International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August 2019

Influence of 'Cocos Nucifera Linn' Fiber Volume Fraction on Water Absorption and Porosity of Foamed Concrete

N. Mohd Zamzani, M. A. Othuman Mydin, A. N. Abdul Ghani

Abstract: Global apprehension and governance on carbon footprint emissions have driven a considerable amount of research on green concrete around the world. 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 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. 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. Moreover, it should be understood that CNF fibers are often discarded as agricultural wastes. Hence, the aim of the present study is to perform experimental studies in order to discern the effect of CNF volume fraction on water absorption capacity and porosity of foamed concrete. There were total of 21 mixes were prepared and test in this study. 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 results show that the water absorption of foamed concrete was slower at the beginning when it contained higher CNF volume fraction than the lower CNF volume fraction. CNF absorbed water and then expanded amid blending. CNF could anticipate fragility and lose microstructure arrangement, which reduces the capacity to oppose excessive loads. On the other hand, the porosity of foamed concrete is reduced due to the increase of CNF for each density examined in the present study. This occurs because of the reaction between the cement paste and CNF. Furthermore, higher density foamed concrete prompts the decrement of permeable structure, while the CNF serves to bridge the matrix. The arrangement of pores for plain foamed concrete without the incorporation of fiber was bigger compared to foamed concrete with the incorporation of CNF. CNF additionally helps in making an increasingly uniform distribution of the air voids. Thus, it will hinder bubbles from merging with one another.

Keywords: foamed concrete, water absorption, coconut fiber, porosity, lightweight foamcrete, green material, porous concrete

Revised Manuscript Received on August 30, 2019.
* Correspondence Author
N. Mohd Zamzani*, School of Housing, Building and Planning, Universiti Sains Malaysia, Penang, Malaysia.
M. A. Othuman Mydin, School of Housing, Building and Planning, Universiti Sains Malaysia, Penang, Malaysia.
A. N. Abdul Ghani, School of Housing, Building and Planning, Universiti Sains Malaysia, Penang, Malaysia.

I. INTRODUCTION

Nowadays, it has been widely agreed that construction needs materials that are durable, light, and simple to use but are more naturally sustainable. Additionally, natural fibers have the potentials to perform equally as synthetic fibers. Moreover, this alternative does not need a high amount of energy and considered as ultimate green products because it utilizes some agricultural wastes as construction materials. However, there is a minimum potential for the plain concrete to prevent cracking. Cracks are a significant issue because it will lead to negative impression of quality, durability and serviceability but they are only regarded as aesthetic problems in most cases [1]. Foamed concrete is classified as a lightweight concrete (400 kg/m^3 to 1850 kg/m^3). In this case, the absence of coarse aggregate causes the foamed concrete to have low density, which consequently leads to lower self-weight. More importantly, this type of lightweight concrete is recognized due to its low cement content, high workability, and low aggregate usage. Meanwhile, other characteristics of lightweight foamed concrete include its ability to be attained ecologically clean, inflammable, and easy to produce. However, it is crucial to note that the mixing time is longer than normal concrete to ensure proper mixing for the purpose of attaining the target density and quality of lightweight foamed concrete [2]. Furthermore, foamed concrete can be categorized as a wider class of lightweight foamed concrete which is made up of cement, water, fine sands, and trapped bubbles that stands in as an aggregate. More importantly, the mixture of lightweight foamed concrete can be replaced or added with other materials in order to enhance the strength and durability; for example, replacing the sand with other sand-like materials such as silica fume and fly ash [3]. In addition, it should be noted that foamed concrete encompasses of mortar matrix with at least 20% of entrapped air void which indicates that it can simply be produced with outstanding workability, high level of sound insulation, good thermal protection, excellent fire resistance, decent heat absorption, good flowability, and self-compatibility [4]. Cocos nucifera linnfibers (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. Moreover, it should be understood that CNF fibers 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 fibers have the potential to be utilized as substitute coarse aggregate in foamed concrete for the purpose of improving the durability properties such as water absorption and porosity [5].

CNF has always been disposed as wastes instead of being utilized as construction materials. The use of foamed concrete with CNF is able to reduce the weaknesses of foamed concrete which include low tensile strength, shrinkage problem, higher water absorption and serious crack propagation, especially in low densities foamed concrete. In addition, the addition of CNF is a practical way to improve the bending performance as well as tensile cracking considering that foamed concrete is generally weak in tension compared to its capacity in compression [6].

In addition, the capability of fibers is dependent on the amount of fibers used in the mixture. Higher percentage of fiber will lead to segregation and roughness of concrete and mortar. However, fibers that are lengthy in the mix will create workability problems that can be discovered using the flow table test and during the pouring of the concrete into the mold. Hence, the aim of the present study is to perform experimental studies in order to observe the influence of CNF volume fraction on water absorption capacity and porosity of foamed concrete.

II. MIX PROPORTIONS AND MATERIALS

Design Mix

A total of 21 mixes were prepared to conduct the experiment. 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, thus indicating that it managed to attain practical workability.

Table. 1 Mixture design proportion

Sample	Density (kg/m^3)	Mix Ratio (S:C:W)	CNF (kg/m^3)	Cement (kg/m^3)	Sand (kg/m^3)	Water (kg/m^3)
Control	650	1:1.5:0.45	-	248.29	372.44	111.73
0.1% CNF	650	1:1.5:0.45	0.72	248.29	372.44	111.73
0.2% CNF	650	1:1.5:0.45	1.44	248.29	372.44	111.73
0.3% CNF	650	1:1.5:0.45	2.22	248.29	372.44	111.73
0.4% CNF	650	1:1.5:0.45	2.94	248.29	372.44	111.73
0.5% CNF	650	1:1.5:0.45	3.67	248.29	372.44	111.73
0.6% CNF	650	1:1.5:0.45	4.44	248.29	372.44	111.73
Control	1050	1:1.5:0.45	-	392.73	589.10	176.73
0.1% CNF	1050	1:1.5:0.45	1.11	392.73	589.10	176.73
0.2% CNF	1050	1:1.5:0.45	2.28	392.73	589.10	176.73
0.3% CNF	1050	1:1.5:0.45	3.44	392.73	589.10	176.73
0.4% CNF	1050	1:1.5:0.45	4.61	392.73	589.10	176.73
0.5% CNF	1050	1:1.5:0.45	5.78	392.73	589.10	176.73
0.6% CNF	1050	1:1.5:0.45	6.94	392.73	589.10	176.73
Control	1450	1:1.5:0.45	-	537.18	805.76	241.73
0.1% CNF	1450	1:1.5:0.45	1.56	537.18	805.76	241.73
0.2% CNF	1450	1:1.5:0.45	3.17	537.18	805.76	241.73
0.3% CNF	1450	1:1.5:0.45	4.72	537.18	805.76	241.73
0.4% CNF	1450	1:1.5:0.45	6.33	537.18	805.76	241.73
0.5% CNF	1450	1:1.5:0.45	7.94	537.18	805.76	241.73
0.6% CNF	1450	1:1.5:0.45	9.56	537.18	805.76	241.73

Retrieval Number F9514088619/2019©BEIESP
DOI: 10.35940/ijeat.F9514.088619
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Cement

The cement used for this investigation was provided by concrete laboratory of School of Housing, Building and Planning (HBP), University Science of Malaysia (USM). Meanwhile, the Ordinary Portland Cement (OPC) used 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.

Fine Sand

Fine aggregate basically refers to natural sand that is obtained from local riverbed. Generally, the particle must be able to pass through 9.5mm sieve, while the appropriate size of fine aggregate should be between 0 to 2mm to ensure that the good properties of concrete can be achieved. In regard to this matter, the current research utilized an 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. Table 2 shows the sieve analysis for sand used in this research.

Table. 2 Sieve analysis for sand

Sieve (mm)	% Passing(Test 1)	% Passing(Test 2)	Limits of ASTM C330/03
9.5	100	100	100
4.75	96	97	95-100
2.36	91	89	80-100
1.18	79	76	50-85
0.6	38	36	25-60
0.3	9.8	11	5-30
0.15	2.6	4.1	0.-10
Pan	0	0	0

Water

Addition of a suitable ratio of water is able to ensure that a lightweight foamed concrete have the required strength, durability, and good performance, particularly in terms of workability. Moreover, water is used in the mix for hydration process for the purpose of stimulating the binding of cementitious material through chemical reaction. The suitable value of water is dependent on the amount of cement used in the mix which involves the chemicals and consistent requirement. Essentially, 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.

Surfactant

Generally, there are various types of synthetic and protein-based foaming agents that have been commonly used. 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 as shown in Figure 1. 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. Meanwhile, Noraite PA-1 refers to the foaming agents that produce stable foam output with the density around 60-70 g/liter. Hence, foamed concrete can be produced using the premix solution by adding 30 liters of water to 1kg of PA-1 of foaming agent. Overall, this particular solution can produce 30 liter of foam in approximation.

Fig. 1 Foam production from Portafoam PM 1

Cocos Nucifera Linn Fiber (CNF)

This experiment 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 with the aim of investigating the effect of the foamed concrete, particularly in terms of durability properties, mechanical properties, and its performance at elevated temperature. CNF was extracted from the outer shell of a young coconut which is randomly oriented. Figure 2 shows the CNF used for the present study, while Table 3 displays its physical properties. Meanwhile, Table 4 demonstrates the chemical composition of CNF used for the current research.

Fig. 2 CNF used for this research

Table. 3 Physical properties of CNF used for this study

Component	Value
Length (mm)	19
Density (g/cm^3)	1.26
Elongation at break (%)	29.6%
Tensile strength (N/mm^2)	168
Young modulus (GPa)	5.78
Diameter (mm)	0.131-1.35
Water absorption (%)	142

Table. 4 Chemical compositions of CNF used for this study

Component	Percentage
Lignin	45.76%
Cellulose	44.31%
Hemi-Cellulose	0.38%
Pectin's	2.91%
Ash	2.07%
Water soluble	4.57%

III. TESTING PROCEDURE

Water Absorption

The purpose of water absorption is to find out the capacity or limit of foamed concrete at the absorption of water and other fluids. Generally, it is communicated by the proportion of load of water absorbed by the composite materials within a timeframe to the load of dry examples. The water atoms have to get through the porosity of the concrete by means of capillary activities at the point when the concrete gets into the water. Apart from that, the natural matters in the concrete would likewise absorb dampness from environs in which the water absorption occurs. In the case of the present study, the test was conducted by referring BS 1881: Part 122 (1983) on cylinders with measurement 75mm ⌀ x 100mm as presented in Figure 3.

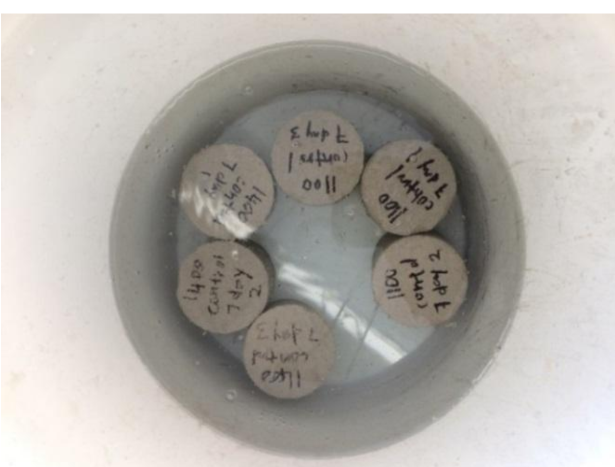


Fig. 3 Water absorption test of foamed concrete specimens

The cylinder specimen with the dimension of 75mm ⌀ x 100mm were withdrawn a day prior to the curing process, which was then cleaned and measure to achieve the immersed surface dry weight, W_{sat} of the specimen. Following this process, the samples were then placed into ventilated oven at ± 105 ºC for 72 ± 2 hours to guarantee that the samples were thoroughly dry in order to allow the oven dried weight of the specimen to be measured. Apart from that, a more detailed calculation was performed, while the water absorption of the foamed concrete managed to be assessed using the following BS 1881: Part 122, 1983:

$$Wa = \frac{Wsat\text{-}Wdry}{Wdry} \times 100\% \quad (1)$$

where

W_a = water absorption of hardened foamed concrete sample (%)

W_{sat} = saturated surface dry weight of foamed concrete sample (kg)

W_{dry} = oven-dried weight of specimen (kg)

Porosity

Generally, porosity value can be assessed using the Vacuum Saturation Apparatus. In the case of the present study, the specimens were dried and then put in a desiccator under vacuum for 3 days, in which the desiccator was found to be occupied with de-aired, distilled water.

Retrieval Number F9514088619/2019©BEIESP
DOI: 10.35940/ijeat.F9514.088619
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The specimens were put into ventilated oven at 105°C to determine oven-dry mass. Next, the specimens were then withdrawn from the oven and chilled under room temperature after 3 days. The purpose of measuring the weight of the specimens is to acquire the oven-dry mass at the point of preparing the samples for vacuum saturated,

while the desiccator was secured using a lid and protected using vacuum grease. Meanwhile, a pressure gage was appended to the vacuum line connector and the vacuum pumping started ad lasted for 3 days. Figure 4 shows the setup of desiccator for porosity test.

Fig. 4 Foamed concrete specimens in a desiccator under vacuum

Following the three days duration, the vacuum pump was shut down and the air was allowed to get into the desiccator. Meanwhile, the samples were immersed in the water which allowed the saturated surface-dry mass and the buoyant mass to be recorded. The permeable porosity of foamed concrete was determined using the following algorithm developed on the notion of increase load as a result of water absorption as well as weight reduction due to buoyancy (Equation 2).

$$Pr = \frac{Wsat-Wdry}{Wsat-Wwet} \times 100\% \qquad (3.2)$$

where

P_r = porosity of hardened foamed concrete sample (%)

W_{sat} = saturated surface dry weight of foamed concrete sample (kg)

W_{dry} = oven dried weight of foamed concrete sample (kg)

W_{wat} = weight of foamed concrete sample (kg) in water (kg)

IV. RESULTS AND DISCUSSION

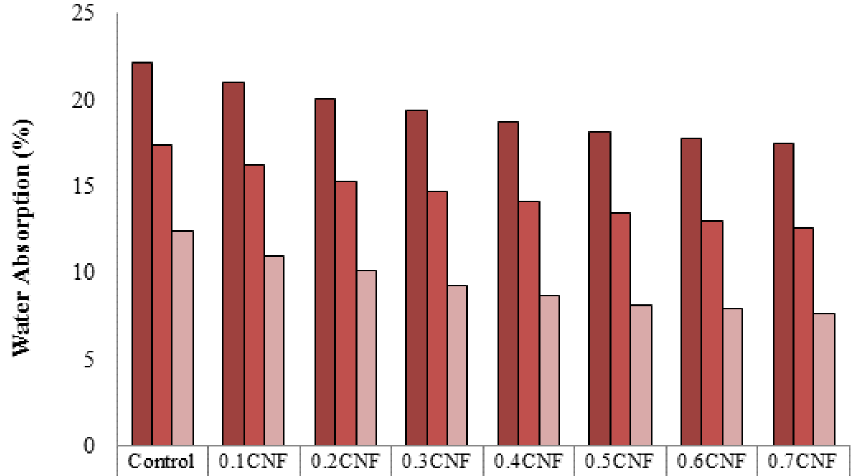
Water absorption

Water absorption test was conducted in the present study for the purpose of deciding the water absorption capacity of foamed concrete in conformity with BS 1881-122. Figure 5 presents the influence of various volume fractions of CNF in foamed concrete on water absorption capacity. Hence, it can be observed from the figure that the percentage of foamed concrete water absorption capability decreases as the volume fraction of CNF increases. This trend is caused by the increase in foamed concrete density which shows that foamed concrete with 0.6CNF and 1450 kg/m^3 density has the lowest water absorption percentage with only 7.6% compared to foamed concrete with the density of 1050 kg/m^3 and 650 kg/m^3 that provide 12.6% and 17.5% water absorption capability, respectively. Meanwhile, foamed concrete with 0.1CNF and density of 1450, 1050, and 650 kg/m^3 show higher percentage of water absorption which is 11.0%, 16.2%, and 21.0%. Therefore, it can be indicated from the results that foamed concrete with 650 kg/m³ possesses high water absorption because the density requires a high amount of foam, thus creating more air voids.

As investigated, larger size of pores was able to be produced by lightweight foamed concrete that has a density of 650kg/m³ led to insignificant associations with the matrix that influenced the quality of lightweight foamed concrete. The pores were near one another and a portion of the air bubbles merged and produced bigger pores.

Moreover, this caused brittleness and loose microstructure development, which decreases the ability to oppose excessive loads. It very well may be seen from the outcomes that the water absorption is higher as the density reduces due to the substantial number and colossal size pores. The capillary pores are another critical factor that impacts the transport of dampness [7].

The reason behind this result can be explained by the slower rate of water absorption of foamed concrete at the initial stage, particularly when it contained higher CNF volume fraction compared to lower CNF volume fraction. Moreover, higher CNF content managed to prevent water from penetrating into foamed concrete due to small size of pores and volume. Meanwhile, the CNF lost its dampness and shrunk back onto their sizes due to drying process. The C-S-H gel creation in matrix of foamed concrete with higher content of CNF abridged the pore size, which resulted in lower water absorption. Water absorption occurred due to the presence of fine void in the foamed concrete. Hence, it can be anticipated that the absorption reduced alongside the age of the foamed concrete. Overall, from the result, it can be concluded that higher CNF content tends to absorb water slower at the underlying stage in contrast with lower level of CNF. A possible explanation to this is that large size of pores lead to weak connection with the matrix. Higher water absorption of natural fibers cause unsteady volume and low attachment among fiber and matrix whereby and natural fiber tends to decay quickly in the alkaline environment of cement and concrete [8]. The water absorption of foamed concrete is primarily influenced by paste phase instead of entrained pores that are not unified.



	Control	0.1CNF	0.2CNF	0.3CNF	0.4CNF	0.5CNF	0.6CNF	0.7CNF
650kg/m3	22.2	21.0	20.1	19.4	18.7	18.1	17.8	17.5
1050kg/m3	17.4	16.2	15.3	14.7	14.1	13.5	13.0	12.6
1450kg/m3	12.4	11.0	10.1	9.3	8.7	8.1	7.9	7.6

Fig. 5 Water absorption of foamed concrete of different CNF volume fraction

Figure 6 demonstrates the relationship between fiber volume fraction and water absorption for all three densities. It very well may be observed that there is a non-direct reduction in water absorption of foamed concrete with higher amount of CNF volume division. This trend is consistent for all the densities examined. Regression analysis shows that the patterns that best depict the connection between CNF volume fraction and water absorption can be regarded as a linear function. The regression line with the R^2 value acquired for each of the three densities nearest to the value of 1 was taken as the regression line that best demonstrates the pattern of the water absorption data.

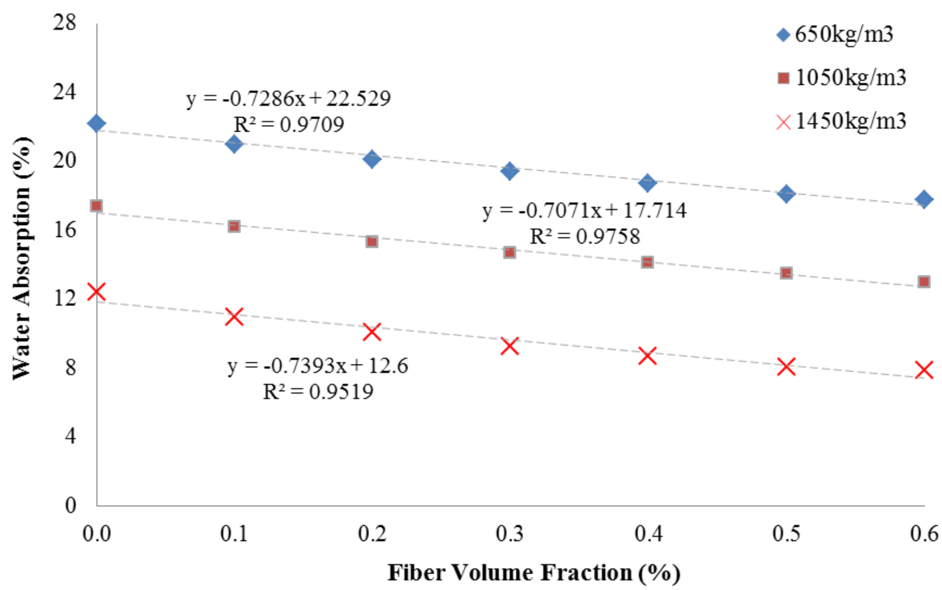


Fig. 6 Correlation between CNF volume fraction and water absorption of different densities of foamed concrete

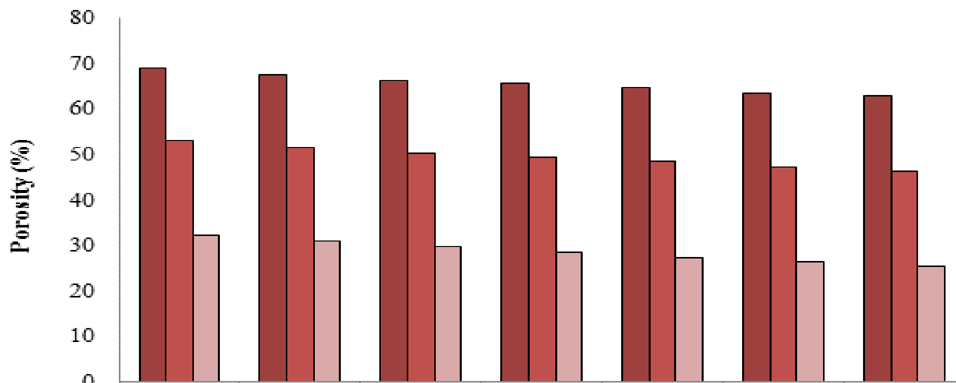
On another note, it should be pointed out that the internal structure of foamed concrete comprises of entrained air voids and capillary pores, thus indicating that not all of the pores and voids aggressively reacted to water absorbance. As can be seen from Figure 6, higher volume fraction of CNF in foamed concrete mix precludes water from penetrating into the cementitious matrix, thus owing to the small size of capillary pores, gel pores, and interlayer space. The development of pores and voids were diverse with various volume fractions of CNF. Furthermore, the fundamental result of the hydration of Portland cement in foamed concrete was Calcium Silicate Hydrate with higher percentage of CNF that reduced the pore sizes, thus leading to low water absorption.

Porosity of foamed concrete

The mechanical properties of foamed concrete are undoubtedly dependent on the porosity and its pore structure. The higher percentage of porosity will affect the strength of foamed concrete. Moreover, it is important to note that the air pore in the foamed concrete can be entrapped or entrained. Figure 7 illustrates the influence of different CNF volume fraction in foamed concrete on its porosity.

As seen in Figure 7, it can be clearly observed that the porosity level of foamed concrete reduces slowly as the CNF volume fraction and density of foamed concrete increases. On another note, the alteration and morphology variation of the CNF causes the reduction in porosity of foamed concrete. The results shown in Figure 7 exhibit that foamed concrete with 0.6CNF and density of 1450, 1050, and 650 kg/m^3 provide the porosity values of 25.3 %, 46.2%, and 62.9%. Meanwhile, foamed concrete of 0.1CNF with the density of 1450, 1050, and 650 kg/m^3 show higher porosity percentages which are 30.9%, 51.4%, and 67.6% respectively. Overall, it can be understood that the porosity of lightweight foamed concrete reduces due to the increases in CNF for the entire densities investigated in the current research. However, CNF with the density of 1450 kg/m³ possesses the lowest percentage of porosity compared to 650 kg/m³ and 1050 kg/m³. A possible explanation to this may be the reaction between the cement paste and CNF. Hence, it is crucial to note that higher density foamed concrete led to the reduction in the porous structure, while the CNF helped to bridge the matrix. Lower porosity of lightweight foamed concrete is activated by the changes in the morphology of CNF [9].

In addition, the foam provides access for air to infiltrate into the mix slurry during the mixing process. Accordingly, to lessen the density, a high amount of foam is required in order to allow air voids to enter the mix. In other words, this indicates that low density foamed concrete requires more foam in order to achieve higher value of porosity. Moreover, the increase in the number of voids due to high percentage of porosity can reduce the compressive strength of foamed concrete. Therefore, this suggests that there is insufficient surface area that combines the pores and the matrix as a result of the insignificant association between the pores and the matrix. Apart from that, binding materials are constrained at this density because of the additional foam with the aim of delaying the setting and hardening of foamed concrete.



	Control	0.1CNF	0.2CNF	0.3CNF	0.4CNF	0.5CNF	0.6CNF
650kg/m3	69.0	67.6	66.4	65.7	64.6	63.5	62.9
1050kg/m3	53.2	51.4	50.4	49.3	48.4	47.2	46.2
1450kg/m3	32.1	30.9	29.6	28.4	27.3	26.3	25.3

Fig. 7 Porosity of foamed concrete of different CNF volume fraction

Figure 8 shows the Correlation between water absorption and porosity of different CNF volume fraction for for 650 kg/m^3, 1050 kg/m^3 and 1450kg/m^3 densities. As can be seen from Figure 4.11, there was a significant amount of scatter in the data. The R^2 value for the trend-line drawn through all of the results from all batches was indicative of how closely the water absorption was correlated to porosity of foamed concrete. The regression analysis represents that the patterns that best depict the connection between water absorption and porosity was described as a linear function. The regression line with the R^2 value nearly to the value of 1 was recorded as the regression line that best describes the trend of the water absorption and porosity data. Lower density mixtures absorbing significantly higher percentages of water than those with higher densities. From these results, it could be concluded that because the mixtures with lower densities absorb more water, they were potentially less durable than the mixtures with higher densities [10].

Additionally, the porosity of foamed concrete increased with the increase in water absorption. Both of porosity and water absorption were affected by the pore structure of foamed concrete cement paste, and liquid transfers from surface into interior [11]. So, it indicated that water absorption provides great influence on foamed concrete.

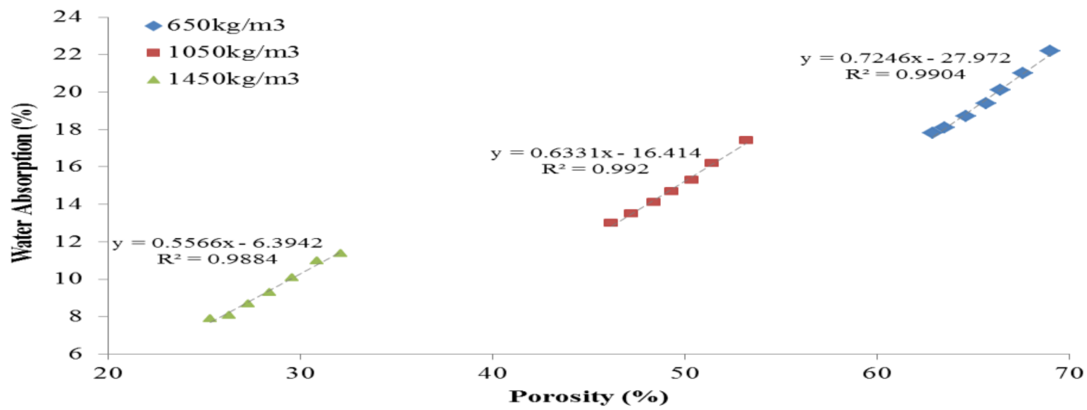


Fig. 8 Correlation between water absorption and porosity of different CNF volume fraction for different densities of foamed concrete

V. CONCLUSIONS

From this study, the following main conclusions might be drawn on the influence of CNF volume fraction on water absorption and porosity of foamed concrete:

1) Water absorption of foamed concrete was slower at the beginning when it contained higher CNF volume fraction than the lower CNF volume fraction. This is on the grounds that higher CNF content can prevent water from entering the foamed concrete as a result of small size of pores and volume. Additionally, CNF absorbed water and then expanded amid blending. At that point towards the end of the drying procedure, the fiber lost its dampness and shrunk back to their unique dimension, thus leaving extremely fine voids around themselves. In addition, it was difficult for the concrete to absorb water when there are fine voids. In this way, it was expected normal that the absorption will diminish alongside the age. This execution demonstrated that CNF could anticipate fragility and lose microstructure arrangement, which reduces the capacity to oppose excessive loads.

2) Porosity of lightweight foamed concrete is reduced due to the increase of CNF for each density examined in the present study. This occurs because of the reaction between the cement paste and CNF. In addition, higher density foamed concrete prompts the decrement of permeable structure, while the CNF serves to bridge the matrix. Meanwhile, the arrangement of pores for plain foamed concrete without the incorporation of fiber was bigger compared to foamed concrete with the incorporation of CNF. CNF additionally helps in making an increasingly uniform distribution of the air voids. In this way, it will hinder bubbles from merging with one another.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge financial support from NAPREC Grant No. USM/401/PPBGN/510059/I-124

REFERENCES

1. M Kozlowski, M Kadel and A Kukielka, Fracture energy of foamed concrete based on three point bending test on notched beams, Procedia Eng.2015;108, 349-354
2. MM Kamal, MA Safan, ZA Etman and MA Abd-elbaki. Effect of polypropylene fibers on development of fresh and hardened properties of recycled self-compacting concrete. Int. J. Eng. Adv. Tech. 2013; 2, 86-94
3. MA Othuman Mydin, NARozlan and S Ganesan. Experimental study on the mechanical properties of coconut fiber reinforced lightweight foamed concrete. J Mater Environ Sci. 2015; 6, 407-411
4. JS Ruben and G Baskar, Experimental study of coir fiber as concrete reinforcement material in cement based composites, Int J Eng Res Appl. 2014;4,128-131
5. S Solemazadeh and MA Othuman Mydin. Influence of High Temperatures on Flexural Strength of Fomaed Concrete Containing Fly Ash and Polypropylene Fiber. Int. J Eng.2013;26, 365–74
6. J Norgaard and MA Othuman Mydin. Drywall Thermal Properties Exposed to High Temperatures and Fire Condition. J Teknol. 2013; 62, 63-68
7. SH Kosmatka, B Kerkhoff and WS Panarese. Design and Control of Concrete Mixtures. 14th ed. Portland Cement Association, USA, 2003.
8. MO Mydin and YC Wang Mechanical properties of foamed concrete exposed to high temperatures. Constr. Build. Mater. 2012; 26, 638-54
9. SH Sulaiman. 2012, Water Permeability and Carbonation on Foamed Concrete. Master dissertation, University Tun Hussein Onn Malaysia, Malaysia, 2012
10. K Chandramouli, RP Srinivasa, N Pannirselvam, ST Seshadri and P Sravana. Strength properties of glass fibre concrete. ARPN J. Eng. Appl. Sci. 2010; 5, 1-6
11. MA Othuman Mydin, M Musa and AN Abdul Ghani. Fiber Glass Strip Laminates Strengthened Lightweight Foamed Concrete: Performance Index, Failure Modes and Microscopy Analysis.AIP Conf. Pro. 2018;2016,020111