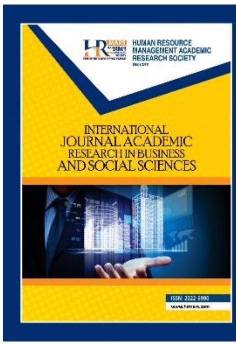

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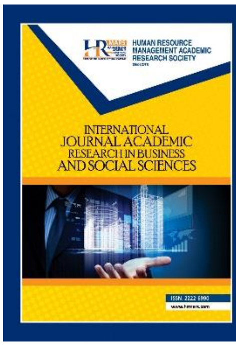

Stimulus of Raw Oil Palm Trunk (OPT) Fibre on Durability Properties of Lightweight Foamed Concrete

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Abstract

Lightweight Foamed Concrete (LFC) has gained a huge amount of attention because of its high flowability, low self-weight, lower use of aggregate, low strength, and its thermal insulation. Furthermore, LFC is an environmentally friendly material because of its minimal usage of aggregate and high potential to incorporate waste material such as fibre. This research was conducted to assess the potential utilisation of oil palm trunk (OPT) fibre strengthened LFC in terms of its durability. Two densities of 600kg/m^3 and 1200kg/m^3, were cast and tested with 4 different percentages of OPT fibre, which were 0.15%, 0.30%, 0.45% and 0.60%. The parameters evaluated were water absorption, porosity, drying shrinkage, ultrasonic pulse velocity. The results revealed that the inclusion of OPT in LFC helps to minimise water absorption and the porosity of LFC. Moreover, the inclusion of OPT also enhances the drying shrinkage and ultrasonic pulse velocity of LFC.

Keywords: Foamed Concrete, Porosity, Water Absorption, Drying Shrinkage, Ultrasonic Pulse Velocity

Introduction

LFC is a material low in mechanical properties compared to contemporary concrete of a normal weight (Serri et al., 2014). It can be defined as a cementitious material containing at least 20% by volume of mechanically trained moisture in the mortar slurry, in which air pores are fixed in the matrix utilising a suitable foam (Ramli et al., 2014). LFC can be created with the introduction of a foaming agent into a cement-based mortar. The foaming agent can be added, and the foam develops through a gentle yet rigorous mixing. Alternatively, the foaming agent can be aerated before it is applied to the mixture (Musa et al., 2019).

LFC has gained a huge amount of attention because of its high flowability, low self-weight, lower use of aggregate, low strength, and its thermal insulation. Moreover, LFC is an environmentally friendly material because of its minimal usage of aggregate and high potential to incorporate waste material such as fibre (Raj et al., 2019). The large amount of cement usage and the low elastic modulus of the aggregate in the production of LFC increases its drying shrinkage (Mydin et al., 2018). The addition of fibre into LFC is to strengthen its durability properties. Adding small volumetric fractions of short fibres can reduce the impact of early-age reduction of the concrete's durability. It also can restrict the growth of cracks under loads.

There has been a broad utilization of natural fibres in producing LFC due to the increasing interest in natural fibres in clinging to a more environmental and cost-effective value in construction industries. However, it should be understood from a structural standpoint that the primary purpose of adding fibre in cementitious material is to improve the durability of engineering properties. Natural fibre can play an important role to enhance the matrix bond that will help to develop the tensile strength and structural integrity of the concrete. Momen et al (2018) determined that the finest fibres have a very good essence that assist to improve the qualities of concrete. The study also stated that the use of natural fibre can help to improve the shrinkage and ductility. Reinforced concrete with the inclusions of fibres can reduce plastic shrinkage and improve durability, which is in line with the study conducted by Jalal et al (2017) which postulated that the flexural resistance and durability of concrete will be improved by including the fibres into the concrete.

Thus, natural fibre is seen as a resolution to improve LFC with improved durability performances, which is a new form of binder that can combine Portland cement in bonding with cement matrices. The fibres are mostly sporadic, erratically dispersed throughout the cement matrices (Elrahman *et al.,* 2019). The inclusion of fibres in FC is to delay and control the tensile cracking of composite material (Munir *et al.,* 2015). Fibres thus transform the inherent unstable tensile crack propagation to slow controlled crack growth. This crack controlling properties of the fibre helped to reinforce the delays and the initiation of flexural and shear cracking (Memon *et al*., 2018). It imparts extensive post cracking behaviour and extensively enhances the ductility of the composite (Jhatial *et al.,* 2017). Therefore, this research explores the potential utilisation of OPT fibre in FC to improve the durability properties of LFC.

Material Constituents

The Ordinary Portland cement (OPC) was used in this study, complying with the BS 12 standard. This product is available in 50 kg bags and in bulk. Fine inorganic material forms a paste once water is added to the mixture. Next, the fine aggregate used in this study was natural fine sand supplied by a local distributor. Sieve analysis was conducted to assess the suitability of the sand to use according to BS882. Fine sand was used with a size of 1.18 mm to improve the LFC flow attributes and stability. Additionally, protein agent used for this study was Noraite-PA-1, at a ratio of 1:33 to the volume of water. The clean water used in the mix together with the protein agent was to create a good foaming agent. The density of FC was determined by the volume of foam added into the mix. The stability of foam is important in producing FC since the generator will act as a medium to transfer the agent into the stable foam. The weight of the foam used in this investigation varied between 60-80 g/litre. Finally, the oil palm trunk (OPT) fibre utilized in this study was washed properly before being used as an infill in LFC. The fibre volume used was 0.15%, 0.30%, 0.45%, 0.60% and 0.00% of the total weight mix volume. A total of 5 mixes were prepared for this research. For all 5 mixes, the sand-cement ratio was fixed at 1:1.5, and the water-cement ratio was 0.4.

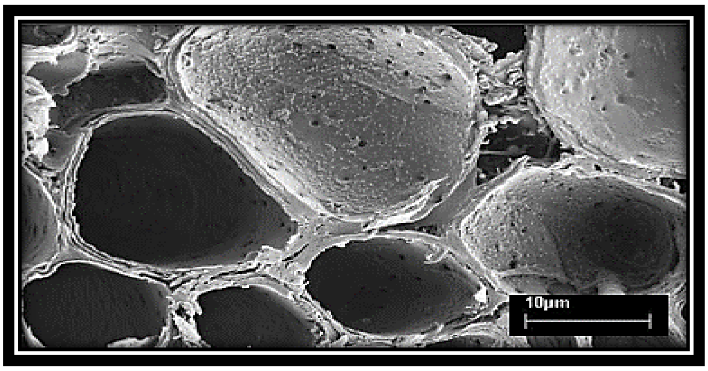

Fig. 1 – Morphology details of oil palm trunk (OPT) fibre structures

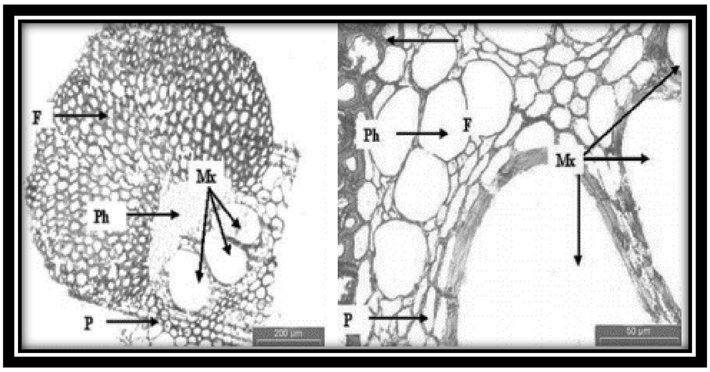

Fig. 2 – Transverse section of oil palm trunk fibre

Experimental Setup

The water absorption test was conducted on a 75 mm diameter x 100 mm height cylinder according to BS 1881: Part 122 (BS1881-122, 1983) (see Fig. 3), and the porosity test was conducted according to BS 1881: Part 122 (BS1881-122, 1983) on a 45 mm diameter x 50 mm height cylinder (see Fig. 4). The drying shrinkage test was performed on a 5 mm x 75 mm x 275 mm prism according to ASTM C878 (ASTM C878, 2014) (see Fig. 5), and the ultrasonic pulse velocity (UPV) test was performed on a 100 mm x 100 mm x 500 mm prism according to BS 12504: Part 4 (BS12504-4, 2004)

Fig. 3 - Water absorption test was performed according to BS 1881: Part 122

Fig. 4 - Porosity test was performed according to BS 1881: Part 122

Fig. 5 - Shrinkage test was carried out according to ASTM: C 878

Results and Discussion

Water Absorption

Fig. 6 shows that the increase of OPT fibre will reduce the water absorption in the specimen of lightweight FC. The OPT fibre at 0.15% absorbs water higher compared to other OPT percentages, namely 21.9% for 600 kg/m³ and 11.0% for 1200 kg/m³. This is because the small pore size and volume will prevent water from infiltrating the specimen. The control specimens were 22.6% for 600 kg/m³ and 12.1% for 1200 kg/m³, which showed the highest result since it absorbs water. For the 0.30% of OPT it shows 19.9% for 600 kg/m³ and 9.8% for 1200 kg/m³, and for 0.45% of OPT it shows 19.3% for 600 kg/m³ and 9.3% for 1200 kg/m³. Lastly, for 0.60% of OPT it shows 18.1% for 600 kg/m³ and 8.8% for 1200 kg/m³. An increment of OPT percentages will reduce the water absorption of FC.

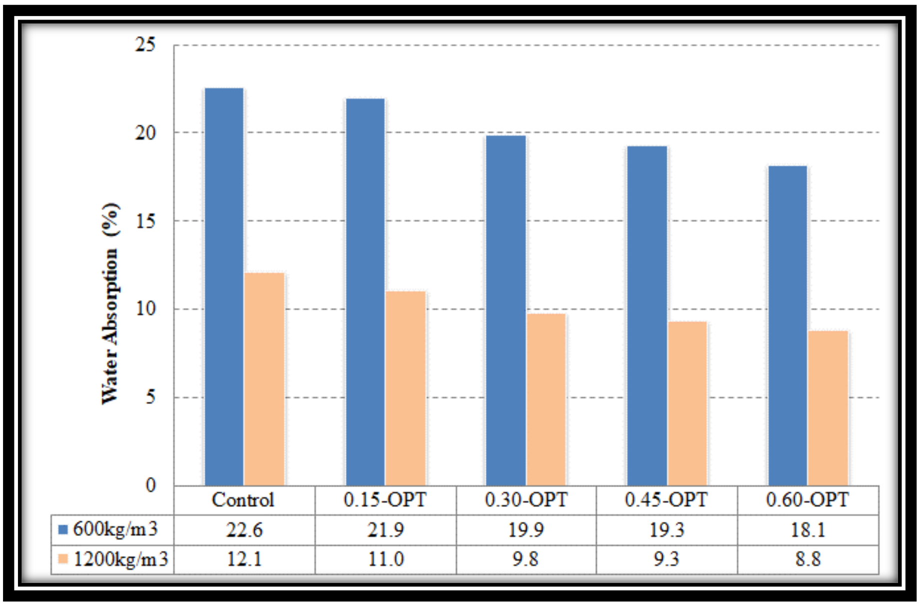

Fig. 6 - The water absorption capacity of FC with different percentages of OPT fibre of both densities

Porosity

Fig. 7 shows the porosity result for 600 kg/m³ and 1200 kg/m³ densities of FC with different percentages of OPT fibre. The OPT fibre at 0.15% absorbs water higher compared to other percentages of OPT; 67.8% for 600 kg/m³ and 33.6% for 1200 kg/m³. The result shows that the increase of OPT will decrease porosity. This is because the small pore size and volume will prevent water from infiltrating the specimen. The control specimen was 69.7% for 600 kg/m³ and 35.5% for 1200 kg/m³, which shows the highest result since it absorbs water. Next, for the 0.30% of OPT it shows 66.9% for 600 kg/m³ and 32.2% for 1200 kg/m³. In addition, for 0.45% of OPT it shows 65.7% for 600 kg/m³ and 31.7% for 1200 kg/m³. Lastly, for 0.60% of OPT it shows 64.8% for 600 kg/m³ and 30.6% for 1200 kg/m³. The result in this experiment shows that the increment of OPT percentages reduces the porosity of FC.

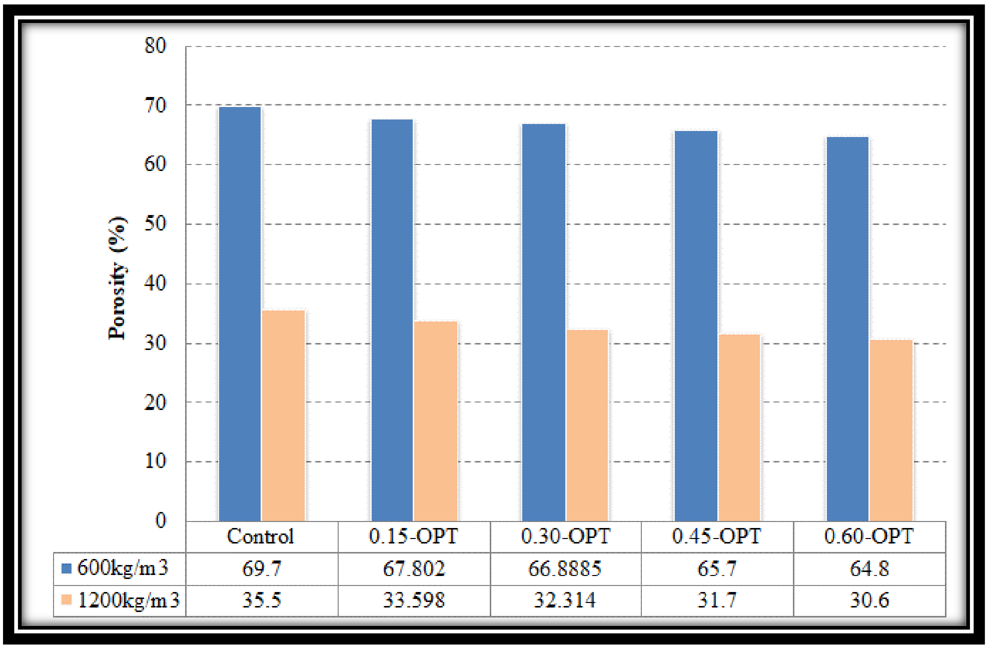

Fig. 7 - The porosity of FC with different percentages of OPT fibre of both densities

Drying Shrinkage

Figures 8 and 9 show that drying shrinkage for all specimens are high from an early age until 30 days and then continues to increase. The addition of OPT causes the drying shrinkage of the specimen to increase. The 0.45% OPT fibre leads to a better result of drying shrinkage for both densities because it drastically increases. The density of 600 kg/m³ causes more general shrinkage than 1200 kg/m³, given the higher amount of foam content used in the mix. OPT reacts as an aggregate that gives the compact composition of the microstructure, which lessens and decreases the size and measures of the pores, thus improving the drying shrinkage (Fu *et al.*, 2020). The highest value is for the control specimen. Notably, the highest value of drying shrinkage is not good for concrete since it can cause cracks in the future.

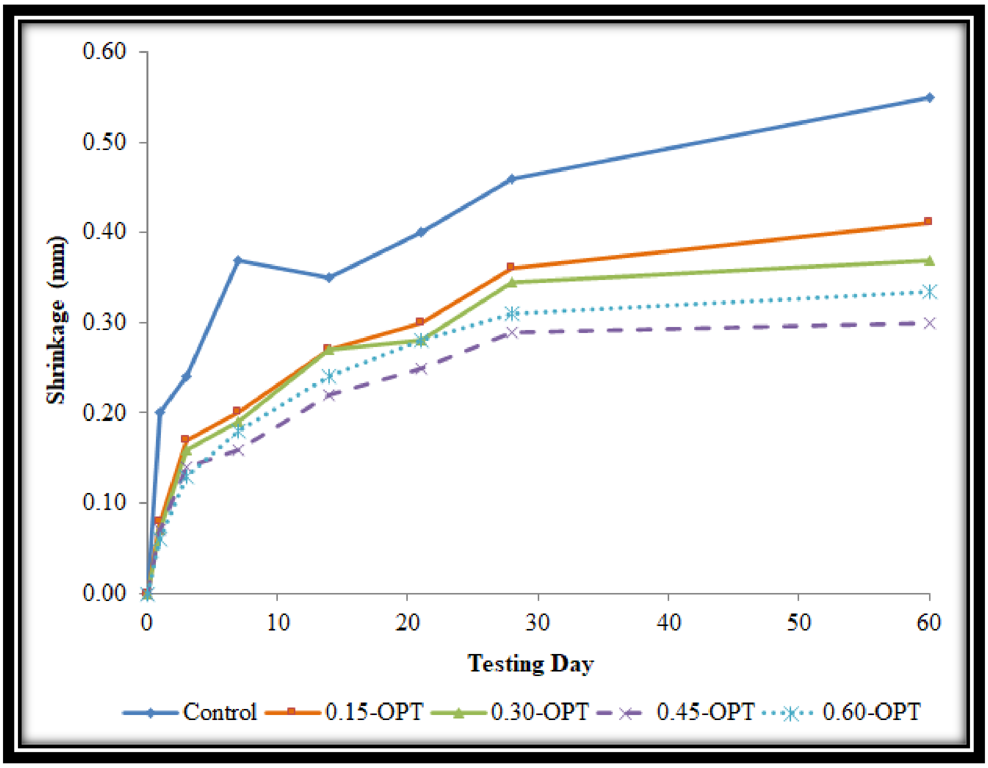

Fig. 8 - Drying shrinkage result with different percentage of OPT fibre for 600 kg/m³ density

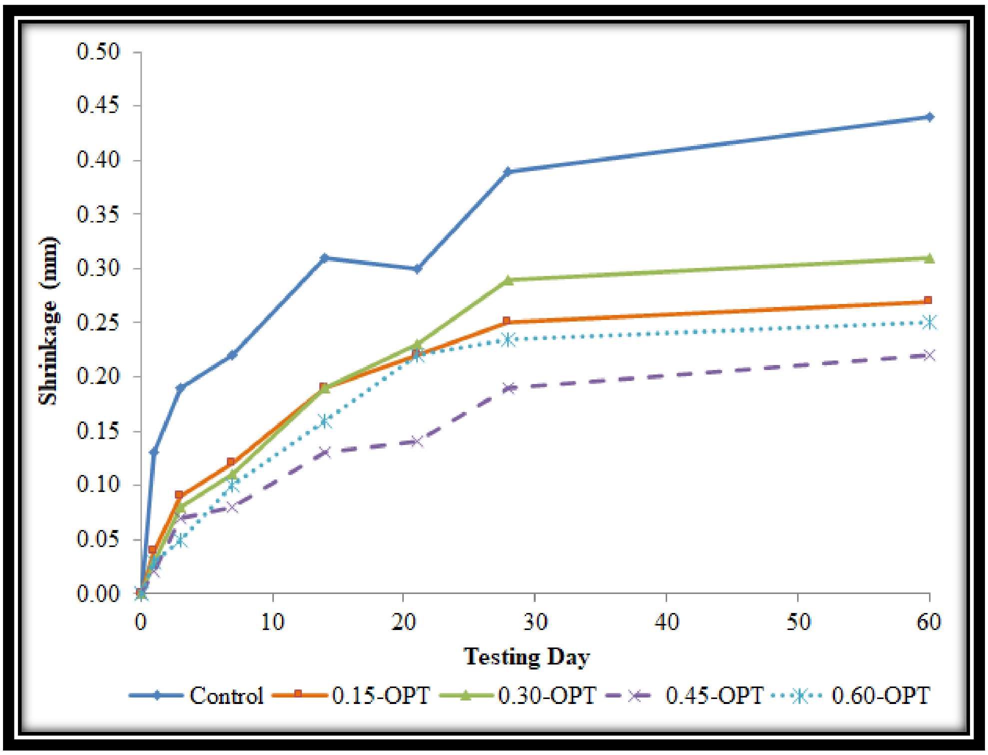

Fig. 9 - Drying shrinkage result with different percentage of OPT fibre for 1200 kg/m³ density

Ultrasonic Pulse Velocity (UPV)

Fig. 10 shows the UPV result of 600 kg/m³ and 1200 kg/m³ densities of FC with different percentages of OPT fibre. The UPV method is completely harmless and is suitable for assessing the quality of concrete. This method can be used to detect internal cracks and other defects and concrete changes such as deterioration in an aggressive chemical environment, freezing and dilution. From the graph below, we can conclude that the concrete does not contain large voids or cracks, which would no doubt affect its structural integrity. The 0.45% OPF volume fraction contributed to the highest result of UPV. Therefore, the UPV is important to assess the presence of large voids in the interface zone and, finally, to check the OPT's quality and strength. The lowest value of UPV was for the control specimen. This method allows for calculating the strength of concrete and for concrete test specimens.

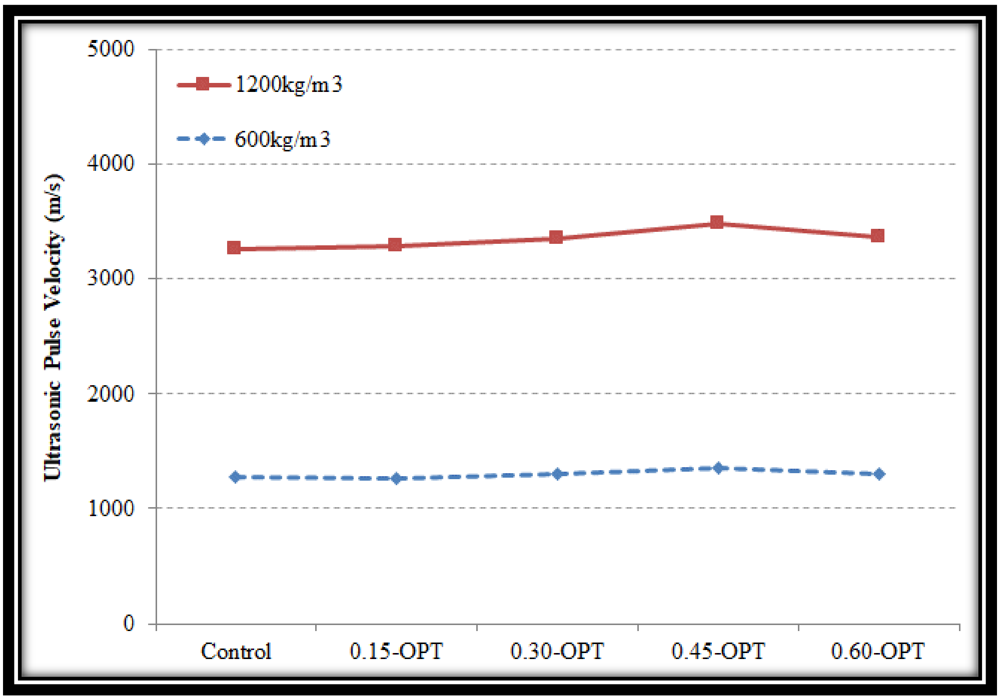

Fig. 10 - Ultrasonic pulse velocity (UPV) of FC with different percentages of OPT fibre of both densities

Conclusion

For this research, the durability properties of LFC with the inclusion of different proportions of oil palm trunk (OPT) fibre into different densities of LFC were carried out. Two densities of LFC, 600 kg/m^3 and 1200 kg/m^3, were prepared and tested with five different percentages of OPMF added, which were 0.00%, 0.15%, 0.30%, 0.45% and 0.60%. The experimental results reveal that the best results, in terms of the durability properties (water absorption, porosity, drying shrinkage and ultrasonic pulse velocity), were achieved with the optimum inclusion of 0.45% volume fraction of OPT fibre for both densities considered in this research. At 0.45% volume fraction of OPT fibre, the fibres and the cementitious matrix attained maximum compaction, which resulted in good mix homogeneity. Beyond the optimum level of OPT fibre addition, agglomeration and the non-uniform dispersion of fibres was observed, which led to decrease in all durability properties. The theoretical and contextual contribution of this research will pave the way to fabricate high performance LFC with excellent durability properties with the addition of oil palm biomass waste specifically trunk fibre. The output from this experimental investigation will give a better insight of the potential use of natural fibre in LFC.

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