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EFFECTIVENESS OF 'COCOS NUCIFERA LINN' FIBRE REINFORCEMENT ON THE DRYING SHRINKAGE OF LIGHTWEIGHT FOAMED CONCRETE

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ABSTRACT

Green environment is a puzzling and stimulating concern that has received a considerable attention in today's construction industry. The construction industry in Malaysia is seen to embrace green construction due to the project requirements that need to be adhered to achieve the certification for Green Building Index (GBI). It is important to note that the GBI rating tool was first introduced in Malaysia back in the year 2005 with the main objective of enhancing awareness among industrial players and encouraging sustainable construction in built environment. Therefore, the utilization of natural fiber like Cocos Nucifera Linn Fiber (CNF) in foamed concrete is considered as a useful option in making concrete as a sustainable material to overcome this problem. Thus, the main objective of this study is to perform experimental studies in order to discern the effect of CNF volume fraction on drying shrinkage foamed concrete. To achieve the objective of this research, 21 batches of foamed concrete mix were prepared. Three densities of 650 kg/m^3, 1050 kg/m^3, and 1450 kg/m^3 were fabricated. CNF was used as additives in the present study at 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, and 0.6% by volume fraction of the total mix. The experimental results showed that the drying shrinkage for all specimens is significantly high in early age until 30 days and gradually increases. Meanwhile, the drying shrinkage of foamed concrete samples is significantly enhanced through the incorporation of CNF. In particular, 1450kg/m^3 density of 0.5% CNF demonstrate the best outcome. Overall, it tends to be presumed that the incorporation of CNF in foamed concrete adds to better shrinkage resistance and have great embodiment that help to upgrade the strength of foamed concrete and enhance ductility.

Keywords: foamed concrete; coconut fibre, shrinkage; lightweight mortar; coir.

1. INTRODUCTION

Governance on carbon footprint emissions had driven a considerable amount of research on green concrete around the world. In particular, special attention has been given on environmental deliberations with respect to base mix material sourcing, concrete mix design, design of structural component, construction method, construction technology, and the aspect of concrete structure maintenance. Thus, it can be stated that concrete industry players in Malaysia play a significant role in achieving a holistic and sustainable development of the society [1].

In the present day, it should be acknowledged that most of the construction products are produced using materials that require a high amount of energy and not naturally sustainable which can lead to global problem. Hence, the use of natural fibres in foamed concrete is considered as a useful option in making concrete as a sustainable material to overcome this problem. In regard to this matter, it should be understood that there are various advantages in using lightweight foamed concrete which include lightweight, able to deliver good thermal insulation, and influent savings of several materials such as cement, fine aggregate, stable foam, and water. These materials are the basic components of foamed concrete but there are other types of admixture that can be used to enhance the strength of lightweight foamed concrete.

Furthermore, the low density of lightweight foamed concrete is caused by the absence of coarse aggregate which subsequently leads to lower self-weight. On another note, lightweight foamed concrete can be used for structural elements, semi-structural, non-structural partitions, and thermal insulating materials. In addition, lightweight foamed concrete are usually developed in numerous densities ranging from 400 kg/m^3 up to density of 1800 kg/m^3 [2] More importantly, foamed concrete are ecologically clean, inflammable, and easy to produce compared to other materials despite the fact that the mixing time of foamed concrete is longer. Generally, lightweight foamed concrete is known to have a good compression but poor tension strength, thus making it fragile. Meanwhile, the access of air bubbles and the interrelation between them tend to increase significantly due to the reduction of density. As a result, the increase of water vapor will lead to the reduction in foamed concrete strength. However, the weakness in tension can be reduced by adding a sufficient volume of certain fibres. In this case, it should be understood that the use of fibres are able to arrest cracks formation and improve strength and ductility with the overall aim of improving its toughness.

2. LITERATURE REVIEW

A considerable amount of studies has proven the effectiveness of fibres into mixtures in terms of durability and the enhancement of mechanical properties. According to Othuman Mydin *f.* [3], fibres have their own advantages and disadvantages and it can be categorized into two, namely synthetic fibres known as man-made fibres and natural fibres that are more environmental-friendly. Nevertheless, the finest fibres tend to have a very good

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essence which is able to assist in the enhancement of the strength and properties of concrete. Apart from that, the use of natural fibre can help to improve shrinkage and ductility [4].

In regard to this matter, natural fibres are known as sustainable resources which are the main reason why they are currently getting a lot of attention in replacing synthetic fibre. Unlike synthetic fibres, there are numerous benefits of natural fibres which include low density, biodegradable, and hard to melt on heating. More importantly, natural fibres are capable of strengthening cementitious material, particularly in the invention and fabrication of building materials. Currently, the most commonly used natural fibres are bamboo, coir, sisal, cane, jute, and henequen fibres [5].

According to Rahman *et al.* [6], there has been a wide application of natural fibres in producing lightweight concrete due to the increasing interest in natural fibres in adhering to a more environmental and cost-effective value in construction industries. Nevertheless, 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. Fibre could enhance the matrix bond that will help to develop the tensile strength and structural integrity of the concrete [7].

Cocos nucifera linn fibres (CNF) refer to agricultural waste or by-products that can be obtained through the distribution of coconut oil and can be accumulated in a large amount in Malaysia. It should be understood that CNF fibres are often discarded as agricultural wastes. Nevertheless, numerous schemes concentrating on the lower cost of materials have been recommended despite the important need of green concrete production and reasonably priced housing system for both whom live at the countryside and metropolitan areas in Malaysia. As a result, it has been recommended that agricultural wastes and residues should be utilized as partial or full replacement of building materials. Accordingly, it is crucial to note that CNF fibres have the potential to be utilized as substitute coarse aggregate in lightweight foamed concrete for the purpose of improving the strength and durability.

Domingo-Cabo *et al*. [8] determined that the finest fibres have a very good essence that assist to improve the strength and 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 is able to reduce plastic shrinkage and improve durability [9], which is in line with the study conducted by Olaoye *et al.* [10] which postulated that the flexural resistance and durability of concrete will be improved by including the fibres into the concrete.

3. MATERIALS AND DESIGN MIX

This section will discuss on the materials utilized in this research together with the mix design proportions. The mixture design proportion of 650 kg/m^3, 1050 kg/m^3, and 1450 kg/m^3 is shown in Table-1. Small variations in the densities will only produce small values in the properties; therefore these three densities were selected to have a comparable study for a better understanding of the properties. It is important to note that CNF was used as additives in the present study at 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, and 0.6% by volume fraction of the total mix. As mentioned previously, the proportion of mortar was cement, sand, and water which were represented by the ratio of 1:1.5:0.45. Meanwhile, water to cement ratio used for the current research is 0:45.

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Table-1. Design Mix of foamed concrete.

Sample	Density (kg/m^3)	Fibre (kg/m^3)	Cement (kg/m^3)	Sand (kg/m^3)	Water (kg/m^3)
Control	650	-	248.29	372.44	111.73
0.1CNF	650	0.72	248.29	372.44	111.73
0.2CNF	650	1.44	248.29	372.44	111.73
0.3CNF	650	2.22	248.29	372.44	111.73
0.4CNF	650	2.94	248.29	372.44	111.73
0.5CNF	650	3.67	248.29	372.44	111.73
0.6CNF	650	4.44	248.29	372.44	111.73
Control	1050	-	392.73	589.10	176.73
0.1CNF	1050	1.11	392.73	589.10	176.73
0.2CNF	1050	2.28	392.73	589.10	176.73
0.3CNF	1050	3.44	392.73	589.10	176.73
0.4CNF	1050	4.61	392.73	589.10	176.73
0.5CNF	1050	5.78	392.73	589.10	176.73
0.6CNF	1050	6.94	392.73	589.10	176.73
Control	1450	-	537.18	805.76	241.73
0.1NF	1450	1.56	537.18	805.76	241.73
0.2CNF	1450	3.17	537.18	805.76	241.73
0.3CNF	1450	4.72	537.18	805.76	241.73
0.4CNF	1450	6.33	537.18	805.76	241.73
0.5CNF	1450	7.94	537.18	805.76	241.73
0.6CNF	1450	9.56	537.18	805.76	241.73

The Ordinary Portland Cement (OPC) used in this study was obtained from Cement Industries of Malaysia that was labelled as ‘Castle’. The cement was classified as Type 1 cement based on BS: EN 196 and MS 522: Part 1: 1989 Specifications for OPC. In this case, the product weighed 50 kilograms bags in bulk form. The uncrushed fine aggregate in mortar mixes as a constituent material with a fineness modulus of 1.35 as well as a specific gravity of 2.74. The sieved fine aggregates were than stored in a tank and ready to be used for mixing. The water to cement ratio employed for the current research was 0.45 because it is able to achieve the desired workability. Apart from that, it is important to note that the water used in the current research has a good and acceptable quality with suitable pH ranging from 6.5 to 8.0 and originated from Universiti Sains Malaysia, School of Housing, Building and Planning. This study focused on different percentages of CNF (0.1%, 0.2%, 0.3%, 0.4%, 0.5%, and 0.6%) which acted as an admixture in foamed concrete mix. CNF was extracted from the outer shell of a young coconut which is randomly oriented. In the case of the present study, the NORAITE PA-1 foaming agent which is protein-based was selected for this experimental program due to its characteristics of good quality, potent and dense cell bubble structure. It is important to understand that foam is produced using foam generator (Portafoam PA-1). The foaming generator equipped with a digital timer that can set the flow rate acts a medium that transforms the liquid chemical into stable foam. Noraite PA-1 refers to the foaming agents that produce stable foam output with the density around 60-70 g/liter. Foamed concrete can be produced using the premix solution by adding 30 liters of water to 1kg of PA-1 of foaming agent. This particular solution can produce 30 liter of foam in approximation. Figure-1 shows the production of stable foam from Portafoam PM 1 and preparation of foamed concrete.

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Figure-1. Foam production from Portafoam PM 1 and preparation of foamed concrete.

4. METHODS

The aim of conducting drying shrinkage test is to investigate the development of concrete. Moreover, this technique is able to build up the information on the impact of the samples on the drying shrinkage. The aim of this experimental test is to justify the capability of fibres in resisting volume changing. 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.

Figure-2. Measurement of dying shrinkage.

5. RESULTS AND DISCUSSIONS

The purpose of conducting drying shrinkage test is to determine the expansion of concrete. Moreover, this method is able to develop data on the effect of specimen on the drying shrinkage. In addition, it is important to note that the aim of this experimental test is to justify the benefaction of fibres in resisting volume changes. The result for drying shrinkage is presented in Figures 3-5. In this case, it can be clearly observed that drying shrinkage for all specimens is dramatically high in early age until 30 days and then it continues to increase slowly. The control mixes are shown to have higher drying shrinkage for 650 kg/m³, 1050kg/m³, and 1450 kg/m³ densities. Moreover, the addition of CNF causes the drying shrinkage of lightweight foamed concrete specimens to improve drastically. Meanwhile, the findings show that for CNF of 0.3% with 650 kg/m³ density and 0.4% of CNF with 1050 kg/m³ density show the lowest result in drying shrinkage. On the other hand, 0.5% CNF with 1450 kg/m³ density indicates the best result. Therefore, it can be concluded that the inclusion of CNF in lightweight foamed concrete contributes to better shrinkage prevention.

The comparison that can be observed between Figures 3, 4 and 5 show that low density of lightweight foamed concrete will in general shrink more because of the higher amount of foam content as well as the least of aggregates content that is used inside the mix. More importantly, the addition of CNF in lightweight foamed concrete provides the best outcomes in lessening the shrinkage in contrast to control mix of lightweight foamed concrete. The CNF reacts as aggregates or filler that give compact composition of microstructure which in this way lessens as well as decreases the size and measures of pores [11].

Generally, the major factor that influences the shrinkage behavior of a concrete is cement paste. The shrinkage of foam concrete is a component of foam volume which is consequently by implication identified with the amount and properties of shrinkable paste. Moreover, shrinkage tends to be higher in the scope of low dampness content. As expressed by Nambiar and Ramamurthy [12], the reduction of drying shrinkage is caused by increase in the foam content. Lesser drying shrinkage at higher foam volume is caused by lower substance of paste in the mix, thus consequently cause lower content of pores to affect the shrinkage.

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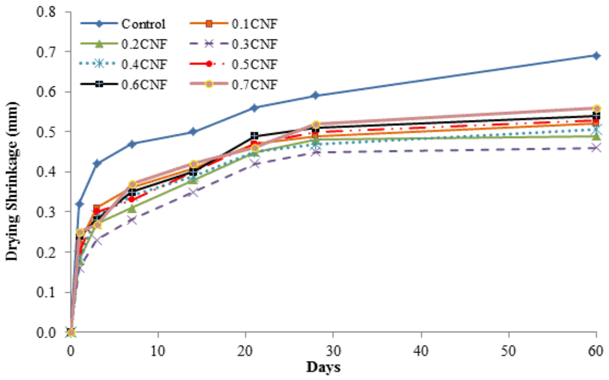

Figure-3. Drying shrinkage of 650 kg/m^3 density foamed concrete of different CNF volume fraction.

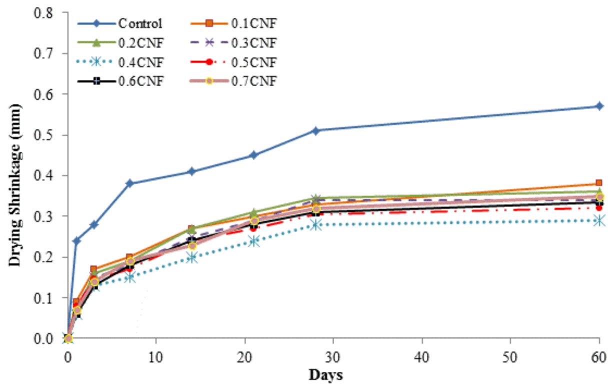

Figure-4. Drying shrinkage of 1050 kg/m^3 density foamed concrete of different CNF volume fraction.

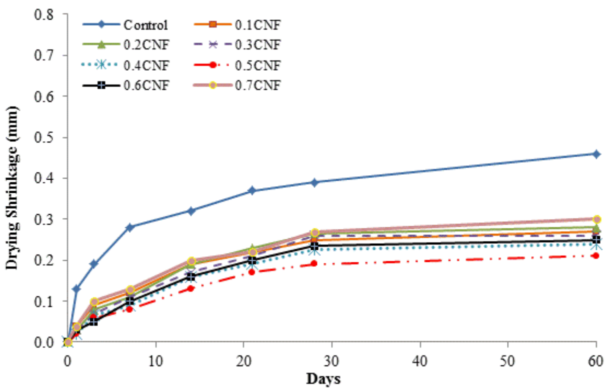

Figure-5. Drying shrinkage of 1450 kg/m^3 density foamed concrete of different CNF volume fraction.

According to Bagherzadeh, *et al.* [13], the increase of CNF percentage in concrete reduces drying shrinkage. Nevertheless, there is no presence of aggregates in the context of lightweight foamed concrete, which makes it to shrink even more compared to normal strength concrete. Hence, the inclusion of CNF in lightweight foamed concrete mix acts as an aggregate due to its capacity of void filling, which consequently reduces the shrinkage effect in the cement matrix. Apart from that, the efficacy of CNF in reducing shrinkage at the same time able to lower the percentage of the cracks of lightweight foamed concrete. Furthermore, CNF has the ability to bridge cracks once the first crack occurs, particularly for the purpose of preventing it from opening.

Entrained huge air voids do not alter the physiognomies of fine pore structure of hardened cement matrix substantially [14]. Hence, micro-pores for a specified design mix distress the drying shrinkage that could be equitably connected to the lightweight foamed concrete paste content [15]. More importantly, the decrease in drying shrinkage value of lightweight foamed concrete with the addition of CNF contrasted with control mix may likewise be ascribed to the decrease in surface tension of pore water and CNF in the presence of protein based foaming agents which are fundamentally surfactants.

According to Narayanan and Ramamurthy [16], the shrinkage of lightweight foamed concrete is a function of density and thus indirectly related to the amount and properties of shrinkable paste. Shrinkage increases greatly in the range of high moisture content and porosity (lower densities). Even though removal of water from comparatively bigger artificial air pores will not contribute to shrinkage, artificial air voids may have, to some extent, an effect on volume stability indirectly by allowing some shrinkage; this effect was more at higher foam volume.

5. CONCLUSIONS

Drying shrinkage is considered as one of the shortcomings of foamed concrete which most of the time occurs amid the early time of casting time. According to past examination, it was found that higher foam content in foamed concrete will prompt the decrement of drying shrinkage. Notwithstanding, this exploration program has discovered that CNF enhances the quality and properties of lightweight foamed concrete. In view of the examination results, the outcome showed that drying shrinkage for all samples is significantly high in early age until 30 days and gradually increases. Meanwhile, the drying shrinkage of foamed concrete samples is significantly enhanced through the incorporation of CNF. In particular, 1450kg/m³ density of 0.5% CNF demonstrate the best outcome. Overall, it tends to be presumed that the incorporation of CNF in foamed concrete adds to better shrinkage resistance and have great embodiment that help to upgrade the strength of foamed concrete and enhance ductility.

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REFERENCES

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

[2] Jalal M., Tanveer A., Jagdeesh K., Ahmed F. 2017. Foam Concrete. International Journal of Civil Engineering Research. 8(1): 1-14.

[3] 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: 1-8.

[4] Falliano D., Domenico D. De, Ricciardi G. & Gugliandolo E. 2018. Mechanical Characterization of Extrudable Foamed Concrete : An Experimental Study. International Journal of Civil and Environmental Engineering. 12(3): 290-294.

[5] Pickering, K. L., Efendy, M. G. A., Le, T. M. 2016. A review of recent developments in natural fibre composites and their mechanical performance. Composites Part A: Applied Science and Manufacturing. 83: 98-112.

[6] Rahman A., Ching C., Ching K. Y., Awanis N. 2015. Surface Modification of Natural Fiber using Bi 2 O 3 /TiO 2. Composite for Photocatalytic Self-cleaning. 10(4): 7405-7418.

[7] Soleimanzadeh S., Othuman Mydin M. A. 2013. Influence of High Temperatures on Flexural Strength of Fomaed Concrete Containing Fly Ash and Polypropylene Fiber. Int. Journal of Engineering. 26(1): 365-374.

[8] Domingo-Cabo A., Lázaro C., López-Gayarre F., Serrano-López M. A., Serna P., Castaño-Tabares J. O. 2009. Creep and shrinkage of recycled aggregate concrete. Construction and Building Materials. 23(7): 2545-2553.

[9] Othuman Mydin M. A., Md. Noordin N., Utaberta N., Mohd Yunos M. Y., Segeranazan S. 2016. Physical Properties of Foamed Concrete Incorporating Coconut Fibre. Jurnal Teknologi. 78(5): 99-105.

[10] 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.

[11] Othuman Mydin M. A., Md Sani N., Taib M. 2014. Industrialised Building System in Malaysia: A Review. MATEC Web of Conferences. 10: 01002.

[12] Nambiar E. K. K., Ramamurthy K. 2009. Shrinkage Behavior of Foam Concrete. Journal of Materials in Civil Engineering. 21(11): 631-636.

[13] Bagherzadeh R., Pakravan H. R., Sadeghi A.-H., Latifi M., Merati A. A. 2012. An investigation on adding polypropylene fibers to reinforce lightweight cement composites (LWC). Journal of Engineered Fibers and Fabrics. 7(4): 13-21.

[14] 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. 7(5): 45-50.

[15] Othuman Mydin M. A., Rozlan N. A, Ganesan S. 2015. Experimental study on the mechanical properties of coconut fiber reinforced lightweight foamed concrete. Journal of Materials and Environmental Science. 6(2): 407-411.

[16] Narayanan N. & Ramamurthy K. 2000. Structure and properties of aerated concrete: A review. 22(5): 321-329.