Recent Trends in Civil Engineering and Built Environment Vol. 5 No. 1 (2024) 287-293

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

The Influence of EPS and POFA as Replacement Material in the Production of Non-Load Bearing Brick

Siti Nur Syafiqah Jamiran[1], Nurain Izzati Mohd Yassin[1]*

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Senior Lecturer, Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia

DOI: https://doi.org/10.30880/rtcebe.2024.05.01.029
Received 23 June 2022; Accepted 01 January 2024; Available online 30 June 2024

Abstract: The purpose of this study was to investigate the influence of expanded polystyrene (EPS) and palm oil fuel ash (POFA) as replacement materials in the production of lightweight concrete brick. In this study, sand was replaced by EPS by 30%, 40%, and 50% of its volume in the concrete brick mixture. POFA, on the other hand, was replaced 10% of the cement volume. The replacement materials were used to prepare a concrete brick with dimensions of 215mm x 103mm x 65mm. Concrete bricks constituting EPS and POFA were evaluated in terms of density, compressive strength, and water absorption. Before the test, these samples were undergoing air curing process for 7 and 28 days, respectively. The performance of concrete bricks incorporating EPS and POFA as replacement materials were compared to the performance of ordinary concrete bricks. The brick with the largest waste replacement at 10% POFA and 50% EPS produces better results than others samples because it has the highest waste material and satisfy the lightweight and compressive strength requirements for a lightweight brick. The consumption of EPS and POFA in the production of non-load bearing brick are effective to lessen production costs while also designing a more sustainable environment for our future generations.

Keywords: Brick, EPS, POFA, Density, Compressive Strength, Water Absorption

1. Introduction

The Malaysian government remains responsible to updating infrastructure and funding programs for the B40 and M40 groups as outlined in the Twelfth Malaysia Plan (2021-2025) in key plans where the government empowers by assigning a few initiatives such as the Fund for Affordable Housing, Youth Housing Scheme, and Rent-to-Own Program [1]. As proposed in the 12th Malaysia Plan, these measures should make it easier for low-income households to enter the property market and purchase homes. As a consequence, the B40 and M40 groups will have a greater chance of owning a home. However, in order to maximize the amount of housing units, the government must address sustainability

*Corresponding author: nurainy@uthm.edu.my

issues, particularly in the construction sector. If the government does not consider the role of the environment, the increase in housing area will have a harmful effect on the environment. Due to the obvious high demand for housing and the growing acceptance of sustainability, Malaysia's construction industry and experts have teamed up to create sustainable building materials such as lightweight concrete bricks [2].

Lightweight construction materials, such as lightweight concrete bricks, have the potential to promote the economy and society by lowering construction costs in terms of manufacturing, transportation, and handling. It may be able to lower housing costs as a result of this action [3]. In general, concrete bricks are made from sand, cement, and water [4]. The use of lightweight materials for construction will decrease the dead load of buildings, resulting in minimal segments of structure element. As a result, the overall cost of the project can be lowered [5]. The focus of this research is on the production of non-load bearing brick which is a sustainable lightweight concrete brick that made of cement, sand, and replacement materials. In this study, expanded polystyrene (EPS) will be used as sand replacements while palm oil fuel ash (POFA) will be used as cement replacements.

Ling *et al.* [6] define EPS as polystyrene in raw beads which broadens when heated with steam. It is lightweight, has a high load bearing capacity, and is an excellent thermal insulator. Along with its lightweight characteristics, which can lessen the weight of a concrete brick comparable to its density, EPS was chosen as a sand substitute material [7]. It is broadly used in packaging and construction due to its lightweight, rigidity, excellent temperature insulation, and higher intensity resistance. According to Musab [8] and Adnan *et al*. [9], although EPS is popularly used in the processing industry, it is a waste that cannot be decomposed organically. As a necessary consequence, to address the issue, EPS has been extensively used as an aggregate substitute in brick manufacturing.

Palm oil fuel ash (POFA) is another agricultural waste which can be used to make concrete bricks as a replacement material. POFA is a type of agro-waste generated by the palm oil industry. It is created by burning palm fruit byproducts from the oil palm tree. In essence, the waste of palm oil in the palm oil industry was increasing significantly. It not only takes up space, but it also pollutes the environment and poses health risks. Since it is not reused or recycled in any way, this waste became a critical challenge for palm oil power plants. As a side effect, POFA, which has a high silica concentration in its chemical composition, could be used as a cementitious material [10]. POFA as a cement replacement has been studied further by researchers [2].

As an outcome, the focus of this research has been on the manufacturing of concrete bricks incorporating EPS and POFA at various percentages of replacement. The brick properties have been tested include density, compressive strength, and water absorption rate.

2. Methodology

2.1 Research Design

Several cement brick mixtures with varying EPS and POFA replacement ratios were created. The mechanical properties of the cement brick mixtures were determined through a series of laboratory tests. This study focused on the properties of cement such as brick density, water absorption, and compressive strength. This project’s detailed objectives are as follows:

i. To determine the effect of expanded polystyrene (EPS) and palm oil fuel ash (POFA) as replacement materials towards brick density

ii. To identify the impact of expanded polystyrene (EPS) and palm oil fuel ash (POFA) as replacement materials towards compressive strength

iii. To determine the implications of expanded polystyrene (EPS) and palm oil fuel ash (POFA) as replacement materials towards water absorption

2.2 Materials

The materials used for the production bricks are sand, cement, expanded polystyrene (EPS), palm oil fuel ash (POFA), and water. Natural sand passing through 5 mm sieve were used, and being dried in oven for 24 hours at 105°C. It is responsible to fill the air voids between the particles and bond the brick mixture together. Ordinary Portland cement was used to conduct the experiment due to its density which is 1254 kg/m³ according to Malaysia Standard Specification MS 522: Part 1: 2003 [11].

For replacement materials, EPS and POFA were utilised in this study. The percentages of 2mm EPS replacement ranged from 30% to 40% to 50% of the total sand. ST Polyfoam Industries Sdn Bhd in Batu Pahat, Johor, supplied the EPS. POFA was obtained from Bell Palm Industries Sdn. Bhd., a local palm oil factory in Batu Pahat, Johor. The collected POFA were dried in an oven at 105°C for 24 hours to remove moisture before sieving up to 150μm to remove coarse particles and cement fineness. The water used in the concrete brick mixture is ordinary tap water acceptable for cement mixing. It is considered pure water since it is devoid of water contaminants and dangerous substances.

2.3 Testing Method

The mechanical properties that affected this study are brick density, compressive strength, and water absorption. The performance of the specimens was compared to the ordinary concrete brick mixtures.

2.3.2 Density test

The density of a lightweight concrete brick has been determined by calculating the weight of the sample in kilograms by the volume of the sample in cubic meters. This density test was carried out in accordance with BS EN 12390-7-2009 (Testing hardened concrete, hardened concrete density) [12], which applies to lightweight, normal-weight, and heavy-weight concrete.

2.3.2 Compressive strength test

The compressive strength test is a mechanical test that has been performed to determine the compressive strength of ordinary concrete bricks as well as concrete bricks containing EPS and POFA as material replacements. The sample concrete bricks with dimensions of 215mm x 103mm x 65mm were tested after 7 days and 28 days of the air curing process. The compressive strength average was calculated using the results of three tests on concrete bricks. The compressive strength test was performed on specimens containing control specimens as well as EPS and POFA as material replacements.

2.3.2 Water absorption test

This study has been conducted the water absorption test after the specimens were cured for 7 and 28 days. The concrete bricks were dried for 24 hours. Water absorption test is a test to determine the amount of water absorbed by the concrete brick. It is a general test to be done in order to find out number of pores present inside the specimens.

3. Results and Discussion

3.1 Density Test

The density of a sample is defined as its mass divided by its volume. Density tests are performed during the casting process and after the samples have been exposed to air curing for 7 days and 28 days to determine their fresh and dry densities. Every sample's density was calculated by dividing its mass by its volume.

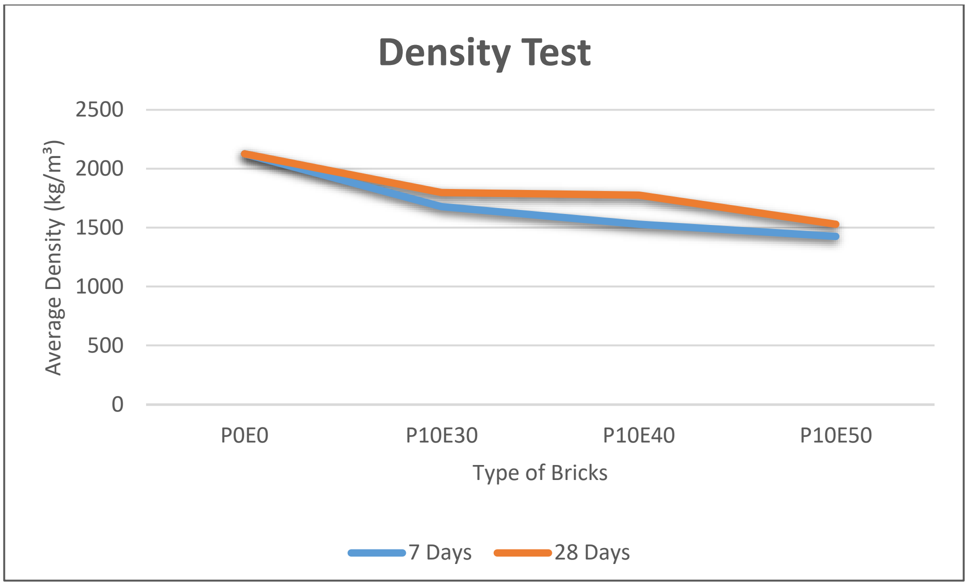

Figure 1: Graph for density test

According to Figure 1, the density of brick decreases when the EPS and POFA replacement ratios increase. The average density of control brick was 2128.793kg/m³ on day 7, and 2126.477kg/m³ on day 28. When the amount of EPS replacement reached 50%, the density of concrete brick reduced to 1425.759kg/m³ at day 7 and 1530.693kg/m³ at day 28. These results are similar with research from Hani *et al.* [2], where brick with E50P25 as its maximum replacement element has a density of 1385.71 kg/m³, which is 36% less than regular brick. Since the density of the brick specimens decreased, the average density of concrete brick incorporating EPS and POFA met the criteria of lightweight concrete brick. Due to the relatively low-density characteristic, this has proven that EPS has reduced dramatically brick density [3]. The density displays the declines caused by the combination of EPS and POFA. The greater the EPS and POFA replacement, the lesser the brick density. Due to the obvious density of the raw material, this outcome has a correlation. EPS has an incredibly low density of 17.92 kg/ m³. Furthermore, POFA has a lower density than OPC, which is 987.49 kg/ m³. This will undoubtedly alter the density of bricks. The amount of curing days has little effect on density because the longer the curing period, the lower the density. The majority of bricks with 30%, 40%, and 50% EPS substitution are termed as lightweight bricks because their density is less than 1800 kg/ m.

3.2 Compressive Strength Test

A compressive strength test was performed to determine the maximum compressive load that a brick with dimensions of 215mm x 103mm x 65mm can withstand before fracturing. This test was performed on brick samples that have been aged for 7 and 28 days following the air curing process. As the percentage of EPS and POFA increases, the compressive strength of the brick decreases. The highest percentage of EPS has the lowest compressive strength of the brick. The extremely low strength of EPS, which is relatively small, has been the factor of the significant drop in strength [13].

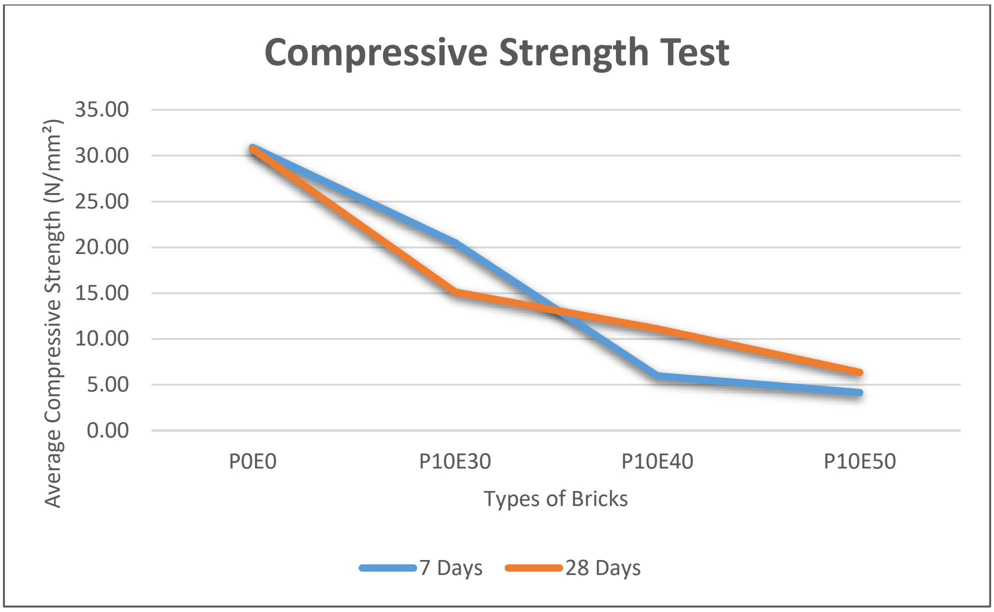

Figure 2: Graph for compressive strength test

Figure 2 showed the compressive strength of concrete brick with 10% POFA replacement with different ratio of EPS replacement. Compressive strength of concrete brick with 10% POFA replacement and 50% EPS replacement after 7 days and 28 days were 4.13N/mm² and 6.33N/mm² respectively, which were slightly lower than the control brick. Tamut *et al.* [14] made a similar finding, reporting that in their investigations, EPS replaced sand to varying degrees (5, 10, 15, 20, 25, and 30%) in their research. Their study discovered that the concrete's compressive strength has decreased by up to 55% compared to standard concrete. As the percentage of EPS replacement increased, the compressive strength of concrete brick with 10% POFA replacement decreased. The presence of 40% EPS and 10% POFA in concrete brick resulted in a slightly higher compressive strength at 28 days of curing than at 7 days of curing. This was caused by an increase in the pozzolanic reaction in the concrete brick mix. The brick becomes more stable and everlasting. Furthermore, the pozzolanic response extended the length of hydration, resulting in an increase in strength at the end age. Overall, bricks incorporating POFA and EPS performed better than control specimens in terms of load resistance.

3.3 Water Absorption Test

The ability of water to fill porosity is referred to as water absorption. The testing was done on brick samples after 7th and 28th days of curing and the data was recorded. Samples were being dried in an oven and immersed in water to determine their dry and wet weights.

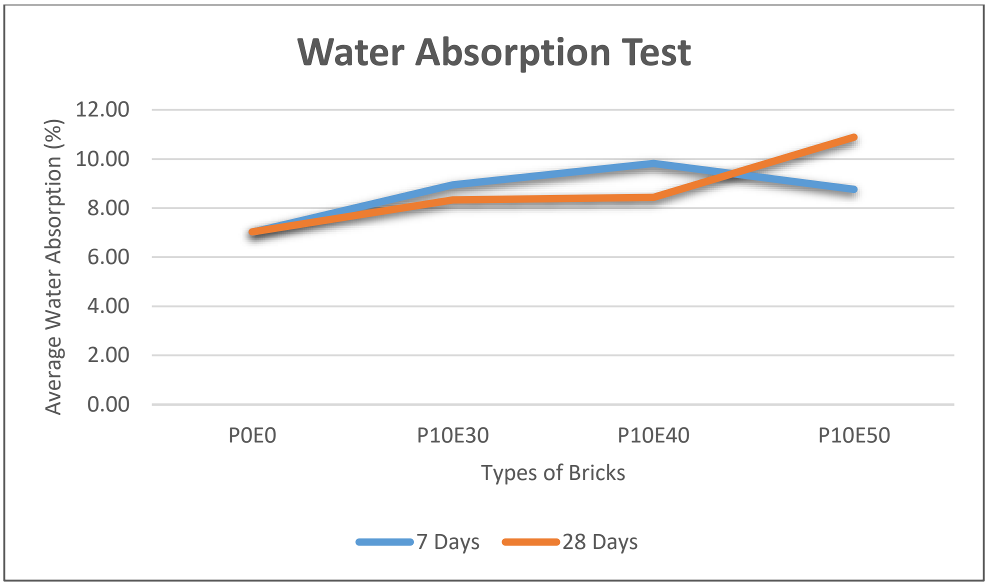

Figure 3: Graph for water absorption test

For water absorption properties, the results demonstrate that the percentage of water absorption increases as the replacement of POFA is 10% as shown in Figure 3. In the meanwhile, as the substitution of EPS increases, the percentage of water absorption decreases. The percentage of water absorption for 50% of EPS replacement decreased to 8.77% at 7th days while it achieved the highest water absorption, 10.89% during 28th days. The amount of replacement materials significantly influences the water absorption of the bricks. This can be seen, as the amount of POFA increases, so does the rate of absorption of the samples. This is indicative of the fact that POFA has a coarser structure than cement. The creation of voids in the brick samples was induced by the coarser structure of POFA. Furthermore, POFA has a greater water absorption capacity. As a result, specimens containing large amounts of POFA soaked up more water. Water absorption of brick samples, on the other hand, decreases when the amount of EPS increases. P10E30 (AC) water absorption was 8.33 % on day 28, whereas P10E50 (AC) water absorption was 10.89 % on day 28. The proportion of water absorption decreases as EPS replenishment increases. This is simply due to the fact that EPS is non-absorbent, which aids in the reduction of water absorption [3].

4. Conclusion

Since EPS has a low density, replacing it results in a significant difference in brick weight. The incorporation of POFA has an effect on density because its density is lower than the OPC. All of the bricks with different EPS and POFA replacement have acceptable strength, and the optimum EPS and POFA replacement after 7 days curing which was still allowable for non-load bearing structure. Bricks with EPS and POFA replacement produced specimens with lower density and compressive strength when compared to a control sample with 0% EPS and 0% POFA replacement. Lower density materials have lower compressive strength in essence. As a result, the brick with the largest waste replacement at 10% POFA and 50% EPS produces better results because it has the highest waste material and satisfy the lightweight and compressive strength requirements for a lightweight brick.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Twelfth Malaysia Plan, 2021-2025. (2021). Epu.gov.my. https://rmke12.epu.gov.my/en

[2] Suraya Hani, A., Nurain Izzati, M. Y., Sallehuddin Shah, A., Shahiron, S., Mohamad Hairi, O., Mohd Sufyan, A., Mohamad Luthfi, A. J., Zalipah, J., Mohamad Nor Akasyah, W. A., & Nurul Amirah, K. (2019). Strength and water absorption properties of lightweight concrete brick containing expanded polystyrene and palm oil fuel ash. IOP Conference Series: Materials Science and Engineering, 513, 012004. https://doi.org/10.1088/1757-899x/513/1/012004

[3] Izzati, M. N., Hani, A. S., Shahiron, S., Shah, A. S., Hairi, O. M., Zalipah, J., ... & Amirah, K. N. (2019, April). Strength and water absorption properties of lightweight concrete brick. In IOP Conference Series: Materials Science and Engineering (Vol. 513, No. 1, p. 012005). IOP Publishing

[4] Rahman, M. E., Boon, A. L., Muntohar, A. S., Hashem Tanim, M. N., & Pakrashi, V. (2014). Performance of masonry blocks incorporating Palm Oil Fuel Ash. Journal of Cleaner Production, 78, 195–201. https://doi.org/10.1016/j.jclepro.2014.04.067

[5] Adnan, S. H., Mohd Yassin, N. I., Shahidan, S., Osman, M. H., Ahmad Jeni, M. L., Wan Jusoh, W. A., Jamellodin, Z., Abdul Hamid, N. A., & Ahmad, F. (2021). Concrete Brick Properties Incorporating EPS and POFA as Replacement Materials. Journal of Advanced Research in Materials Science, 77(1), 14–25. https://doi.org/10.37934/arms.77.1.1425

[6] Ling, I. H., & Teo, D. C. L. (2011). Properties of EPS RHA lightweight concrete bricks under different curing conditions. Construction and Building Materials, 25(8), 3648–3655. https://doi.org/10.1016/j.conbuildmat.2011.03.061

[7] Kamarulzaman, N. A., Adnan, S. H., Sari, K. M., Osman, M. H., Jeni, M. A., Abdullah, M. S., ... & Anuar, M. W. (2018). Properties of Cement Brick Containing Expanded Polystyrene Beads (EPS) And Palm Oil Fuel Ash (POFA). Journal of Science and Technology, 10(4).

[8] Musab A.S.A. (2016). The Mechanical And Physical Properties Of Concrete Containing Polystyrene Beads As Aggregate and Palm Oil Fuel Ash As Cement Replacement Material

[9] Adnan, Suraya Hani & Alfatih, Musab & Jamellodin, Zalipah. (2017). The mechanical and physical properties of concrete containing polystyrene beads as aggregate and palm oil fuel ash as cement replacement material. AIP Conference Proceedings. 1891. 020016. 10.1063/1.5005349.

[10] Harsha V N, Aiswarya V S, Beyoola Wilson, & Preethi M. (2017). Palm Oil Fuel Ash as Partial Replacement of Cement in Concrete. International Journal of Engineering Research And, V6(03). https://doi.org/10.17577/ijertv6is030514

[11] Ms 522 Part 12003 Portland Cement (Ordinary and Rapid-Hardening) Part 1 Specification

[12] BS EN 12390-7:2009 Testing hardened concrete. Density of hardened concrete

[13] Miled, K., Sab, K., & Le Roy, R. (2007). Particle size effect on EPS lightweight concrete compressive strength: Experimental investigation and modelling. Mechanics of Materials, 39(3), 222-240

[14] Tamut, T., Prabhu, R., Venkataramana, K., & Yaragal, S. C. (2014). Partial replacement of coarse aggregates by expanded polystyrene beads in concrete. Int. J. Res. Eng. Technol, 3(2), 238-241.