Laboratory Investigation on Axial Compressive Strength of Lightweight Foamed Concrete Confined with Woven Fibreglass Mesh

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Abstract – Lightweight foamed concrete (LFC) is a self-compacted concrete that has a low density which is almost half of the normal weight concrete. Its application in construction work gains interest among researcher due to the variety of benefits such as low self-weight, easy to construct, economic, etc. However, LFC considered as brittle materials and possesses low compressive strength. Thus, in this research authors will implement the confinement technique to increase its compressive strength. The confinement was done by utilized the woven fibreglass mesh (textile fabric) and the effect of its weight per area (g/m^2) was observed. The density of LFC was fixed at 1100kg/m^3 with 1:1.5 of cement to sand ratio and water to cement ratio constant at 0.45. The LFC specimens were confined with 1-layer of 110g, 130g, 145g, and 160g of woven fibreglass mesh per area. The result shows that the confinement of 160g of woven fibreglass mesh significantly improved the compressive strength of LFC by 56.1% at 180-day compared to the unconfined specimens at same day test. Authors also verified that the weight of woven fibreglass mesh has a noticeable impact on the compressive strength of LFC.

Keywords – Compressive strength, foamed concrete, confinement, textile fabric, AR-fibreglass

I. Introduction

High strength to weight ratio is one of the characteristics of lightweight foamed concrete (LFC). This type of concrete possesses large scale of density which is range between 300kg/m^3 to 1840kg/m^3, 87% to 23% lighter than conventional concrete [1]. The reduction of its self-weight is due to the insertion of foam in cement slurry during the mixing process [2][3]. This process creates an air cell system where the bubble form considered as aggregate with zero weight in this concrete since no coarse aggregate being utilized [4]. This advantage leads to the reduction of foundation size and structural dead load due to its low density [5]. Furthermore, LFC also preferable building material because of its porous nature that provides high fire resistance and thermal insulation, and low thermal conductivity [6][7][8], good sound insulation [9][10], resistance to aggressive environment [11][3] and regarded as a sustainable construction material in the construction industry [12]. As reported by Fu et al. [13], for the past 30 years, LFC is widely utilized as void filling, ditch repair, retaining wall, floor structure, etc. and its application limited to non-structural and semi-structural elements only due to its brittleness. Thus, numerous researches have been conducted to enhance the mechanical performance of LFC.

Most of the previous study revealed that the inclusion of synthetic or natural fibres in LFC improved its mechanical properties [14][15][16]. However, many drawbacks also reported such as settlement and corrosion of steel fibres [17] and deterioration of natural fibres [18] which is influenced its performance for the long service life of building structure. This factor needs to be considered by the contractor during the selection of building materials as a concern for future building maintenance plan to conserve the life span of the building. Despite that production of textile fabric can be considered to be utilized as reinforcement elements for LFC. The different between mentioned fibre with textile fabric is its physical structure where the synthetic and natural fibre is a short fibrous fibre while the textile fabric is continuous fibre with meshes (weft and waft) structure. The textile fabric has been used as reinforcing elements for cement-based concrete with less than 2mm diameter of aggregate and it showed a superior result. Moreover, the textile fabric totally functioned if it was combined with the homogeneous mixture to ensure it penetrates completely to the fibre. Hence, utilization of textile fabric for LFC reinforcement can be considered as an advantage for it due to the absence of coarse aggregate.

Besides, many factors that needs to be considered for the selection of textile fabric materials such as its types (carbon, aramid, basalt, glass), the structure of textile fabric (2D or 3D), etc. In this study, woven fibreglass mesh which is alkali-resistance of synthetic fibre was selected due to its low self-weight, flexible, resist to environment attack yet low cost compared to other materials. Therefore, in this preliminary investigation authors would like to discover the effects of the different weight of woven fibreglass mesh per area confined with LFC under axial loading.

II. MATERIALS AND MIX PROPORTIONS

Cement, fine sand, and water are the basic ingredient in producing the LFC to form a homogeneous mix. The constituent materials used in this research were Ordinary Portland Cement, fine sand (sieved using sieve size 1.18mm), and clean water without any harmful substance. Besides, NORAITE PA-1 is the protein-based foaming agent selected to create stable bubble foam and added into the mortar slurry to produce a light concrete than conventional concrete. This foaming agent was diluted with water in the ratio of 1:30 of water to surfactant and produced foam with a density range in between 65-75g/L. Since the weight of woven fibreglass mesh per area (g/m^2) is the manipulated variable thus the density of LFC, and mix proportion for this research remains constant while the textile fabric used is the same type which is alkali resistance woven fibreglass mesh with 110g, 130g, 145g, and 160g of weight per area (g/m^2). The LFC specimens were confined with 1-layer of each respective weight of the textile fabric and the control specimen (unconfined) as a reference sample. Table 1 shows the materials and mix proportions detail implement in this study.

Table 1 Materials constituents utilized.

Manipulated variable	Constant variable					
Specimen	Mix density (kg/m^3)	Mix ratio		Mix proportions, kg/m^3		
		Cement/ sand	Water/ cement	Cement	Sand	Water
Control	1100	1:1.5	0.45	410.79	616.18	184.86
110g						
130g						
145g						
160g						

III. LABORATORY ASSESSMENTS

Compressive strength is one of the important properties of LFC and it is usually utilized for designing purposes in the concrete industry. To investigate the effect of woven fibreglass mesh confinement, the textile fabric was cut according to the mould size and placed in the mould (refer to Figure 1) using hand lay-up technique as demonstrated by Salimian et al. [19]. The compressive test has been done as specified in the test BS EN12390-Part 3-2009 [20] on LFC cubes with the aid of a compressive test machine (GOTECH GT-7001-BS300 Universal Testing Machine) at the HBP Testing Unit in the School of Housing Building & Planning USM as shown in Figure 2. The compressive strength was measured by the maximum resistance from the axial loading. The size of the cubes was used is 100x100x100mm.

In order to gain strength, the samples were wrapped with black plastic bags for the curing process. The specimens were unwrapped 24 hours before the test and kept in the oven at temperature of 105±ºC. As reported by [12], this process were done to lessen the build-up of pore water pressure in the saturated microstructure of the LFC. Then, the specimens were left to cool to reach a stable temperature after having completed the drying process. The weight of each cube was noted for the data analysis and only ±50 different measurement is allowed. The exceed weight of LFC from the desired density will be eliminated. However, all the specimens in this research achieved the target dry density which is 1100kg/m^3 with ±10-15 differences. These lightweight foamed concrete cubes were tested for 7, 28, 56 and 180 days of curing.

Figure 1 Woven fibreglass mesh placed in mould.

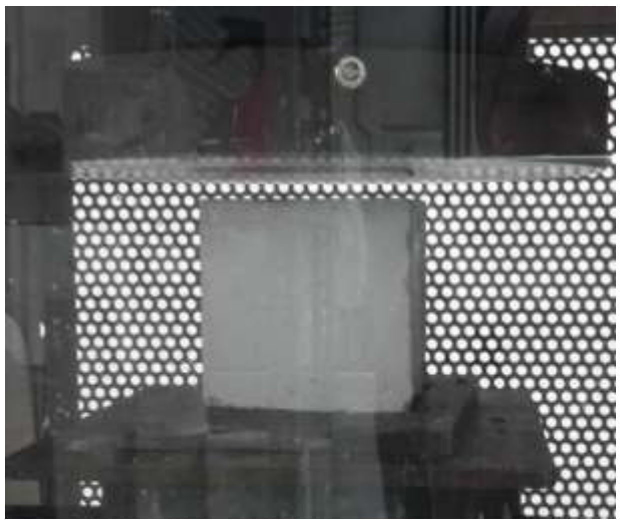

Figure 2 Setup for compressive test using GOTECH GT-7001-BS300 Universal Testing Machine.

IV. RESULTS AND DISCUSSION

Figure 3 shows the development of the compressive strength with the curing ages for the LFC specimens from day-7 up to day-180. Overall, the development of compressive strength increased at all test ages. For instant, the compressive strength of the control specimen increased up to 30.6% at 180-day while for the specimen confined with 160g of woven fibreglass mesh boosted approximately 60% at 180-day compared to the strength achieved at day 7. Besides, the increase of weight of woven fiberglass mesh per area (g/m^2) also influenced the compressive strength for LFC specimens.

As shown in Table 2, the confinement of LFC specimens shows significant increment when compared to the control specimen. At day-180, 25.3%, 38.8%, 39.9% and 56.1% of compressive strength increment was achieved when the LFC specimen confined with 110g, 130g, 145g, and 160g of woven fibreglass mesh, respectively. This is because the confinement of woven fibreglass mesh improved the ductility of LFC specimens and prevents premature failures due to the increase in deformation capacity. This result in agrees with the experimental study found by [21], where they concluded that the unconfined concrete showed brittle failure while the confined concrete showed the ductile behavior that attributed to the confinement effect of the outer jacket.

Besides, Gayathri et al. [22] also revealed that the concrete strength can be improved by increasing its load bearing capacity thru the additional of textile fabric that having high GSM (gram per square meter). Hence, the confinement of 160g of woven fiberglass mesh in LFC shows the highest compressive strength compared to all other specimen and the lowest compressive strength was obtained by the control specimen.

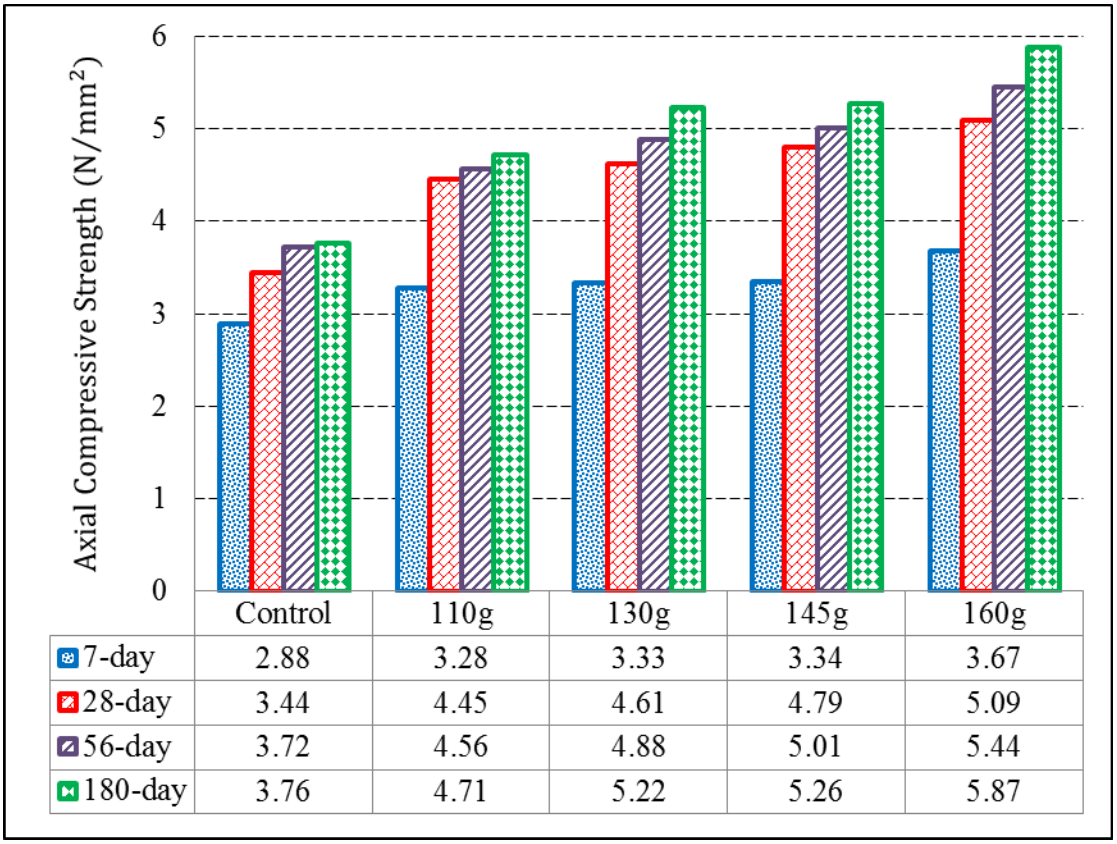

Figure 3 Axial compressive strength of LFC specimens confined with different weight of woven fibreglass mesh per area (g/m^2).

Table 2 Percentage of increment in compressive strength of LFC specimens confined with different weight of woven fibreglass mesh per area (g/m^2) compared to the control specimens.

Specimen	Percentage of increment (%)			
	7-day	28-day	56-day	180-day
110g	13.9	29.4	22.6	25.3
130g	15.6	34.0	31.2	38.8
145g	16.0	39.2	34.7	39.9
160g	27.4	48.0	46.2	56.1

V. CONCLUSION

Overall, all the specimens confined with woven fibreglass mesh showed an increased compressive strength compared to the control specimens. However, 160g of woven fibreglass mesh weight per area shows the significant improvement of compressive strength. It can be concluded that the weight of woven fibreglass mesh noticeable influenced the mechanical performance of LFC. The higher the weight per area of textile fabric, the higher compressive strength would be achieved.

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REFERENCES

[1] Hedjazi, S. (2019). Compressive Strength of Lightweight Concrete. In IntechOpen (pp. 1–18). https://doi.org/10.5772/intechopen.88057

[2] Amran, Y. H. M., Farzadnia, N., & Ali, A. A. A. (2015). Properties and applications of foamed concrete; A review. Construction and Building Materials, 101(December), 990–1005. https://doi.org/10.1016/j.conbuildmat.2015.10.112

[3] Ramamurthy, K., Nambiar, E. K. K., & Ranjani, G. I. S. (2009). A classification of studies on properties of foam concrete. Cement and Concrete Composites, 31(6), 388–396. https://doi.org/10.1016/j.cemconcomp.2009.04.006

[4] Zaidi, A. M. A., & Li, Q. M. (2009). Investigation on penetration resistance of foamed concrete. Proceedings of the Institution of Civil Engineers - Structure and Buildings 2009, 77–85. https://doi.org/10.1680/stbu.2009.162.1.77

[5] Chen, Y., & Xu, Y. F. (2019). Compressive strength of fractal-textured foamed concrete. Fractals, 27(1), 1–11. https://doi.org/10.1142/S0218348X19400036

[6] Liu, T., Shi, G., Li, G., & Wang, Z. (2019). Lightweight foamed concrete with foam agent addition. IOP Conference Series: Materials Science and Engineering, 490(3), 1–6. https://doi.org/10.1088/1757-899X/490/3/032033

[7] Musa, M. (2019). Investigation of Durability, Thermal and Mechanical Properties of Oil Palm Empty Fruit Bunch (EFB) Fibre Strengthen Lightweight Foamed Mortar (LFM). Universiti Sains Malaysia.

[8] Sari, K. A. M., & Sani, A. R. M. (2017). Applications of Foamed Lightweight Concrete. MATEC Web of Conferences, 97, 1–5. https://doi.org/10.1051/matecconf/20179701097

[9] Kim, H. K., Jeon, J. H., & Lee, H. K. (2012). Workability, and mechanical, acoustic and thermal properties of lightweight aggregate concrete with a high volume of entrained air. Construction and Building Materials, 29, 193–200. https://doi.org/10.1016/j.conbuildmat.2011.08.067

[10] Meyyappan, P. L., & Bharathbalji, G. (2019). Effect of Flyash in Enhancing the Strength and Durability Characteristics of Foam Concrete. International Journal of Recent Technology and Engineering, 8(4S2), 60–63. https://doi.org/10.35940/ijrte.d1015.1284s219

[11] Jones, M. R., & McCarthy, A. (2005). Utilising unprocessed low-lime coal fly ash in foamed concrete. Fuel, 84(11), 1398–1409. https://doi.org/10.1016/j.fuel.2004.09.030

[12] Richard, A. O., & Ramli, M. B. (2015). The Effects of Curing Methods on Early-age Strength of Sustainable Foamed Concrete. Advances in Research, 3(6), 548–557. https://doi.org/10.9734/air/2015/13373

[13] Fu, Y., Wang, X., Wang, L., & Li, Y. (2020). Foam Concrete : A State-of-the-Art and State-of-the-Practice Review. 2020.

[14] Falliano, D., De Domenico, D., Ricciardi, G., & Gugliandolo, E. (2018). Experimental investigation on the compressive strength of foamed concrete: Effect of curing conditions, cement type, foaming agent and dry density. Construction and Building Materials, 165, 735–749. https://doi.org/10.1016/j.conbuildmat.2017.12.241

[15] Fedorov, V., & Mestnikov, A. (2018). Influence of cellulose fibers on structure and properties of fiber reinforced foam concrete. MATEC Web of Conferences, 143, 02008. https://doi.org/10.1051/matecconf/201714302008

[16] Roslan, A. F., Awang, H., & Mydin, M. A. O. (2013). Effects of various additives on drying shrinkage, compressive and flexural strength of lightweight foamed concrete (LFC). Advanced Materials Research, 626(December), 594–604. https://doi.org/10.4028/www.scientific.net/AMR.626.594

[17] Olaoye, R. A., Oluremi, J. R., & Ajamu, S. O. (2013). The Use of Fibre Waste as Complement in Concrete for a Sustainable Environment. Innovative Systems Design and Engineering, 4(9), 91–98. Retrieved from https://s3.amazonaws.com/academia.edu.documents/31489800/The_Use_of_Fibre_Waste_as_Complement_in_Concrete_for_a_Sustainable_Environment.pdf?response-content-disposition=inline%3B filename%3DIISTE_journals_June_30th_Publications.pdf&X-Amz-Algorithm=AWS4-HM

[18] Wei, J., & Meyer, C. (2016). Utilization of rice husk ash in green natural fiber-reinforced cement composites: Mitigating degradation of sisal fiber. Cement and Concrete Research, 81, 94–111. https://doi.org/10.1016/j.cemconres.2015.12.001

[19] Salimian, A., Hadizadeh, M., & Zeini, M. (2016). Investigations on the Reinforcement of Mechanical Properties of Gypsum Composites Containing E-glass Woven Fabrics. Journal of Textiles and Polymers, 4(1), 20–26. Retrieved from http://www.itast.ir/article_13886_9d8a5a4b94166c61b71586275c42de9d.pdf

[20] British Standard Institution. (2009). BS EN 12390-3 Testing hardened concrete. Compressive strength of test specimens. British Standard Institution,London.

[21] Huang, L., Yang, X., Yan, L., He, K., Li, H., & Du, Y. (2016). Experimental study of polyester fiber-reinforced polymer confined concrete cylinders. Textile Research Journal, 86(15), 1606–1615. https://doi.org/10.1177/0040517515596932

[22] Gayathri, C. N., Singh, R. B., & Dhanalakshmi, G. (2018). Mechanical behaviour of textile reinforced concrete. International Research Journal of Engineering and Technology (IRJET), 5(5), 2227–2231. Retrieved from https://www.academia.edu/38216913/IRJET-_Mechanical_Behaviour_of_Textile_Reinforced_Concrete