Progress in Engineering Application and Technology Vol. 3 No. 1 (2022) 289–296

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

The Performance of Reinforcement Concrete Beam Containing Palm Oil Fuel Ash (POFA) and Expanded Polystyrene (EPS) in Term of Flexural Behavior

Goh Duan Kai[1], Mohamad Hairi Osman[1]*, Mohd Eizzuddin Mahyeddin[1]

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2022.03.01.030
Received 16 January 2022; Accepted 11 April 2022; Available online 25 June 2022

Abstract: The high demands on concrete cause environmental pollution as the process of producing cement increase the emission of CO_2. Besides, the high demand of mining nature aggregate for produce concrete will cause exploitation of natural resources. Palm oil fuel ash (POFA) and expanded polystyrene (EPS) were highly potential waste material that can act as the replacement materials to produce a high performance and ecofriendly concrete. Hence, the aim of this study was to investigate the ability of POFA and EPS act as the replacement materials in reinforcement concrete beam. The objectives of this study were to compare the compressive strength, investigate the flexural behavior and determine the optimum percentage of reinforcement concrete beam that containing POFA and EPS. The samples reinforcement beams sized 1000 mm x 150 mm x 15 0mm with substitution of 10.00 %, 20.00 % POFA and 10.00 % EPS were produced to conduct the laboratory tests. Besides, the compressive strength test was carried out through concrete cube and the flexural test was carried out through the reinforcement beam. It found that the workability of concrete mix decreased as the percentages of POFA, and EPS added increased. The mass was shown decreased when the beam samples contained POFA and EPS. For the compression strength and flexural strength, it found that the sample contained 10.00 % POFA had a better performance and the sample contained 10.00 % POFA and EPS had a similar performance with normal concrete. Although the 10.00 % POFA and EPS sample had the similar performance in strength, it was still more valuable than normal concrete since it was more low density, eco-friendly, low cost and the strength performance maintained.

Keywords: POFA, EPS, Concrete Beam, Flexural

Corresponding author: mhairi@uthm.edu.my

1. Introduction

Concrete was one of the fundamental materials in building construction. Since concrete was the basic material in a construction, therefore it would keep familiar for used within the future [1]**.** However, it was making some issues for the environment which were global warming and exhaustion of natural sources. The total production of cement around the world was about 4.1 billion tons and created about 5.00 to 7.00 % of total CO_2 emissions in 2018 [2]. For issue of exhaustion of natural, it was caused by high demand mining the natural aggregates. There are about 8 to 10 million tons of natural aggregates would be consumed every year [1]. Besides, the rapid development in building construction made the construction industry had keep improving the quality and produce more type of concrete. Hence, it was recommended to use waste or recycled material in concrete to produce a high performance and ecofriendly concrete.

Malaysia as a second producer of palm oil product, there had nearly 4 million ton of POFA were produced and wasted in 2010 [3]. Besides, the human was also facing the problem to dispose the waste materials from industrial such as EPS. Hence, Palm oil fuel ash (POFA) and expanded polystyrene (EPS) had high potential as the waste material used to produce a better performance concrete than normal concrete. POFA could be act as replacement material in concrete because of its pozzolanic properties. The high silica content of POFA caused it to have a good pozzolanic reaction and act as a replacement in concrete by enhancing the strength and durability properties [3]. Moreover, it also had high potential to reduce the construction materials cost and environmental impact due to it was free and ecofriendly than cement.

Furthermore, EPS was a waste material from packing manufacturing and industrial. In recent years, EPS was valued research for applying in construction industry. In fact, there are some construction industry who already try to use EPS as a replacement material in concrete in real time for non-structural construction. Since EPS was easy to get with a closed cellular structure, water resistance, low thermal transmission and low-density material, therefore it was very suitable as a replacement material of aggregate to produce lightweight concrete. In addition, the EPS beads had much lower strength compared to ordinary lightweight aggregates [4]. So that, it was high potential to produce a much lightweight concrete.

1.1 Objective

This research aimed to create a lightweight concrete beam by using POFA and EPS as a replacement material. EPS was used to replace some sand due to it was in small rounded-shaped particles and it was easily mixed in concrete or mortar. For the POFA, it was highly potential to improve the strength of the concrete. Therefore, the objectives of this study were:

- To compare the compression strength of concrete containing palm oil fuel ash (POFA) and expanded polystyrene (EPS) with normal concrete.
- To investigate the flexural behavior of reinforcement concrete beam which contained palm oil fuel ash (POFA) and expanded polystyrene (EPS).
- To determine the optimum percentage of reinforcement concrete beam contained palm oil fuel ash (POFA) and expanded polystyrene (EPS) as replacement material.

1.2 Scope of study

This research was focusing to analysis the perfect ratio of POFA and EPS as replacement material in concrete in order to improve the flexural properties of the concrete beam. Besides, it was focused on creating a lighter density of the concrete beam that could withstand the load designed and improve the beam concrete strength by using of POFA and EPS as replacement material. It was conducted by using 0.00 %, 10.00 %, 20.00 % of POFA and 0.00 %, 10.00 % of EPS as the replacement materials in reinforcement concrete beam samples with size 1000 mm x 150 mm x 150 mm. Each specimen would

have 3 beam samples, as shown in Table 1. Next, the volume of POFA and EPS added as replacement materials of the fine aggregate and cement would follow the proportion set by using DOE method.

Table 1: Beam sample specimen for different percentage ratio of POFA and EPS

EPS POFA	0%	10%
0%	3	3
10%	3	3
20%	3	3

2. Methodology

The Figure 1 was showing the methodology flow chart of this study.

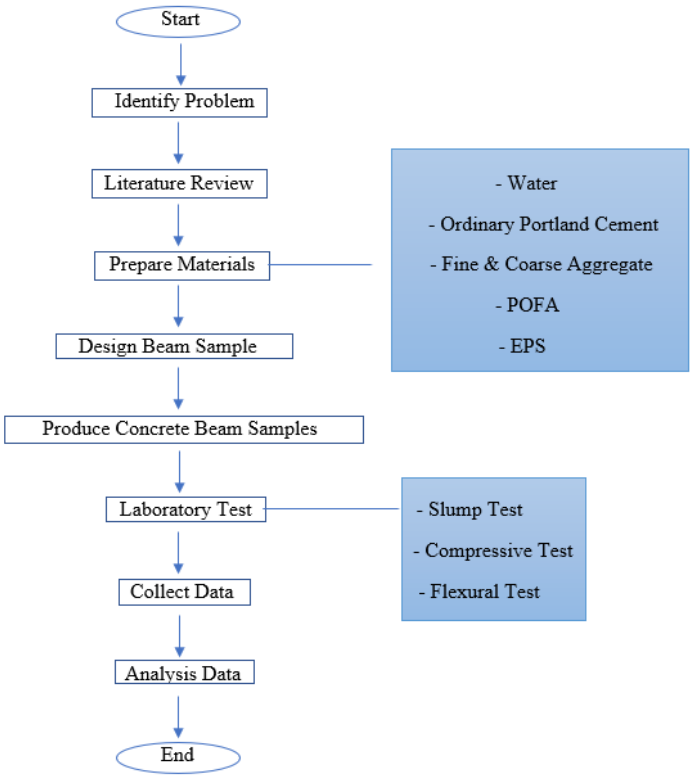

Figure 1: Methodology flow chart

2.1 Preparation of concrete beam sample

It had 18 beam samples with 3 samples each specimen would make for this research. The concrete mix had done by following the mix ratio with the percentage of POFA and EPS replacement used. Firstly, the materials of cement, aggregate, POFA and EPS were prepared to follow the mix ratio of the design calculation. The materials were put together into a tray and adding water to mix it together. A shovel was used to mixing it balanced. After the fresh concrete was done, the formwork inside was brushed with oil as a release agent to make sure the beam sample can easily remove from formwork. The reinforcement bar was placed into the intermediate of formwork and the fresh concrete mix was poured inside. It must be made sure the reinforcement bar was surrounded by the concrete. After the formwork was fully poured with concrete, compacted work was applied by using compacting rod to make sure there was not hollow in the beam sample and flattened the beam sample surface. The beam sample was left at the lab to get harder.

2.2. Laboratory test

2.2.1 Slump test

The slump test was conducted according to ASTMC 143 standard for finding the workability. Every ratio of mix concrete was taken and conducted slump test before it pours into the formwork. After the mix concrete conduct slump test, it would be mix back into its ratio concrete and pour into the formwork. To make sure the experiment gets the actual result, it must be made sure that the cone mould must clean before use for every time of slump test, did not have any interruption during experiment and complete every slump test in 2.30 min.

2.2.2 Compressive strength test

Compressive test was a test to determine the hardened of concrete mix. It was the most important factor for determining how effectively concrete mix can bear loads that affected its size. Normally, the concrete sample in compressive test could be in a cube or cylinder shape. However, only cube concrete sample would use for in the test in this study. In this research, it would follow the standard of BS 1881: Part 116: method for determination of compressive strength of concrete cubes to run the test. Next, the things needed to take care of this test was it must be made sure that the bearing surface of machine was cleaned before the concrete cube sample placed inside and the sample must be placed on the centre of the lower platen.

2.2.3 Flexural behavior test

Flexural behavior test was conducted to find the capacity and the deflection of reinforcement concrete beam sample. It was to find out the ability and the best percentages of adding EPS and POFA to concrete beam to improve the flexural behavior. The capacity of beam sample was determined by the maximum load applied on it and deflection was determined by the displacement achieved when the beam sample was at maximum load. The flexural behavior test was conducted by Center-Point Loading test according to ASTM C293 and dial gauge was installed at the top and beside the loading roller of every beam sample to analyses the displacement. The test setup was shown in Figure 4. The detail needed to pay attention in this test was made sure all the rollers were clean, free of dirt and the loading roller must on the center of beam sample.

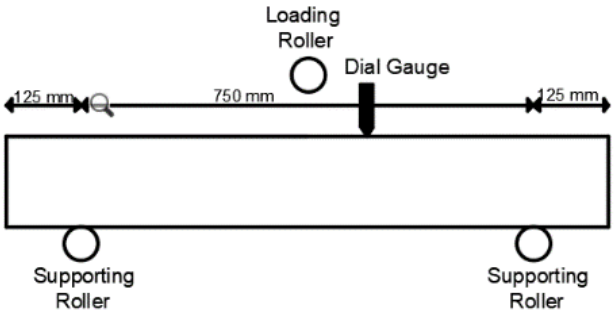

Figure 2: Test setup

3. Results and Discussion

3.1 Slump test

Table 2: Slump test result

Specimens	Percentage of POFA (%)	Percentage of EPS (%)	Slump Value (mm)
1	0	0	47

2		10	44
3	10	0	38
4		10	36
5	20	0	33
6		10	30

Based on the Table 2, the slump value of normal concrete which was specimen 1 is 47 mm and the value had a bit decreased to 44 mm when 10.00 % of EPS replace into concrete. Next, it was recorded a big decreasing to 38 mm for the specimen 3 that added 10.00 % of POFA as replacement material and 36 mm for the specimen 4 that added 10.00 % POFA and 10% EPS. For specimen 5 that added 20.00 % of POFA and specimen 6 that added 20.00 % POFA and 10% EPS are recorded at 33 mm and 30 mm. Based on analysis the result, it found that when the percentage of POFA and EPS keep increased, the slump value keep decreased because this may because of the high porosity of POFA and EPS that decreased the volume of cement paste. Furthermore, EPS use as replacement of concrete would decrease the volume of cement paste as compared with normal concrete [5]. Therefore, it found that by added POFA as the replacement material of cement in concrete would have a big decreased of slump value and added EPS as the replacement

3.2 Mass of sample

Table 3: Mass of sample

Specimens	POFA (%)	EPS (%)	Sample 1 (kg)	Sample 2 (kg)	Sample 3 (kg)	Average Mass of Sample (kg)	Different mass with specimen 1 (kg)
1	0	0	57.30	57.80	57.55	57.55	-
2		10	55.70	55.40	54.30	55.41	-2.14
3	10	0	57.10	57.25	57.10	57.15	-0.40
4		10	55.65	54.80	53.05	54.50	-2.81
5	20	0	56.70	56.90	56.75	56.78	-0.77
6		10	54.50	53.05	54.30	53.95	-3.60

Based on the result, it was found that the average of normal concrete was 57.55 kg and had a decreased of 2.14 kg to 55.41 kg after 10.00 % EPS was replaced in concrete. The specimen 3 that added 10% POFA as replacement material was recorded as 57.15 kg which only had a slightly different 0.40 kg with the normal concrete and the specimen 4 that added 10.00 % POFA and EPS was recorded as 54.50 kg which had 2.81 kg different with the normal concrete. Next, the average mass of specimen 5 that contain 20.00 % POFA and specimen 6 that contain 20.00 % POFA and 10.00 % EPS were recorded as 56.78 kg and 53.95 kg which had a less 0.77 kg and 3.60 kg compared with the normal concrete. From analysis of the data above, it could find that by replacing the POFA and EPS would decrease the mass of the concrete. Besides, it also finds that by replacing EPS as replacement material would have much decreased the mass of concrete compare with replacing POFA in concrete. It was because EPS was very lightweight, which was 12 to 20 kg/m^3 compare with fine aggregate which was heavier [4]. Therefore, by adding POFA and EPS in concrete as replacement material would decrease the weight of concrete.

3.3 Compressive strength test

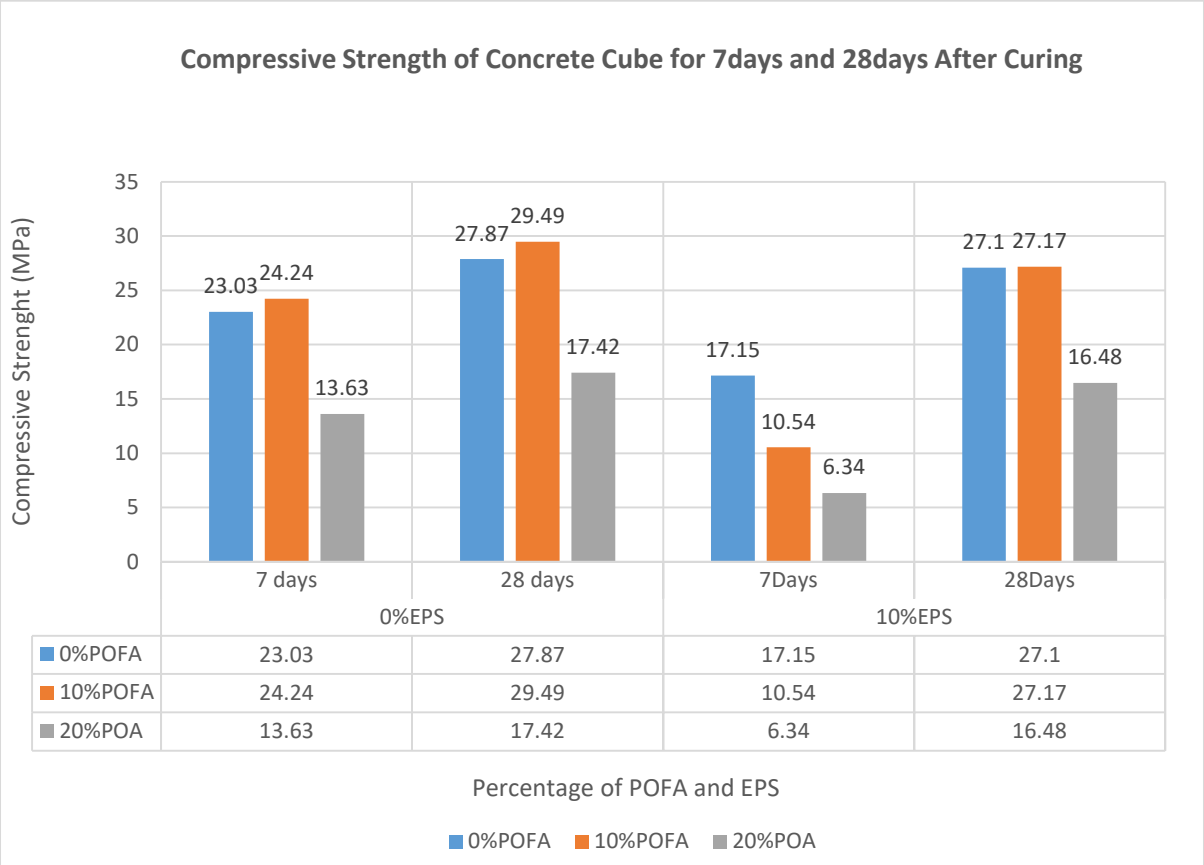

Figure 3: Graph of the compressive strength of concrete cube for 7 days and 28 days after curing

Based on the Figure 3, the compressive strength of normal concrete for 7 days after curing was 23.03 MPa and 28 days after curing was 27.87 MPa. For the 10.00 % POFA concrete cube without EPS, it had recorded 24.24 MPa and 29.49 MPa for 7days and 28 days after curing respectively, which had an increase of 1.21 MPa and 1.62 MPa compared with normal concrete cubes. However, the concrete that contained 20% was recorded a big drop to 13.63 MPa for 7 days after curing and 17.42 MPa for 28 days after curing. Next, for the cube sample that contained 10.00 % EPS without added POFA had a less compressive strength, which were 17.15 MPa for 7 days curing and 27.10 MPa for 28 days curing compares with the normal concrete. However, the concrete cube contained 10.00 % POFA and 10.00 % EPS was recorded a similar compressive strength with the normal concrete after 28 days curing but big different at 7days after curing, which was recorded 27.17 MPa. For the concrete cube contained 20.00 % POFA and 10.00 % EPS, it was recorded the most bed result compare with other, which were 6.34 MPa and 16.48 MPa for after 7 days and 28 days curing respectively. Based on the analysis above, it found that the concrete cube contained 10.00 % POFA had a best performance in compressive strength. It was because the high contained of SiO_2 in POFA allowed it to has a pozzolanic reaction between Silica (Si) and calcium hydroxide ($Ca(OH)_2$) to produce calcium silicate hydrate (C-S-H) gel compound to increase the performance of concrete. However, too much POFA added also would destroy or reduce the chemical reaction of cement in concrete. But based on the previous study Hamada et al.(2021), it found that the 20.00 % POFA contain in concrete had the best performance in compressive strength [6]. The difference between result may be because of some aspects. Fistly, it may be because of the materials collect place because POFA from every felda would has difference carbon contained. Next, it may also because of the materials preparation since this project did not done any repairation on the POFA such as sieve or burning the POFA to make sure it was dry. Moreover, it also found that the compressive strength would decrease when the percentage of EPS increased. This was

under expected since the study research was stated that aggregate strength has the greatest impact on the strength of concrete and EPS beads have practically zero strength [7]. However, the concrete cube contained 10.00 % POFA and 10.00 % EPS had a similar compressive strength with normal concrete due to it drop the performance of 10.00 % POFA in concrete. As a simple conclusion in this part, the 10.00 % POFA added into concrete would increase the compressive strength of concrete and would decrease as the percentages of POFA and EPS keep increased.

3.4 Flexural behavior test

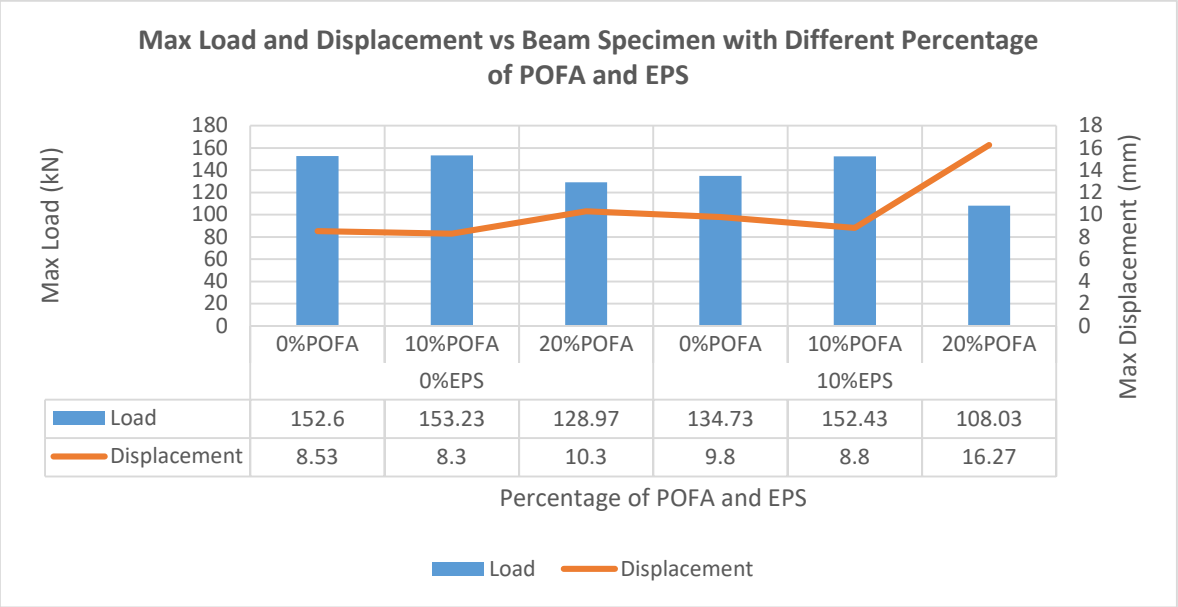

Figure 4: Graph of maximum load capacity and maximum displacement of beam samples

Based on the Figure 4, the maximum load capacity and displacement of normal concrete were recorded 152.60 kN and 8.53 mm respectively. The maximum load of 10.00 % POFA and 0.00 % EPS concrete beam was increased, and the displacement was decreased compared with the normal concrete. It was recorded 153.23 kN and 8.30 mm respectively. There was a drop of maximum load and increase of displacement for the 20.00 % POFA concrete beam which had recorded 128.97kN and 10.30 mm. For the concrete beam contained 10.00 % EPS only, it was recorded 134.73 kN for the maximum load and 9.8mm for displacement. While the concrete beam was added 10.00 % POFA and 10.00 % EPS, it was recorded a similar result with the normal concrete beam, which were 152.00 kN and 8.80 mm. Next, the 20.00 % POFA and 10.00 % EPS concrete beam were given the bed result compare with other, which were 108.03 kN and 16.27. Based on the analysis, it was shown that when the maximum load increase, the maximum displacement would decrease. This was because the stronger concrete beam would need more load to fail it, but at the same time it was harder to bend it. Based on the study research Muthusamy et al. (2019), it found that 10.00 % of POFA added would have a best performance in flexural strength compare with other percentages concrete [8]. Hence, it was expected that the 10.00 % POFA concrete beam was had the best performance in flexural strength and the 10.00 % POFA and 10.00 % EPS concrete beam had a similar flexural strength with normal concrete. Last, it was concluded that the 10.00 % POFA added into concrete would get the best performance in flexural strength and would decrease as the percentages of POFA and EPS keep increased.

4. Conclusion

This study was aimed to produce a high-performance concrete. Since this study was using POFA and EPS as the replacement materials, hence a most eco-friendly concrete would be produced. There were many previous studies researches shown that POFA and EPS had the high potential as replacement materials in concrete. The summarized conclusion about the experiment result was stated below:

1. Percentages of POFA and EPS added would affect the properties and performance of concrete.
2. The workability of concrete would decrease as increase the percentages of POFA and EPS used as replacement materials in concrete.
3. The mass of concrete would decrease as increase the percentages of POFA and EPS used as replacement materials in concrete.
4. The compressive strength of concrete contained 10.00 % POFA would have the best result and would decrease when the percentages of POFA and EPS increase as replacement materials.
5. The maximum load capacity for concrete beam contained 10.00 % POFA would have the best result and would decrease as the percentage of POFA and EPS increase.

Based on the conclusion stated, POFA and EPS would not be 100.00 % act as replacement materials in concrete. However, by replacing 10.00 % of POFA in the concrete as replacement materials would increase the performance of concrete. Although the concrete contained 10.00 % POFA and EPS had the similar performance in strength with the normal concrete, it was still more valuable than normal concrete since it was more low density, eco-friendly, low cost and the strength performance maintained.

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] S. Y. Kwek, & H. Awang, Artificial lightweight aggregate from palm oil fuel ash (POFA) and water treatment waste. *IOP Conference Series: Materials Science and Engineering*, *431*, 082005. https://doi.org/10.1088/1757-899X/431/8/082005 (2018)

[2] A. M. Alnahhal, U. J. Alengaram, S. Yusoff, R. Singh, M. K. H. Radwan, & W. Deboucha, Synthesis of sustainable lightweight foamed concrete using palm oil fuel ash as a cement replacement material. *Journal of Building Engineering*, *35*(March 2020), 102047. https://doi.org/10.1016/j.jobe.2020.102047 (2021)

[3] H. Alabduljabbar, H. Mohammadhosseini, M., Md. Tahir, & R. Alyousef, Green and sustainable concrete production using carpet fibers waste and palm oil fuel ash. *Materials Today: Proceedings*, *39*, 929–934. https://doi.org/10.1016/j.matpr.2020.04.047 (2021)

[4] C. Li, L. Miao, Q. You, S. Hu, & H. Fang, Effects of viscosity modifying admixture (VMA) on workability and compressive strength of structural EPS concrete. *Construction and Building Materials*, *175*, 342–350. https://doi.org/10.1016/j.conbuildmat.2018.04.176 (2018)

[5] D. Hoang Minh, & L. Le Phuong, Effect of matrix particle size on EPS lightweight concrete properties. *MATEC Web of Conferences*, *251*. https://doi.org/10.1051/matecconf/201825101027 (2018).

[6] H. M. Hamada, B. S. Thomas, F. M. Yahaya, K. Muthusamy, J. Yang, J. A., Abdalla, & R. A. Hawileh, Sustainable use of palm oil fuel ash as a supplementary cementitious material: A comprehensive review. *Journal of Building Engineering*, *40*(July 2020), 102286. https://doi.org/10.1016/j.jobe.2021.102286 (2021)

[7] A. Kan, & R. Demirboğa, Effect of cement and EPS beads ratios on compressive strength and density of lightweight concrete. *Indian Journal of Engineering and Materials Sciences*, *14*(2), 158–162 (2007)

[8] K. Muthusamy, J. Mirza, N. A. Zamri, M. W. Hussin, A. P. P. Abdul Majeed, A. Kusbiantoro, & A. M. Albshir Budiea, Properties of high strength palm oil clinker lightweight concrete containing palm oil fuel ash in tropical climate. *Construction and Building Materials*, *199*, 163–177. https://doi.org/10.1016/j.conbuildmat.2018.11.211 (2019)