An Experimental Investigation on Engineering Properties of Alkali Resistant Fibermesh Reinforced Foamed Concrete Jacket

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Abstract- In the last few years, there is emerging attention in using Lightweight Foamed Concrete (LFC) as a lightweight non-structural and semi-structural element in buildings to take advantage of its excellent insulation properties. Though, LFC has been noticed to have some disadvantages: considerable brittleness; results in low compressive and flexural strength, poor fracture toughness, poor resistance to crack propagation and low impact strength. Hence, this research had been conducted to investigate the influence of different layers of fibremesh on the durability properties of lightweight foamed concrete. The fibremesh used in this research is an alkali-resistant (AR) fibreglass mesh categorized as synthetic fibre also known as textile fabric. It has continuous fibre with warp and weft structure that was used as confinement material in this investigation where 160gsm weights per area (g/m2) of the fibremesh was utilized. There are four experimental tests were involved in this preliminary study which was porosity, water absorption, ultrasonic pulse velocity and drying shrinkage test. All the specimens were confined with 1-layer to 3-layers of fibremesh. Two densities of 600kg/m^3 and 1200kg/m^2 were prepared and the result was compared with the control. The results had indicated that 3-layers of fibremesh confinement significantly improved the durability properties of foamed concrete for the porosity, water absorption, ultrasonic pulse velocity and drying shrinkage results.

Keywords – foamed concrete, fibermesh, confinement, porosity, water absorption, drying shrinkage, ultrasonic pulse velocity

I. INTRODUCTION

Currently, the application of an air cell system becomes one of the preferable technologies to be used in a construction project due to its benefits [1,2,3]. It is getting more attention widely since it has the ability to reduce the size of the foundation and structural dead load due to its low density, minimize the operating cost and labour use, and acknowledged as sustainable building material [4,5,6]. This high flowability concrete familiar to be called lightweight foamed concrete has a varied range of density and can be constructed to any desired application such as wall panel, slabs or other load-bearing building elements, lightweight concrete block and void filling [7]. This is the initial investigation on the influenced of different layers of fibremesh confined lightweight foamed concrete to improve its porosity, water absorption, and drying shrinkage performance. The fibremesh used in this research is an alkali-resistant (AR) fibreglass mesh with 160 weight per area (g/m^2) This type of fibremesh is more flexible, easy to handle, cheaper and high durability performance compared to others.

II. MATERIALS AND MIX DESIGN

Lightweight foamed concrete specimens confined with 1-layer to 3-layers of fibremesh (160gsm) will be compared to the control specimens (LFC without any reinforcement). Ordinary Portland Cement (OPC) was used which is in accordance with the specifications of Type 1 Portland Cement in ASTM C150-04. Sand particle size utilized in this research is less than 1.18mm diameter with the specific gravity 2.74 and fineness modulus 1.35 [8]. The grading limits are according to ASTM C778-06. Fine aggregate is suitable for producing the lightweight foamed concrete since the coarse aggregate caused bigger pores existence and create an inconsistent mix which affects the lightweight foamed concrete properties. The presence of water is necessary to mix the cement and fine aggregate to form the cement slurry through chemical reaction which will leads to the hardened of mortar paste. Tap water was used which is complied with ASTM C1602-C05, the specification for mixing water used in producing cement concrete [9].

III. EXPERIMENTAL SETUP

3.1 Water absorption test

Water absorption test was carried out in this study to calculate the water absorption capacity of hardened lightweight foamed concrete in accordance with BS 1881-122 [10]. Prior to the testing, the specimen cubes (100 mm × 100 mm × 100 mm) were taken out one day in advanced from the curing tank. The specimen was wiped to surface dry condition and weighed to obtain the saturated surface dry weight of the specimen. Next, the specimen was oven dried for one day and the oven dried weight of specimen was measured.

3.2 Vacuum Saturation test

Porosity and permeability of LFC are interconnected. Porosity determines the pathway of intrusion of aggressive ions such as carbonates and chloride into the concrete. Permeability determines the rates of intrusion. Porosity was determined by the existence of pores, capillary pores, micro-cracks, Interfacial Transition Zone (ITZ) and porosity in filler [11]. Permeability was determined by the total porosity of the LFC. In this study, the permeability sample was used to determine the porosity after completing the intrinsic permeability test. Porosity was determined by water absorption under vacuum condition. The LFC specimens were weighted as their dried mass after completing intrinsic permeability test. The sample was then put into a desiccator full of water. The desiccator was sealed tightly with super sticky grease. A vacuum pump was connected to the desiccator to vacuum away all the existing gas inside the desiccators. The system was allowed to run for 72 ± 2 hours. The saturated specimens were weighted in air and suspended in water. The porosity was calculated by the following formula [12].

3.3 Ultrasonic Pulse Velocity test

Ultrasonic pulse velocity is the non-destructive test to know the concrete characterization [13]. The ultrasonic wave is generated by a transducer in contact with the test material either in the form of compressional wave or shear wave. These waves are detected by the second transducer placed on the other face of the test material. The ultrasonic wave velocity depends on the elastic properties and density of the concrete (ACI 544.1R, 1996) [14]. The travel time and energy decay through the material have been processed and displayed by the digital computer connected with the transducers. Using the travel time and measured dimension, the ultrasonic pulse velocity has been calculated.

3.4 Shrinkage Test

The test procedure is in compliance with ASTM C878. The sample test must be a prism: 75 mm. square with a gage length of 250 mm and an overall estimated length (including the length of the rod and cap nuts) of 290 mm. A minimum number of three samples were set up for each test in order to get the average result. Figure 2 shows the apparatus that measures the drying shrinkage of foamed concrete. The initial length measurements were taken using a length comparator that is capable of adjusting the measurements to 0.001mm with 250mm invar bar. The length of the comparator was calibrated against the reference invar bar in each of the sample.

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IV. RESULTS AND DISCUSSION

4.1 Porosity

Figure 1 shows the porosity of foamed concrete with different later of confinement for both densities. As can be seen from Figure 1, the control specimen shows the highest porosity value when compared to other specimens which for both densities. The porosity value decreased as number of layers of confinement increased. This is because the presence of fibremesh reduces the air contents in the lightweight foamed concrete as it filled the air void at the confined area and that explained the reason for the control specimen that had higher porosity compared to all other specimens [15,16]. Therefore, 3 layers of confinement of foamed concrete specimens with 160g fibremesh shows the best result.

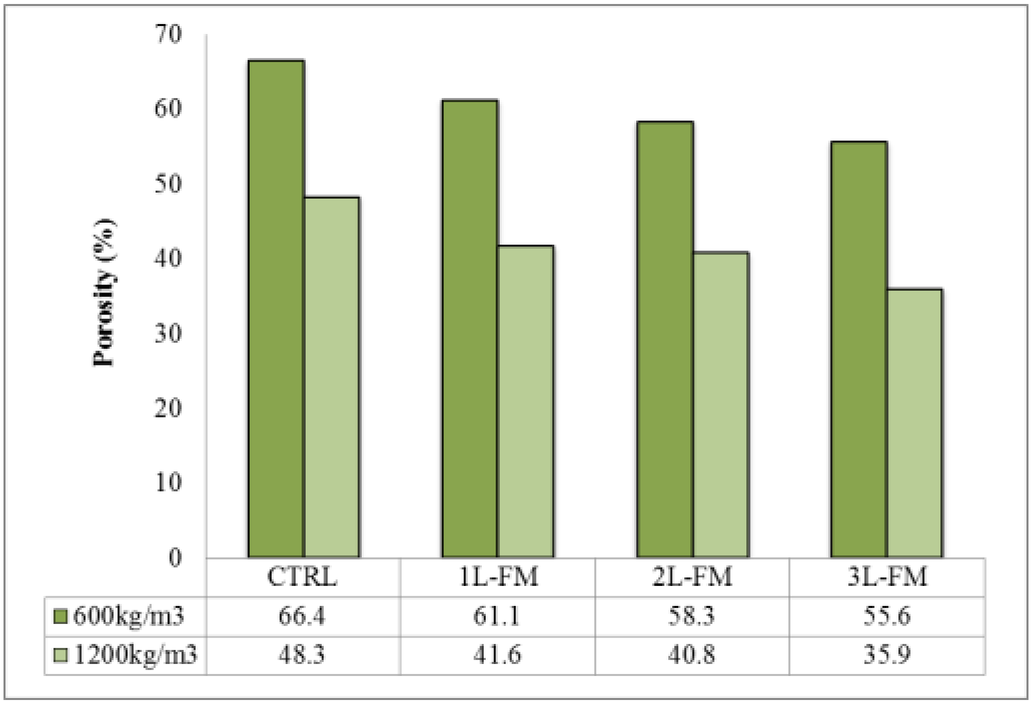


Figure 1. Porosity of foamed concrete with different layers of fibermesh confinement

4.2 Water Absorption

Figure 2 shows the water absorption capacity of foamed concrete with different later of confinement for both densities and the control specimen as a reference sample. Overall, the control specimen possessed relatively high-water absorption value as compared to the specimens with the confinement of fibremesh for both densities. It can be seen that, higher number of layers of fibermesh confinement contribute to greater reduction of water absorption capacity for entire specimens tested in this research. The reduction of water absorption capacity of foamed concrete specimens is due to the enclosed fibremesh array that managed to prevent the penetration of water into the cement matrix [17, 18, 19]. Thus, 3-layers of fibremesh confinement lead to significant improvement of the water absorption capacity of lightweight foamed concrete.

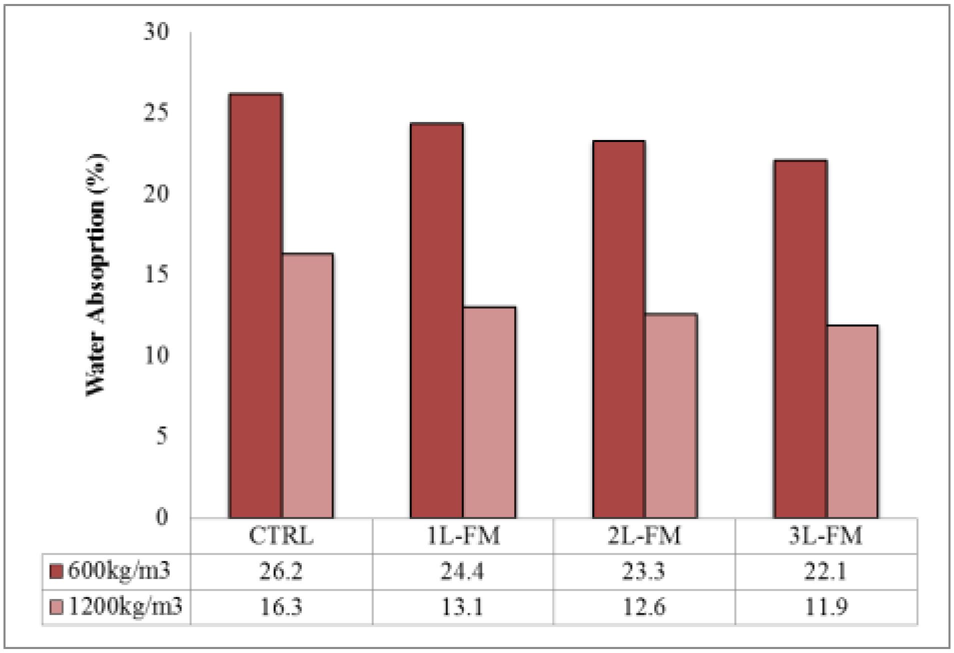


Figure 2. Water Absorption of foamed concrete with different layers of fibermesh confinement

4.3 Ultrasonic Pulse Velocity

Ultrasonic pulse velocity (UPV) is one of the most prevalent non-destructive methods implemented to evaluate concrete toughness. Though it is not a precise apparatus to measure the pore structures in concrete, but it can still provide an excellent initial forecast of the quality of concrete based material. Figure 3 shows the ultrasonic pulse velocity (UPV) results for both densities tested in this study. It can be seen from Figure 3 that higher number of layers of fibermesh confinement has enhanced the ultrasonic pulse velocity (UPV) for both densities in comparison with control specimen.

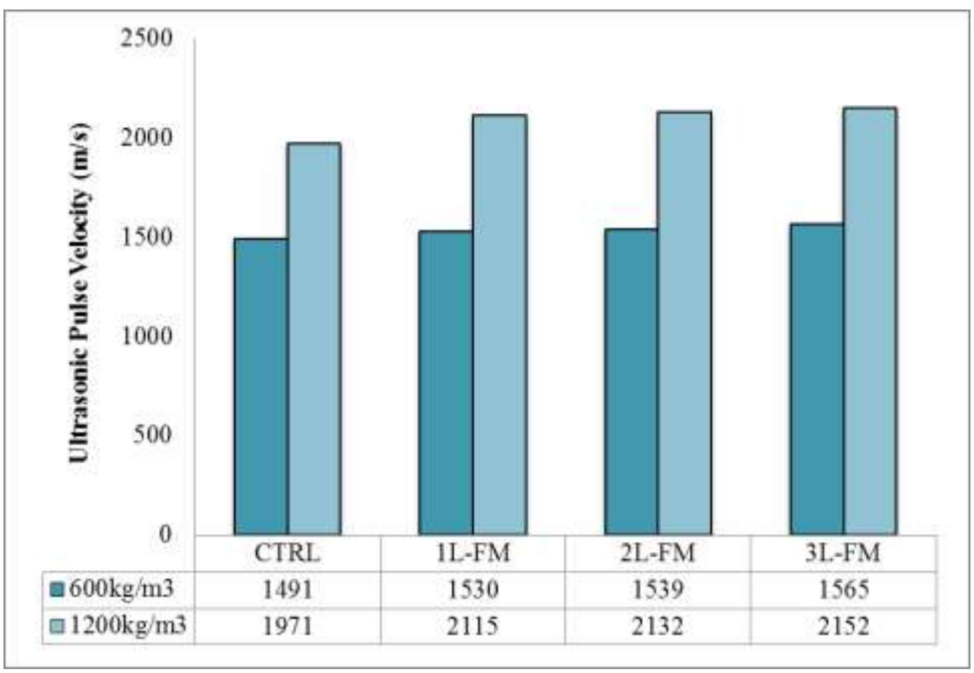
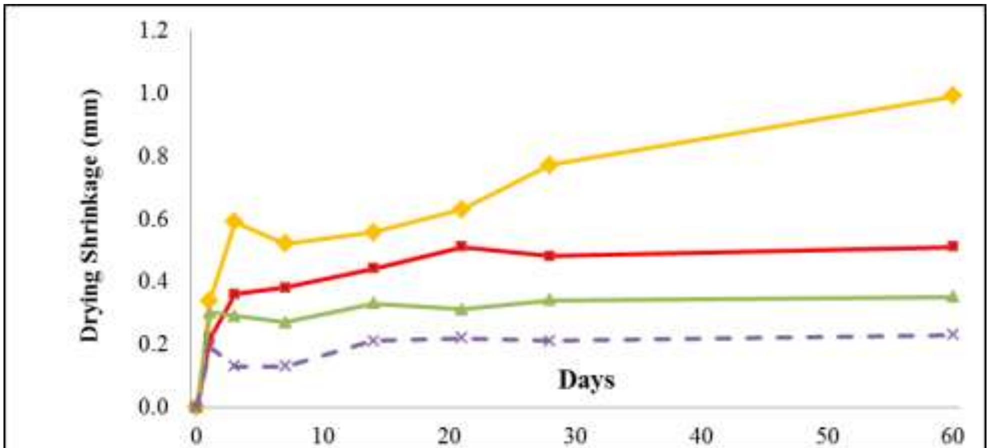


Figure 3. Ultrasonic Pulse Velocity of foamed concrete with different layers of fibermesh confinement

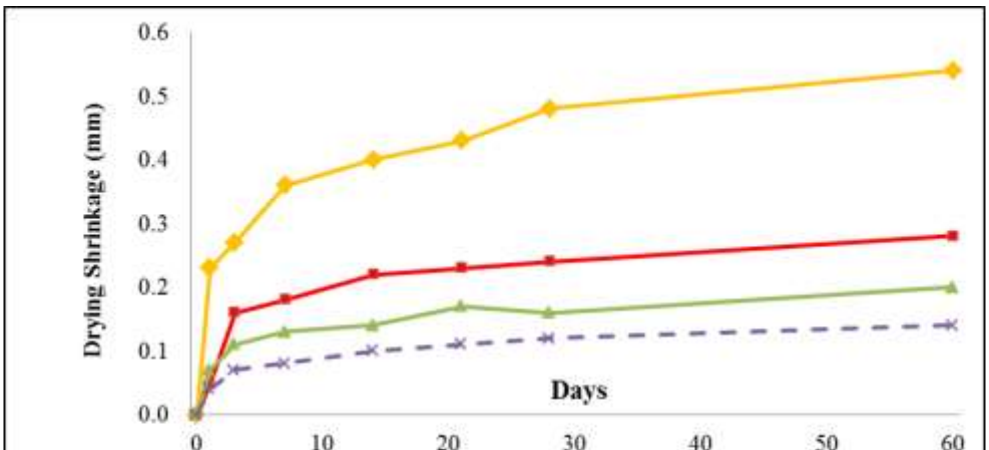
4.4 Drying Shrinkage

Drying shrinkage occurred in the cement matrix is due to the evaporation of internal free water from the concrete or mortar in the hardened state to the surrounding environment. Based on the test result shown in Figure 4 and Figure 5, the control specimen exhibits higher drying shrinkage compared to other specimens. This is because the confinement of fibremesh reduced the drying shrinkage behavior in lightweight foamed concrete specimens, as the fibremesh can maintain the water contain and delay the internal moisture evaporation results hence lessening the drying shrinkage behavior [20]. There is significant improvement of drying shrinkage behavior in foamed concrete specimens confined with fibremesh .



	0	1	3	7	14	21	28	60
Control	0.00	0.34	0.59	0.52	0.56	0.63	0.77	0.99
1L-FM	0.00	0.22	0.36	0.38	0.44	0.51	0.48	0.51
2L-FM	0.00	0.30	0.29	0.27	0.33	0.31	0.34	0.35
3L-FM	0.00	0.19	0.13	0.13	0.21	0.22	0.21	0.23

Figure 4. Drying shrinkage of foamed concrete of 600kg/m^3 density with different layers of fibermesh confinement



	0	1	3	7	14	21	28	60
Control	0.00	0.23	0.27	0.36	0.40	0.43	0.48	0.54
1L-FM	0.00	0.05	0.16	0.18	0.22	0.23	0.24	0.28
2L-FM	0.00	0.07	0.11	0.13	0.14	0.17	0.16	0.20
3L-FM	0.00	0.04	0.07	0.08	0.10	0.11	0.12	0.14

Figure 5. Drying shrinkage of foamed concrete of 1200kg/m^3 density with different layers of fibermesh confinement

V. CONCLUSION

Overall, the confinement of fibremesh significantly enhanced the engineering properties of lightweight foamed concrete. The results had indicated that 3-layers of fibremesh confinement significantly improved the durability properties of foamed concrete for the porosity, water absorption, ultrasonic pulse velocity and drying shrinkage results. Higher number of layers of fibermesh confinement contributes to greater reduction of water absorption capacity for entire specimens tested in this research. The reduction of water absorption capacity of foamed concrete specimens is due to the enclosed fibremesh array that managed to prevent the penetration of water into the cement matrix. In terms of porosity, the presence of fibremesh reduces the air contents in the lightweight foamed concrete as it filled the air void at the confined area and that explained the reason for the control specimen that had higher porosity compared to all other specimens. Confinement of fibremesh reduced the drying shrinkage behavior in lightweight foamed concrete specimens, as the fibremesh can maintain the water contain and delay the internal moisture evaporation results hence lessening the drying shrinkage behavior. There is significant improvement of drying shrinkage behavior in foamed concrete specimens confined with fibremesh.

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REFERENCES

[1] Hilal, A. A., Thom, N. H., & R. Dawson, A. (2015). The Use of Additives to Enhance Properties of Pre- Formed Foamed Concrete. International Journal of Engineering and Technology, 7(4), 286-293.

[2] Li, L. Y., & Purkiss, J. (2005). Stress-strain constitutive equations of concrete material at elevated temperatures. Fire Safety Journal, 40(7), 669-686.

[3] Norgaard, J., & Othuman Mydin, M. A. (2013) Drywall Thermal Properties Exposed to High Temperatures and Fire Condition, Jurnal Teknologi, 62(1), 63-68

[4] Othuman Mydin, M. A., & Wang, Y. C. (2012). Thermal and mechanical properties of lightweight foamed concrete at elevated temperatures. Magazine of Concrete Research, 64(3), 213-224.

[5] Al-Chaar, G. K. (2013). Natural Pozzolan as a Partial Substitute for Cement in Concrete. The Open Construction and Building Technology Journal, 7(1), 33-42.

[6] Arioz, O. (2007). Effects of elevated temperatures on properties of concrete. Fire Safety Journal, 42(8), 516-522.

[7] Bazant, Z. P., Kaplan, M. F., & Haslach, H. W. (1996). Concrete at high temperatures: material properties and mathematical models. Applied Mechanics Reviews.

[8] Bingöl, A. F., & Gül, R. (2009). Effect of elevated temperatures and cooling regimes on normal strength concrete. Fire and Materials, 33(2), 79-88.

[9] Dwaikat, M. B., & Kodur, V. K. R. (2009). Response of Restrained Concrete Beams under Design Fire Exposure. Journal of Structural Engineering, 135(11), 1408-1417.

[10] Eurocode. (2004). EN 1992 -Design of concrete structures. Eurocode 2.

[11] Falade, F., Ikponmwosa, E. E., & Ojediran, N. I. (2010). Behaviour of lightweight concrete containing periwinkle shells at elevated temperature. Journal of Engineering Science and Technology, 5(4), 379-390.

[12] Georgali, B., & Tsakiridis, P. E. (2005). Microstructure of fire-damaged concrete. A case study. Cement and Concrete Composites, 27(2), 255-259.

[13] Gowri, R., & Anand, K. B. (2018). Utilization of fly ash and ultrafine GGBS for higher strength foam concrete. IOP Conference Series: Materials Science and Engineering, 310(1-10).

[14] Othuman Mydin, M. A., Musa, M., & Abdul Ghani, A. N. (2018) Fiber Glass Strip Laminates Strengthened Lightweight Foamed Concrete: Performance Index, Failure Modes and Microscopy Analysis. AIP Conference Proceedings 2016 (020111), 1-8

[15] Othuman Mydin, M.A., Noordin, N.M., Utaberta, N., Mohd Yunos, M.Y., & Segeranazan, S. (2016). Physical properties of foamed concrete incorporating coconut fibre. Jurnal Teknologi, 78(5), 99-105.

[16] Othuman Mydin, M.A., Sahidun, N.S., Mohd Yusof, M.Y., & Noordin, N.M. (2015). Compressive, flexural and splitting tensile strengths of lightweight foamed concrete with inclusion of steel fibre. Jurnal Teknologi, 75(5), 45-50.

[17] Rafi, M. M., Aziz, T., & Lodi, S. H. (2017). Mechanical properties of low-strength concrete at exposure to elevated temperatures. Journal of Structural Fire Engineering, 8(4), 418-439.

[18] Rai, A., & Joshi, Y. P. (2014). Applications and Properties of Fibre Reinforced Concrete. Journal of Engineering Research and Applications, 4(5), 123-131.

[19] Serri, E., Othuman Mydin, M.A., & Suleiman, M.Z. (2014). Thermal properties of Oil Palm Shell lightweight concrete with different mix designs. Jurnal Teknologi, 70(1), 155-159..

[20] Yalley, P. P., & Kwan, A. S. . (2012). Coconut Fibre as Enhancement of Concrete. Journal of Engineering and Technology, 2, 54-73.