UNIVERSITI TEKNOLOGI MARA

FSPU FACULTY OF ARCHITECTURE, PLANNING AND SURVEYING

FULL PAPER PROCEEDING

3RD UNDERGRADUATE SEMINAR

BUILT ENVIRONMENT & TECHNOLOGY

SEPTEMBER 2018

ISBN 978-967-5741-67-8

FACULTY OF ARCHITECTURE, PLANNING & SURVEYING
UNIVERSITI TEKNOLOGI MARA PERAK BRANCH
SERI ISKANDAR CAMPUS

UiTM PERAK @ Seri Iskandar

ENHANCEMENT OF DURABILITY AND ENGINEERING PERFORMANCE OF LIGHTWEIGHT FOAMED CONCRETE REINFORCED WITH ALKALI-TREATED COIR FIBER

Siti Nurain binti Zainal Afandi [1] and Md Azree Othuman Mydin [2]
[1 2] Cluster of Technology, School of Housing, Building and Planning, Universiti Sains Malaysia, 11800, Pulau Pinang, Malaysia
Email: nurainafandi@gmail.com[1] , azree@usm.my[2]

Abstract:
With regards to environmental concerns and in line with Malaysian government's environmental strategy on utilizing sustainable waste materials such as those from natural resources in turn to diminish the harmful effects of synthetic materials on the environment, it has brought a challenge to reconnoiter how it can be attained by promoting the agricultural wastes into useful products. Hence this research attempts to investigate the potential use of coir fiber as reinforcement material in lightweight foamed concrete. The effect of alkali treatment of coir fiber at different percentages of 2%, 4%, 6%, 8% and 10% wt. concentration were investigated comprehensively. Experimental results showed that alkali treatment of coir fiber plays an important role to alter the interface of the fiber adequately prompting a variation in the durability and mechanical properties holistically. As a whole, 6% of alkali treatment of coir fiber is the optimum percentage in which it gave the highest compressive strength and splitting tensile strength. The significance of alkali treatment of coir fiber was the meddling of hydrogen bonding in the fiber surface, consequently increasing the surface roughness as well. This condition is really beneficial for coir fiber and the cement matrix interfacial adhesion as a rougher surface expedites fiber and cement matrix mechanical interlocking.

Keywords: Alkali treatment, Coir fiber; Foamcrete; Mechanical properties; Splitting tensile

1.0 INTRODUCTION

In the last few years, there is emerging attention of using lightweight formed concrete as a non-structural and semi structural component in building and in turn to take advantage of its exceptional insulation properties. The difference between normal strength concrete and lightweight foamed concrete is that foamed concrete has no coarse aggregates (Rahman et. al, 2015). Lightweight foamed concrete is a combination of cement, fine sand, clean water and stable foam. Foamed concrete contains trapped bubbles stand-in as an aggregate therefore making it a superior product in terms of flow ability, thermal properties, workability and lesser self-weight (Kadela & Kukiełka, 2015). However, lightweight foamed concrete has been perceived to have some drawbacks which are extensive breakability; low bending strength, poor breakage durability, poor resistance to crack spread and low impact strength (Jones & McCarthy, 2005). Hence, for the past few decades, attempts have been made to include natural fibers in cementitious matrix to improve and enhance the bending strength, surface toughness, impact resistance, and fracture energy (Soleimanzadeh & Othuman Mydin, 2013). Hence, this research attempts to investigate the potential use of coir fiber as reinforcement material in lightweight foamed concrete. The effect of alkali treatment of coir fiber at different percentages of 2%, 4%, 6%, 8% and 10% wt. concentration were examined closely.

2.0 LITERATURE REVIEW

Lightweight formed mortar has low tensile strength, low flexural strength, poor toughness, almost no ductility, low shock resistance, high plastic shrinkage and cracking, which restrict its applications (Meheddene, 2014). The tensile strength of lightweight formed mortar is low because it normally contains numerous micro cracks (Wang et. al, 2015). The shortcomings of lightweight formed mortar can be reduced by adding reinforcing bars or pre-stressing steel (Jones & McCarthy, 2005). Reinforcing steel is continuous and is specifically located in the structure to increase performance.

Coir fiber is discontinuous and generally distributed randomly throughout the matrix (Meheddene, 2014). Randomly dispersed coir fiber will provide three dimension reinforcement compared to the traditional rebar which provides two dimension reinforcement (Li et. al, 2012). As stated above, coir fiber reinforced lightweight foamed mortar can be a cost effective and useful construction material because of the flexibility in the method of fabrication (Mugahed Amran et. al, 2015)

The treatment of natural fibers with sodium hydroxide offered improved fiber to matrix interaction, enhanced bonding characteristic and composite strength which are typically perceived for treatments with sodium hydroxide concentrations of between 4% to 8% (Othuman Mydin et. al, 2015). Chemical treatment of fibers using sodium hydroxide cleans the fiber planes hence stimulates interfacial bonding and increases the mechanical performance of concrete based materials (Chen et. al, 2014). Physical properties of coir fiber is summarized in Table 1.

Table 1: Physical properties of coir fiber

Mechanical Properties	**Coir fiber**
Density (g/cm3)	1.2
Elongation at break (%)	30
Tensile strength (MPa)	175
Young modulus (GPa)	4-6
Water absorption (%)	130-180

3.0 MATERIALS, MIX DESIGN & TESTING

The Ordinary Portland cement (OPC) used in this research was supplied by Aalborg Portland Malaysia Sdn Bhd. The fine aggregate used was natural sand obtained from a local distributor. A sieve analysis had been carried out to identify the suitability of the sand to be used. Result of sieve analysis is shown in Table 2 and the grading curve of sieve analysis is shown in Figure 1.

Table 2: Result of sieve analysis

Sieve Size Range (mm)	**Mass Retained (g)**	**Cumulative Retained (g)**	**Cumulative % mass Retained**	**Cumulative % mass passing through**
10.00-5.00	0	0	0	100
5.00-2.00	3.8	3.80	0.76	99.24
2.00-1.18	38.30	42.10	8.42	91.58
1.18-0.600	135.00	177.10	35.42	64.58
0.600-0.300	160.60	337.70	67.54	32.46
0.300-0.150	114.30	452.00	90.40	9.60

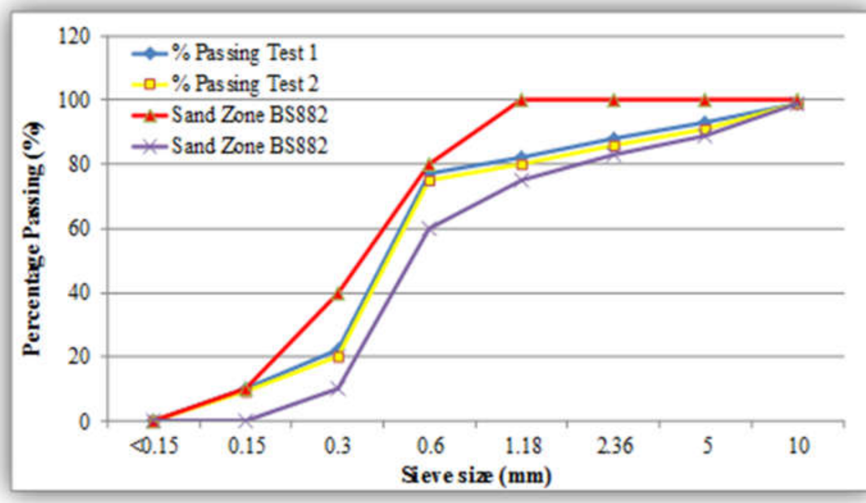

Figure 1: Sieve analysis grading result

Noraite PA-1 surfactant was utilized for the purpose of producing the stable foam. Figure 2 shows the production of stable form using the Portafoam TM-2 Machine. For this research, a water-cement ratio was maintained at 0.45 (Soleimanzadeh & Othuman Mydin, 2013). In terms of alkali treatment, 5 solution percentages had been chosen which were 2%, 4%, 6%, 8% and 10% wt. Table 3 shows the mix design for this research. Two densities of 1100 kg/m^3 and 1400 kg/m^3 were cast and tested.

Figure 2: Production of stable foam via Portaform TM-2 machine

Table 3: Mix proportions

Sample	Mix Density (kg/m^3)	Mix Ratio (S:C:W)	Cement (kg)	Fine Aggregates (kg)	Water (kg)
Control (no fiber)	1100	1:1:5:0.45	27.93	41.90	12.57
Untreated Fiber					
2% Fiber Treatment					
4% Fiber Treatment					
6% Fiber Treatment					
8% Fiber Treatment					
10% Fiber Treatment					
Control (no fiber)	1400		35.30	52.95	15.89
Untreated Fiber					
2% Fiber Treatment					
4% Fiber Treatment					
6% Fiber Treatment					
8% Fiber Treatment					
10% Fiber Treatment					

To attain the durability and mechanical properties of lightweight foamed concrete, several tests were performed such as water absorption (BS 1881-122), porosity (BS 1881-122), ultrasonic pulse velocity (ASTM C597) , Scanning Electron Microscopy (BS EN 01071-10), compression test (BS EN 12390-3) and splitting tensile test (ASTM C496).

4.0 EXPERIMENTAL RESULTS

4.1 Moisture Absorption Capacity

Figure 3 shows the influence of alkali treatment of coir fiber on water absorption of foamed concrete. From Figure 3, it can be seen that the water absorption capacity obtained from the study reveals that the moisture absorption capability of coir fiber was decreased by alkali treatment. Furthermore, the moisture absorption of the treated coir fiber decreases with a rise in alkaline pH in the solution. The fiber that undergoes higher alkali treatment (10% wt.) absorbs water slower at the initial stage compare to untreated coir fiber. It could achieve saturation level slower which is due to alkali treatment which enhanced the surface of the coir fiber by removing certain percentages of oil, lignin and wax that shield the exterior facades of the fiber cell wall.

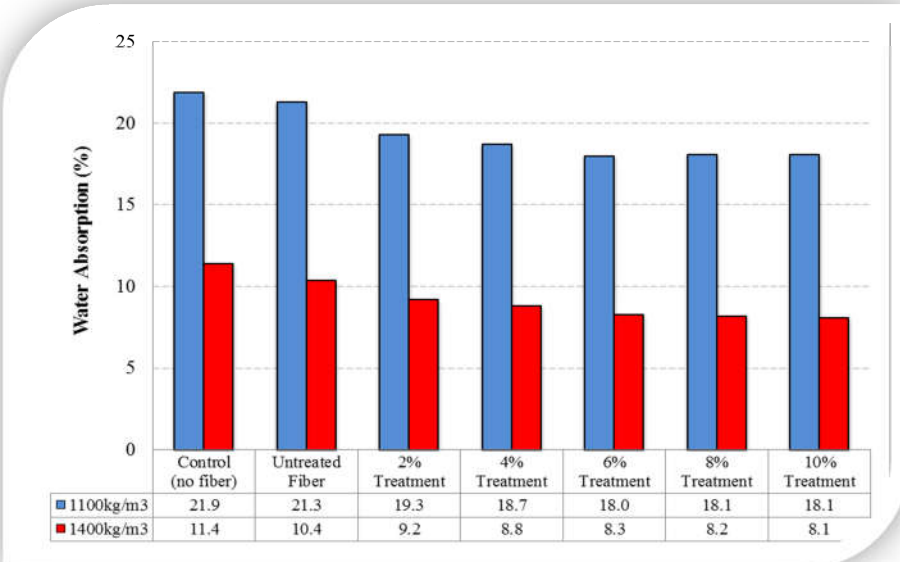

Figure 3: Influence of alkali treatment of coir fiber on moisture absorption capacity of foamed concrete

4.2 Porosity

Figure 4 demonstrates the effect of alkali treatment of coir fiber on porosity of foamed concrete. From Figure 4, we can clearly see that the porosity of foamed concrete decreases with increase in percentage of alkali treatment for both densities. According to Gomes et. al (2004), the reduction in porosity of foamed concrete with the addition of alkali treatment was triggered by alteration and variation of morphology of the treated coir fiber. From SEM analysis, they discovered that the fiber was not truly mono-filament. It was a pack of mono-filament attached and enclosed by lignin. Alkali treatment of coir fiber was incidental to aggravate elimination of lignin significantly. Due to exclusion of lignin, it reduces the diameter of the coir fiber thus decreased the porosity of foamed concrete in whole. This report was buoyed with the results obtained by Oby et. al (2013) in which they found that regular diameter of fiber diminished with the augmentation of alkali treatment percentages. The process of alkali treatment of fiber eradicates certain amount of hemicellulose and wax that jacketed the exterior surface of the fiber and consequently it upsurges the length to diameter ratio considerably.

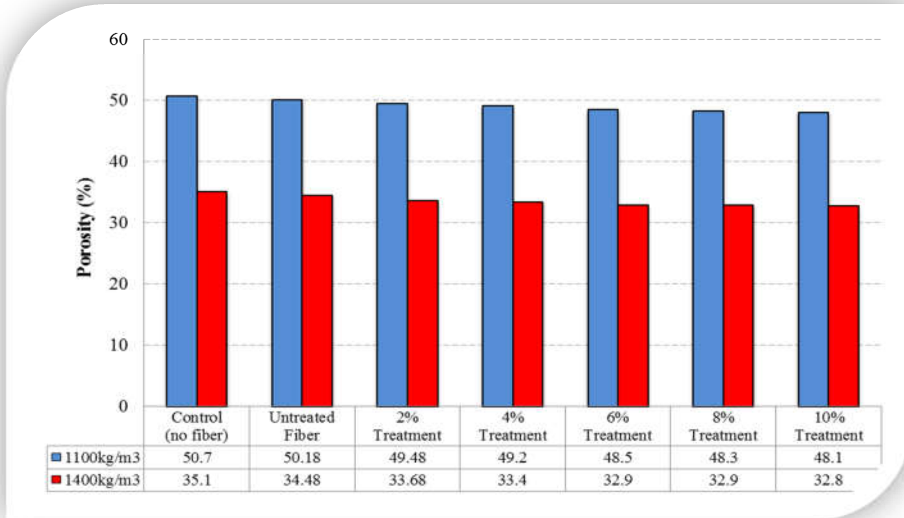

Figure 4: Influence of alkali treatment of coir fiber on porosity of foamed concrete

4.3 Ultrasonic pulse velocity (UPV)

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 quantity the pore structures in concrete, but it can still provide an excellent initial forecast of the quality of concrete based material. Figure 5 shows the ultrasonic pulse velocity (UPV) results for both densities tested in this study. It can be seen from Figure 5 that alkali treatment of coir fiber has enhanced the ultrasonic pulse velocity (UPV) in comparison with control and non-treated foamed concrete specimens. For both densities, 6% wt. sodium hydroxide chemical treatment of EFB fibers gave an excellent ultrasonic pulse velocity (UPV) reading of 2374m/s for 1100 kg/m^3 density and 3221m/s for 1400 kg/m^3. This might be associated to the hydration mechanism of the binary cementitious system in foamed concrete for fiber with higher alkali treatment concentration. The hydration products shaped by alkali components and silicates formation in which it tend to contribute to the modification of the pore structure, leading to reduced gel pores in the foamed concrete matrix and also reduction of coir fiber cross-sectional area probably was due to the altered of coir fiber morphology after the alkali treatment procedure. According to Nitta et al. (2013), the cross section of fiber was extremely transformed through the alkali treatment process in comparison with untreated fiber. They found that the cross sectional area for those fibers undergoes alkali treatment was lesser compared to untreated fiber. Additionally, individual cells in the fiber cross section was transformed from a polygon shape to an oval shape, complemented a lot of gaps between the cells which at the same time improved the ultrasonic pulse velocity (UPV).

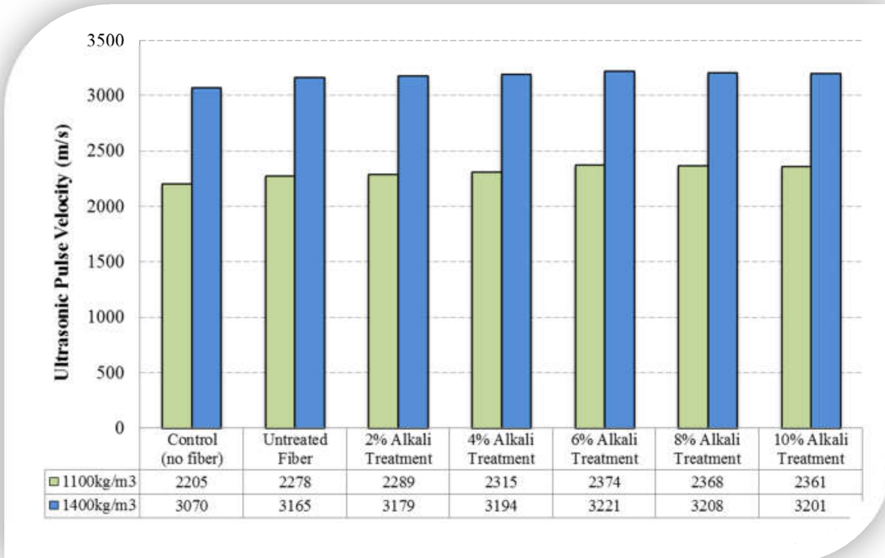

Figure 5: Influence of alkali treatment of coir fiber on ultrasonic pulse velocity of foamed concrete

4.4 Axial Compressive Strength

Figures 6 and 7 display the axial compressive strength results for 1100 kg/m^3 and 1400 kg/m^3 densities respectively. From both figures, it can be clearly seen that 6% wt. alkali treatment of coir fibers contributed to remarkable axial compressive strength results compared to other chemical solution percentages which were 4.2 N/mm^2 for 1100 kg/m^3 density and 7.8 N/mm^2 for 1400 kg/m^3 at 60-day. Alkali treatment of 6% wt. reinforces the bonding between the coir fiber and the cement matrix. Meantime, control and untreated CFB shows lower compressive strength since there are natural and artificial impurities in the coir fiber that lead to some effects to the bonding between the cement matrixes. Treatment of coir fiber beyond 6% did not only remove part of the boundary layers of the natural fibers but moreover caused some deterioration to the coir fiber particles themselves that reduced the overall compressive strength.

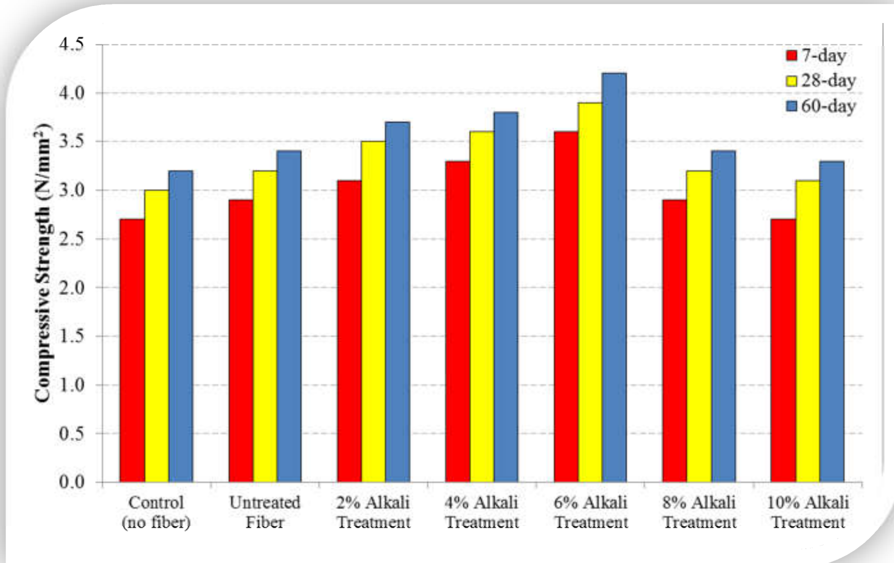

Figure 6: Influence of alkali treatment of coir fiber on compressive strength for 1100kg/m^3 density

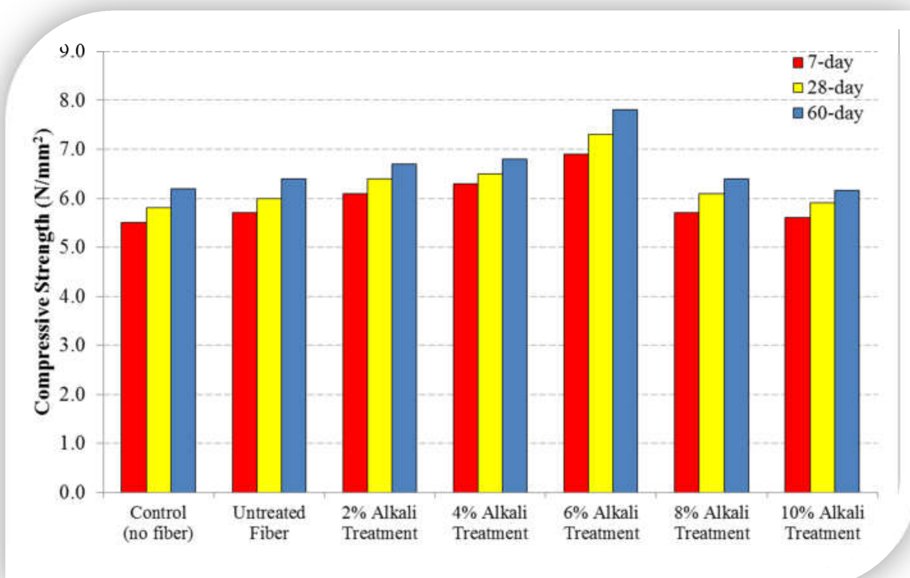

Figure 7: Influence of alkali treatment of coir fiber on compressive strength for 1400kg/m^3 density

4.5 Splitting tensile strength

Figures 8 and 9 demonstrate the splitting tensile strength of 1100 kg/m^3 and 1400 kg/m^3 densities respectively. Identical results were attained as per axial compressive strength. From Figure 8 and Figure 9, it can be seen that 6% wt. alkali treatment of coir fibers contributed to highest splitting tensile strength results in comparison with other alkali treatment solution percentages which were 0.48 N/mm^2 for 1100 kg/m^3 density and 0.93 N/mm^2 for 1400 kg/m^3 at 60-day. The improvement in splitting tensile strength is attributed to the improvement in of coir fibers and interfacial adhesion after treatment. The importance of alkali treatment is the commotion of hydrogen attachment in the fiber surface, thus amassed the surface irregularity. As been shown in Figure 10, a rougher coir fiber surface is attained after the alkali treatment process in which it is beneficial for the interfacial adhesion between the fiber and cement matrix since a rougher surface facilitates in excellent mechanical interlocking. The alkali treatment process at the same time removes high percentages of oils, wax and lignin, which covered the outside surface of the fiber cell wall.

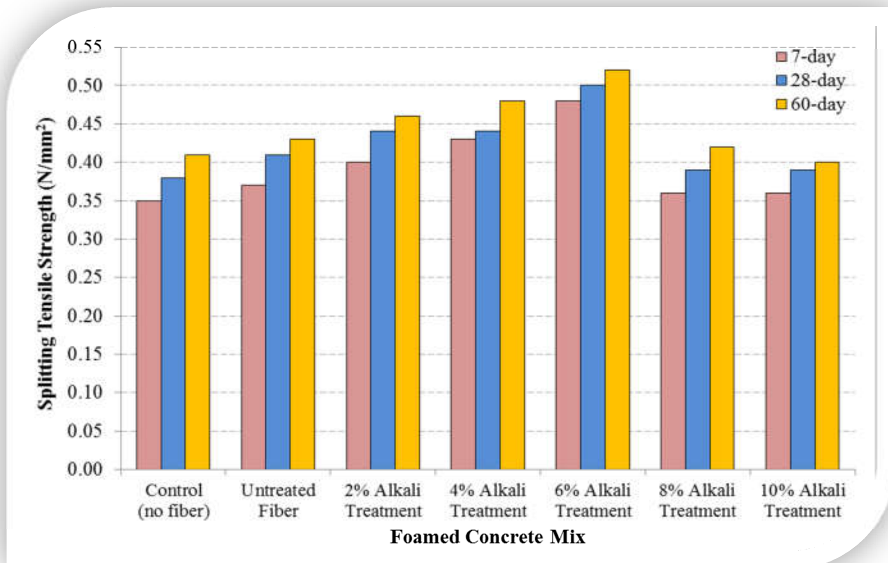

Figure 8: Influence of alkali treatment of coir fiber on splitting tensile strength for 1100kg/m^3 density

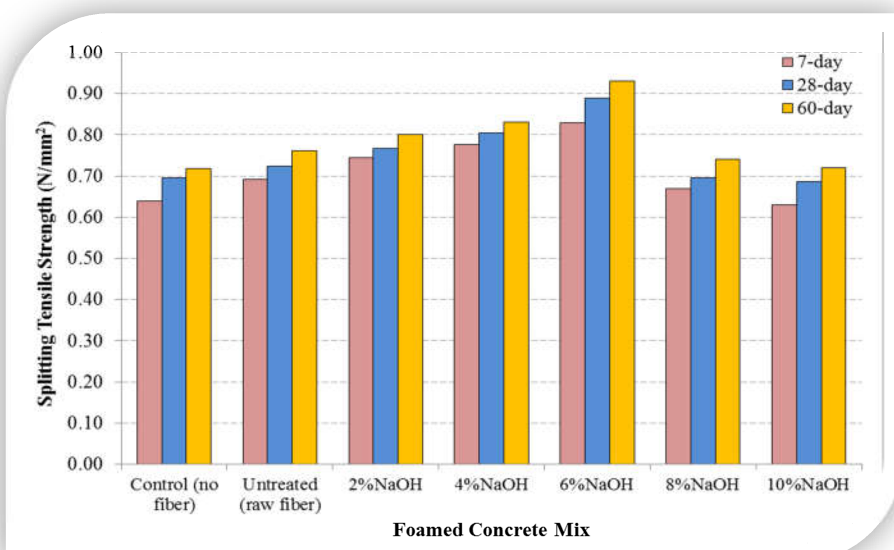

Figure 9: Influence of alkali treatment of coir fiber on splitting tensile strength for 1400kg/m^3 density

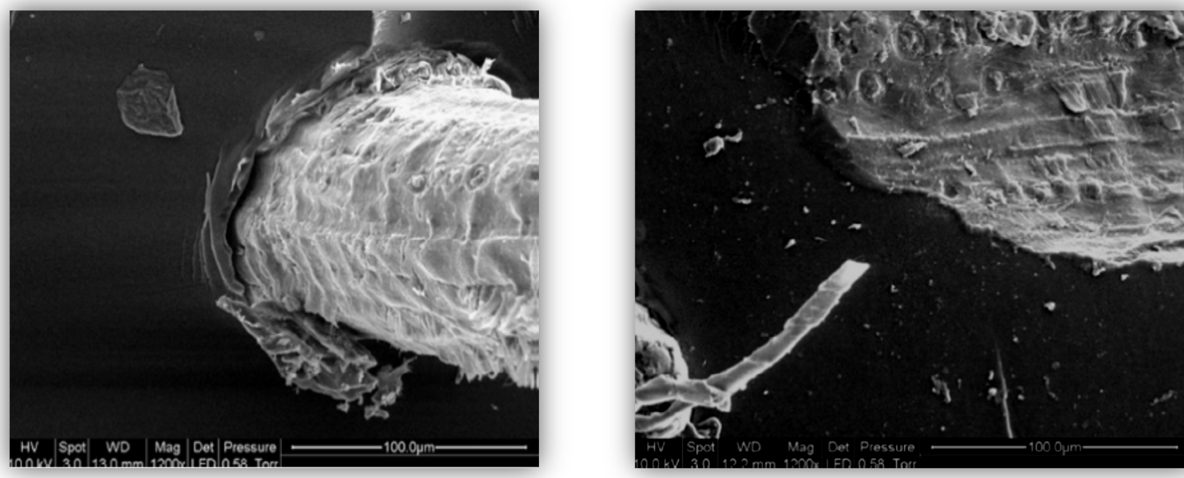

Figure 10: SEM results of coir fiber-cement interface: untreated (left) & treated (right)

4.6 Performance Index

Figures 11 and 12 show the performance index (PI) of 1100kg/m^3 and 1400kg/m^3 densities. Similar trend obtained by performance index, where the performance index is directly proportional to the specimen's curing age. For 1100kg/m^3 density, the highest 60-day performance index was achieved by foamed concrete mix with 6% coir treatment, which is 3.8N/mm^3 per 1000 kg/m^3. On the other hand, highest 60-day performance index achieved by 1100kg/m^3 density is similar (foamed concrete mix with 6% coir treatment) which is 5.6N/mm^3 per 1000 kg/m^3.

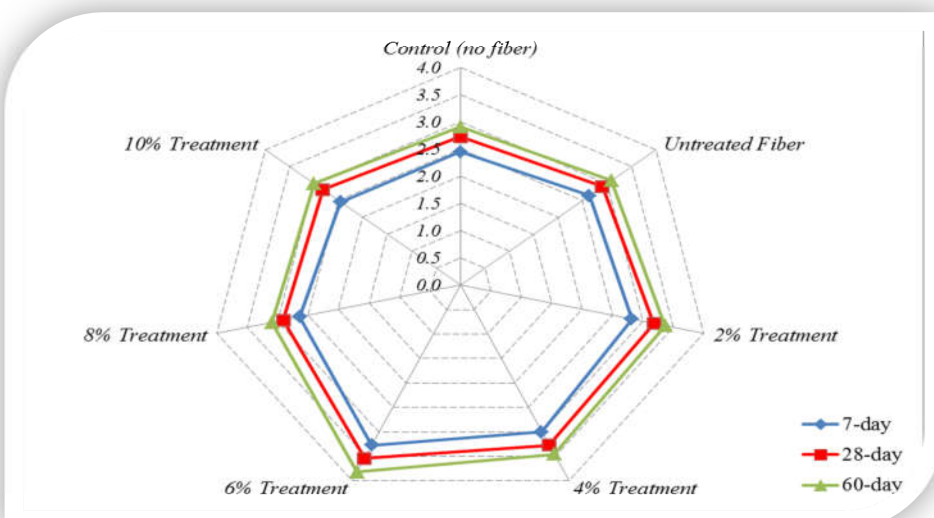

Figure 11: Performance index of 1100kg/m^3 density mix

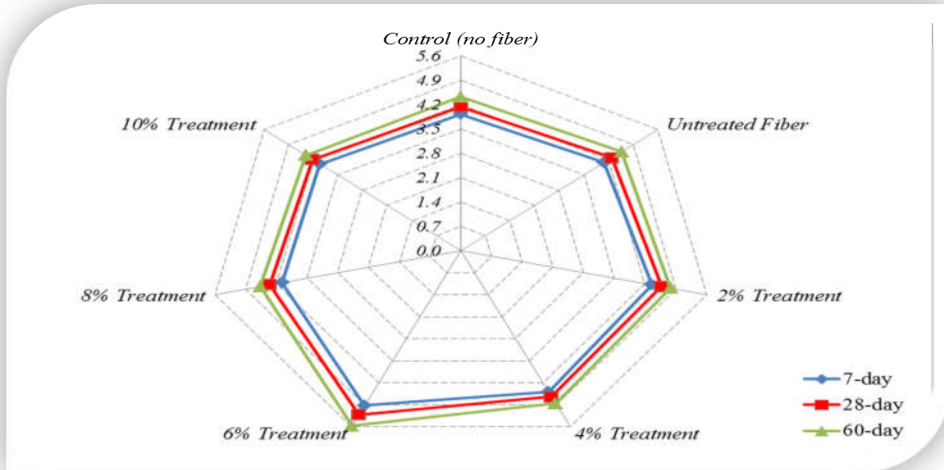

Figure 12: Performance index of 1400kg/m^3 density mix

5.0 CONCLUSION

In this study, the influence of alkali treatment of coir fiber as reinforcement in lightweight foamed mortar on its durability properties and mechanical performance were investigated. The study reveals:

1. By addition of alkali treatment solution percentages of coir fibers, it lessened the moisture absorption capacity and porosity of lightweight foamed mortar intensely.
2. As a whole, 6% wt. alkali solution treatment of coir fibers contributed to excellent ultrasonic pulse velocity, compressive strength and splitting tensile strength results compared to other chemical solution percentages.
3. Enhancement in durability and mechanical properties is accredited to the improvement in fibers and interfacial adhesion after the alkali treatment process. The importance of alkali treatment is the commotion of hydrogen attachment in the fiber surface, thus amassed the surface irregularity.
4. However, using high concentration (beyond 6%) of treatments caused serious deterioration to the coir fiber particles themselves which were clearly observed from the massive reduction in the compressive and splitting tensile strengths of the treated coir fiber specimens.
5. The cross section of coir fiber was extremely transformed through the alkali treatment process in comparison with untreated fiber. The cross sectional area that undergoes alkali treatment was lesser compared to untreated fiber. Moreover, individually cell in the fiber cross section was transformed from a polygon shape to an oval shape, complemented a lot of gaps between the cells which at the same time improved the overall durability and mechanical performance of foamed concrete.
6. A rougher coir fiber surface is attained after the alkali treatment process in which it is beneficial for the interfacial adhesion between the fiber and cement matrix since a rougher surface facilitates in excellent mechanical interlocking. Alkali treatment also removes high percentages of oils, wax and lignin, which covered the outside surface of the fiber cell wall.

ACKNOWLEDGMENTS

The author would like to thank Ministry of Higher Education Malaysia for their funding of this research under Fundamental Research Grant Scheme (Grant No. 203/PPBGN/6711514) with research title: Fundamental Study to Establish Thermal Insulation, Mechanical Properties and Fire Retardant Mechanism of Coir Fibre Reinforced Lightweight Foamcrete.

REFERENCES

Gomes, A., Goda, K., Ohgi, J. (2004). Effects of alkali treatment to reinforcement on tensile properties of curaua fiber green composites. JSME International Journal Series A, Volume 47(4), pp. 541-546, 2004

Jones, M., McCarthy, A. (2005). Preliminary views on the potential of foamed concrete as a structural material. Magazine of concrete research, Volume 57(1), pp. 21-31

Li, X., Liu, M., Ma, B., Jian, S., Su, L., Zhao, Z. (2012). Influence of pore structure on foam concrete and controlling method. Materials Review, Volume 26(4), pp. 141–144

Meheddene, M. M., Hisham S. B., Adel M. E. K. (2014). The Effect of Using Fan Palm Natural Fibers on the Mechanical Properties and Durability of Concrete. International Journal of Materials Science and Engineering, Volume 2(2), pp. 76-80

Mugahed Amran, Y. H., Farzadnia, N., Abang Ali, A. A. (2015). Properties and applications of foamed concrete; a review. Construction & Building Materials, Volume 101, pp. 990–1005

Nitta, Y., Goda, K., Noda, J., W-II, L. (2013). Cross-sectional area evaluation and tensile properties of alkali-treated kenaf fibres. Composites Part A: Applied Science and Manufacturing, Volume 49, pp. 132-138

Obi Reddy, K., Uma Maheswari, C., Shuklaa, M. Song, J. I., Varada Rajulu, A. (2013). Tensile and structural characterization of alkali treated Borassus fruit fine fibers. Composites Part B: Engineering, Volume 44(1), pp. 433-438

Othuman Mydin, M. A., Sahidun, N. S., Mohd Yusof, M. Y., Md Noordin, N. (2015). Compressive, Flexural And Splitting Tensile Strengths Of Lightweight Foamed Concrete With Inclusion of Steel Fibre. Jurnal Teknologi, Volume 7(5): pp. 45-50.

Rahman, N. A., Jaini, Z. M., Zahir, N. N. (2015). Fracture energy of foamed concrete by means of the three-point bending tests on notched beam specimens. Journal of Engineering and Applied Sciences, Volume 10, pp. 6562–6570

Soleimanzadeh, S., Othuman Mydin, M. A. (2013). Influence of High Temperatures on Flexural Strength of Foamed Concrete Containing Fly Ash and Polypropylene Fiber. International Journal of Engineering, Volume 26(1): pp. 365-374.

Wang, L., Chen, Y., Du, G. (2015). Influence mechanism of microstructure of foam concrete on macroscopic properties. China Powder Science and Technology, Volume 21(5), pp. 63-68