the Abaqus to get the result for stress and strain.

3.2.1 Relationship of Stress and Strain on Concrete Cube

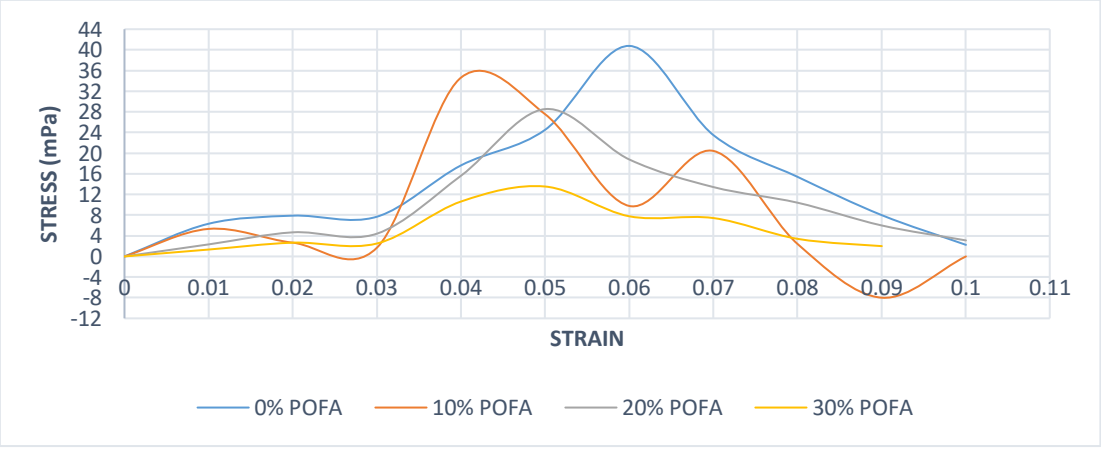

Figure 2: Relationship of Stress and strain on concrete cube containing 0.0 % POFA, 10.0 % POFA, 20.0 % POFA and 30.0 % POFA

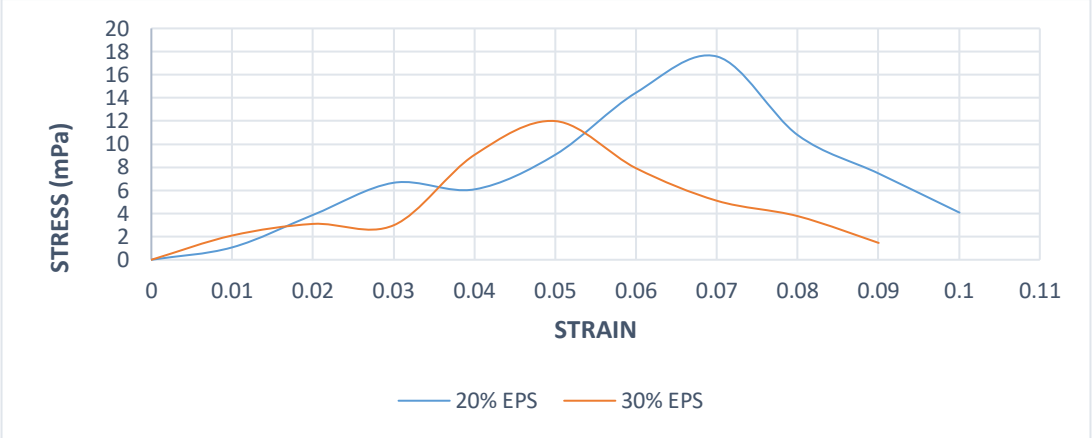

Figure 3: Relationship of Stress and strain on concrete cube containing 20.0 % Modified EPS and 30.0 % Modified EPS

The figure above shows that the trend of stress and strain graph that indicates two sample for each percentage of concrete cube containing POFA and Modified EPS starting from 0.0 % of POFA, 10.0 % POFA, 20.0 % POFA, 30.0 % POFA followed by 20.0 % of Modified EPS and 30.0 % Modified EPS. Figure 2 shows that 0.0 % of POFA the value for stress are highest than the other percentage of POFA. Next, for the 10.0 %, 20.0 % and 30.0 % of POFA shows the decreasing value of strain as the value of percentage of replacement material increases. Meanwhile, for Figure 3 shows 20.0 % and 30.0 % of Modified EPS also shows the decreasing value of strain when the percentage of Modified EPS increases. In addition, the value of stress for 20.0 % and 30.0 % of POFA was highest than the value of stress of 20.0 % and 30.0 % for Modified EPS. It shows that, the replacement of POFA will improve the performance of concrete that the replacement of Modified EPS. To be conclude that, the higher the percentage of POFA and Modified EPS used as the replacement material, the lower the stress strain value of the concrete cube. This is because the expansion of concrete become easier due to the presence of replacement of Modified EPS

3.2.2 Data Analysis for the highest value of Stress

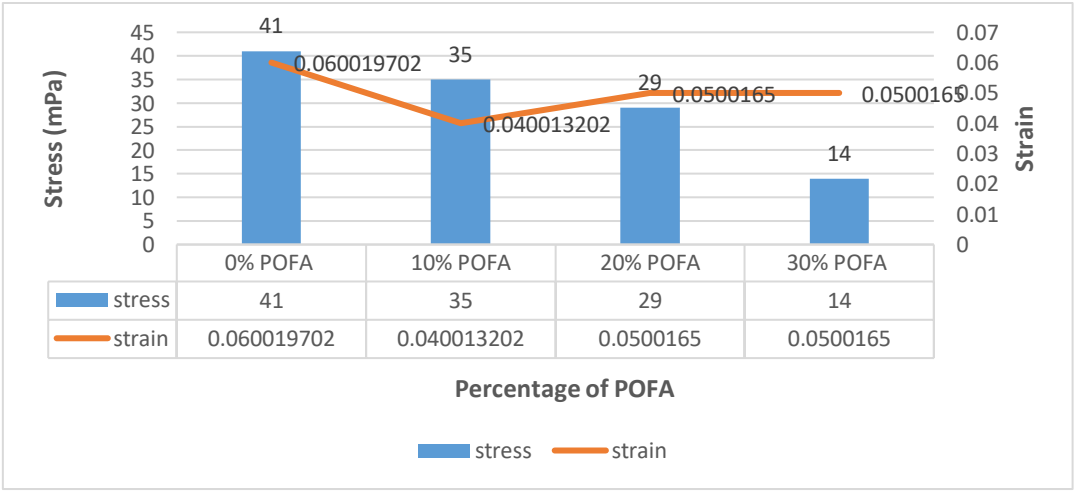

Figure 4: Highest Value of Stress and Strain on concrete cube containing 0.0 % , 10.0 %, 20.0 % and 30.0 % of POFA

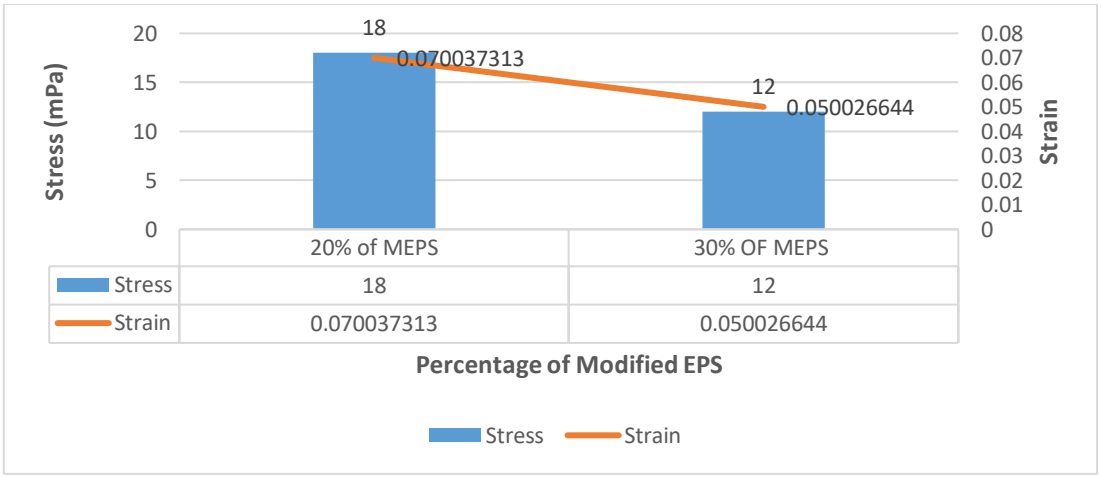

Figure 5: Highest Value of Stress and Strain on concrete cube containing 20.0 % Modified EPS and 30.0 % Modified EPS

The figure above shows that, the highest value of stress for each specimen that was achieved the strength. For figure 4 shows that, the lowest value for stress was 30.0 % of POFA as replacement. The stresses achieve the highest value at strain 0.0500165, same as the value strain of 20.0 % of POFA but the highest stresses value for 20.0 % of POFA was 29 MPa. That's means, the 30.0 % of POFA was easily crack than the 20.0 % of POFA. For the 0.0 % of POFA the value of stresses was 41 MPa and the strain was 0.060019702. For 10.0 % of POFA the value of stresses was 35 MPa and the value of strain was 0.040013202 lower than the value strain of 20.0 % POFA and 30.0 % POFA. So, it will show that, the 30.0 % of POFA easily to crack than the other specimen. While, for figure 5 shows that the value of stress for 20.0 % and 30.0 % Modified EPS. For 20.0 % Modified EPS the value of stresses was 18 MPa and the value of strain was 0.070037313. For 30.0 % Modified EPS, the value of stress was 12 MPa and the strain was 0.050026644. So, the 20.0 % of Modified EPS have a good strength than the 30.0 % of Modified EPS. From the observation, it can conclude that, the value of strain can affect the value of stress of the specimen. Besides that, the highest the percentage of materials replacement also can make the concrete easily to cracked.

4. Conclusion

As a conclusion, through this research the use Palm Oil Fuel Ash (POFA) as replacement cement and Modified EPS as replacement fine aggregates can be analyses using Abaqus, finite element method. The conclusion can be summarized as follows:

i. ABAQUS can analyze the concrete cube and can verify the experimental work result. Then, the first objective was achieved.
ii. The second objective was to compare the relationship of stress and strain for concrete cube that containing POFA and Modified EPS as replacement materials. From the analysis shows that, the higher the percentage of POFA and Modified EPS in concrete cube, the lower the value of the stress. In addition, the value of stress for 20.0 % and 30.0 % of POFA was highest than the value of strain of 20.0 % and 30.0 % for Modified EPS. It shows that, the replacement of POFA will improve the performance of concrete than the replacement of Modified EPS.
iii. The higher the percentage of POFA and Modified EPS used as the replacement material, the lower the stress strain value of the concrete cube. This is because the expansion of concrete become easier due to the presence of replacement of Modified EPS.
iv. The last objective about performances of mechanical properties of concrete that containing 0.0 %, 10.0 %, 20.0 %, 30.0 % of POFA and 20.0 %, 30 .0% of Modified EPS with simulation model by using finite element method based on previous experimental can be verify.

v. The analysis shows that, the highest the percentage of POFA and Modified EPS, the lower the strength of concrete. This is because a high percentage of POFA and Modified will contribute in losing the optimum bonding strength in the concrete.

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