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Durability of Concrete Wall Panel with Fibers Using Non-Autoclaved Aerated Technique (Cowap-FINAT)

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Abstract

Wall is an element that play a big role in construction of house, building and other. The purposes of walls in buildings are to support roofs, floors and ceilings, to enclose a space as part of the building envelope along with a roof to give buildings form and to provide shelter and security. Standard wall panel usually built at construction site. The disadvantage of this method is it cost more, take a lot of time, quality will less controlled etc. In this study, Industrialized Building System (IBS) which means a technology of construction which there are manufactured in controlled environment, either at off site or site.The objectives are to determine the suitable ratio of non-autoclaved aerated concrete (NAAC) and to investigate the best ratio of mixed natural and glass fiber in aerated concrete that give higher strength,to build wall panel based on the best ratio of mixed fiber in non-autoclaved aerated concrete (NAAC).Methodology of this study starts with preparation of both fiber which is treatment,shredding and mixing. Experimental work begun with concrete cube preparation, concrete mix design and fiber ratio and compressive strength test for cube followed with rebound hammer test for wall panel. The percentage compressive strength of AC with 25% of AP is 1.643Mpa. AC 60% fiber glass 40% bamboo fiber with 1.643 Mpa of compressive strength. The average result rebound hammer for aerated wall panel is 11.5. In conclusion, this study can prove that modified wall panel still with lightweight concrete with reduction of 58% of weight from standard concrete which were 2.25 kg to 0.943kg but still has a good compressive strength. However, its still not strong enough to be used in construction industry due to several factors.

1. Introduction

Aerated concrete (AC) is a modern energy-efficient construction material classified as lightweight concrete due to its low density and strength [1]. There are two type of AC which are Autoclave aerated concrete and non-autoclave aerated concrete. The differences between these two types of AC are the curing process. Autoclave aerated concrete (AAC) uses synthetic hardening which is hardening in saturated steam media at pressure above atmospheric meanwhile non-autoclaved aerated concrete (NAAC) uses hydration hardening, which is hardening under natural conditions with electrical heating, in saturated steam media at atmospheric pressure [2]. The curing of NAAC seems more easier and faster to conduct compared to AAC. Then, the Non Autoclave aerated concrete

(NAAC)will be chosen in this project because the objective of this project is to produce strong and light weight wall panel. NAAC surely have lower compressive strength than AAC, the usage of natural fiber to enhance its strength is proposed.

This study also seeks to avoid the usage of nonrenewable materials, which might result in excessive energy, power consumption and cost increase. This is the reason why a sustain material such as bamboo is needed. Bamboo was found to have higher compressive strength and tensile strength in comparison to other materials such as banana stem, bagasse, and *etc* [3]. Bamboo fiber (moso bamboo) having quite strong tensile strength which is 540-630 Mpa [4]. Therefore, bamboo becomes a suitable building material of high usability and is readily available. Other than that, because of the fast-growing root system, it is known as one of the fastest-growing grasses and its growth is three times more than most plants. "The Green Gold" is available at fewer prices as compared with timber and it is as solid as most of the wood available on the market [3]. Then, glass fiber will be added into the concrete to increase its strength.

The lightness and strength of glass fiber, as is well known, will be able to make this concrete wall stronger, hence reducing the need for labour during construction. In addition, previous studies have revealed that glass fiber can give several benefits. For instance, it will boost the strength of concrete. It can be proof by research from [5] the percentage increase in compressive strength compared with bacterial concrete was 11.44 %. Fine aggregate can be classified as a 'nonrenewable' resources [6] which can lead to a problem of more quarries being explored and blown up.In order to overcome that problem, the usage of bamboo fibre is proposed.

This study also conducted the treatment process with two different types of treatment for the bamboo strips which are 5% Sodium Hydroxide (NaOH) and Boric acid. Alkaline method will be used toward the bamboo strips. The solution that will be used is 5% NaOH. The bamboo strip will be soaked in the solution for 24 hours in order to produce cellulose.This treatment method gives roughness to achieve reaction between concrete and fibers. A borax solution can be used as a preservative in cold or hot soaking methods because it is an environmentally friendly liquid that can dissolve in water. It has been demonstrated that borax can protect bamboo against attacks from fungus and insects, but it is also important to investigate how the solution affects bamboo's durability. According to the findings of this study, adding 30% to 50% borax to the preservative solution is enough to significantly boost the compressive strength, tensile strength, and bending strength of bamboo specimens [7]**.** The quality of the bamboo materials was increased by using a solution of borax to preserve them.

For AC preparation, it consist of OPC, calcium hydroxide(lime) and aluminium powder. It's started with 4 different ratio of aluminium powder which is 0.15, 0.25, 0.5 and 0.75 without fiber. After compressive strength test have been done, ratio that produce highest power will be chosen to mix up with fibers. For fibers, 2 different ratio which are 60% fiber glass and 40% bamboo fiber and 60% bamboo fiber and 40% fiber glass will be prepared. Ratio that produce higher reading will be chosen as final ratio to construct the wall panel. In this study, compressive strength test divided into two which are Destructive test(DT) and Non-Destructive Test(NDT). DT was conducted via compression machine of concrete age 7-28 days at average load of 23.33 kN. NDT was conducted via rebound hammer test either on AC sample or wall panel.

The aim of this research is to construct a durable concrete wall panel with fibers using non-autoclaved aerated concrete. In order to enhance the strength of aerated concrete, bamboo fiber and glass fiber is used. Meanwhile, the compressive strength tests, namely the compression test and rebound hammer test, were conducted to investigate the strength of the aerated concrete with mixture of bamboo fiber and glass fiber as alternative fine aggregate.

2. Materials and Methods

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

2.1 Experimental Work

Material preparation involves bamboo strips preparation, treatment, composition, aerated concrete preparation, form work design/casting, and concrete mix design and slump test for a final product with fiber-based fiber.

2.2 Bamboo Treatment Process

The alkaline method is used to treat bamboo strips, using 5% NaOH solution for 24 hours to produce cellulose. The strips are then rinsed and dried under sunlight for neutralization. The borax solution is an environmentally friendly preservative used in bamboo and wood materials to protect against fungi and insects. It significantly increases compressive strength, tensile strength, and bending strength, enhancing the quality of bamboo specimens. The application of borax solution in preservation increases bamboo's mechanical qualities, making them of higher quality.

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The steps and techniques used to treat the bamboo strips and provides information on how to prepare the bamboo strips for treatment as follows:

i. The scientific name for this type of bamboo is Schizostachyum grande, while the commercial name is semeliang bamboo. The bamboo is obtained in Kampung Sungai Balang Kecil, Muar, Johor. The age of bamboo is 3 to 4 years and 1000mm(L) x 20mm(W) x 10mm(H) for each strip.
ii. First, the bamboo strips were soaked in NaOH solution with 50 grams and 10 liters of water to dilute the NaOH for 3 days to remove impurities.
iii. For the second treatment of bamboo, strips were soaked in Borax solution with 250 grams and 10 liters of water to dilute the Borax for 3 days to increase the strength of bamboo.
iv. After the treatment is done. The bamboo strips are dry under the sun for 24 hours.

Wall Panel design. Concrete sandwich wall panels consist of a single insulation layer between two precast concrete layers connected by shear connectors or webs. The thickness of each layer depends on the panel's function and can be classified as non-composite, partially composite, or fully composite. The thicker layer resists the applied load and acts as the structural layer.

Aerated Concrete Preparation. to ensure that the objectives of this study will be achieved. The cement-to-limestone powder ratio in the concrete mix used for the aerated concrete specimens was 1:1. To find the best amount of aluminum powder (AP) to use, two AC cube samples were mixed with varying amounts before being combined with six AC specimens containing bamboo strip mats. Bamboo-strip mats, regular Portland cement, water, and raw materials, namely limestone powder and aluminum powder, were used in this study's composition to create aerated concrete.

2.3 AC sample preparation

Next, two (2) AC cube samples with dimensions of 100mm(L) 100mm(W), and 100mm(H) were used to calculate the ideal AP content for the AC specimens. For the two (2) cube samples of AC in this study, 0.25% of AP and 0.50% of AP were applied. To ascertain the response, an observation was made. between a particular AP concentration and limestone powder. Before being unmolded, both cube samples were allowed to sit for 24 hours. From the observation, 0.25% of AP was selected as the AP content used for AC specimens based on the findings of cube samples of AC. Based on a study that investigated the characteristics of AC with different amounts of aluminium powder (AP), The result shows that the strength of 0.25% AC greater than 0.50%.

Table 1 *The proportion of material in AC with the two ratios of fiber bamboo and fiberglass for the ratio of 0.25% AC.*

No. of concrete sample	Ordinary Portland Cement (kg)	Limestone Powder (kg)	Aluminium Powder (%)	Water ratio of Dry mix	The ratio of Fibers (%)
A	2	2	0.25	0.6	60% fiber bamboo and 40% fiberglass
B	2	2	0.25	0.6	60% fiberglass and 40% fiber bamboo

Table 1 shows the properties of AC with the two ratios of fiber bamboo and fiberglass for the ratio of 0.25% AC. To investigate the objectives of the study, two ratios of fiber bamboo and fiberglass will be mixed with aerated concrete to find the best ratio for the better strength of the mixture. From the test of AC with fibers, the best ratio of fibers is 0.25 with 1.409 MPa and 14.093 kN of load. The production of aerated concrete wall panel**.** The result from compressive strength test is used to build this wall panel which is the usage of aerated concrete with 25% AP and 60% fiber glass and 40% bamboo fiber. The wall panel measurement is 300mm(L) X 300mm(w) X 50mm(H).

The process of making the wall panel which are, the mix design of aerated concrete with fiber was prepared, and the reaction between limestone powder and AP were seen to foam after 10 minutes, after the mould was greased with oil, it was filled layer by layer until it fulfill the mould, and the AC wall panel was unmoulded after 24 hours and left to be cured for 7 days.

Compression Strength Test: Compressive Machine Test. Compressive strength testing measures a material's ability to withstand compression before breaking. It involves compressing a test item into a cube, prism, or

cylinder. Firstly, the two ratios of Aerated concrete have been tested to find the best ratio of Aerated Concrete. Secondly, Two samples of aerated concrete with fibers were chosen for testing, with the strongest cube concrete being the best ratio for wall panels.

The rebound hammer is a portable, inexpensive, and convenient tool for determining the rebound value of hardened concrete surfaces. It is compact, lightweight, and portable, capable of testing both in-situ and fresh concrete after final set. However, it has disadvantages, such as not directly converting rebound value into compressive strength, and not being directly related to the type of aggregate used. This study replaces fine aggregate with natural fiber and glass fiber, highlighting the need for improved testing methods. During operating, the hammer's axis is placed horizontally to the specimen tested. Using a grid to find the spots decreases the possibility of inaccuracy.

3. Results and Discussion

In this chapter, a few experiments have been conducted, such as a determination of density and compressive strength of AC, and comparison between AC drain and standard concrete drain using Semeliang bamboo fiber and fiber glass. The values obtained from the experimental test are evaluated and discussed for further comparison and evaluation.

Analysis of Aerated Lightweight Concrete Specimens. The concrete specimens made were subjected to several analyses to identify the type of concrete produced that meets the standard requirement. The assessments include the density of aerated lightweight concrete, the compressive strength of aerated lightweight concrete between the specimen, and lastly, the comparison between the compressive strength of aerated lightweight concrete using semeliang bamboo fiber and fiber glass with standard concrete drain. The first one is the density of Aerated Lightweight Concrete of 6 specimens measured at 100mm × 100mm × 100mm, containing different aluminium content and compared with 1 cube standard concrete 100mm × 100mm × 100mm.

Table 2 shows the value obtained from six (6) specimens of AC and one (1) cube standard concrete with different days of curing, 7 days and 28 days, and the densities of concrete were obtained.**Fig. 1** clearly shows that the values of density 25% aluminium are higher than the density for50% aluminium. Data collected for 7 days and 28 days are the highest among the others,which are kg/m^3 and kg/m^3. Therefore, specimens with 25% aluminium will havea better life long span than 50% aluminium. Meanwhile, in the density comparison obtained by standard concrete specimens and aerated concretecubes, standard concrete cubes produce a density higher than any aerated concrete specimens. The result shows that an aerated concrete specimen is more lightweight because it does not contain any coarse aggregate in its mix design ratio.

Table 2 *Density of aerated concrete and standard concrete after 7 days and 28 days of curing*

Types of Concrete	Aluminium Percentage (%)	No. of concrete specimen	Weight of concrete specimen (kg)	Volume of concrete specimens (m^3)	Curing (days)	Density (kg/m^3)
	25%	1	1.014	0.051	7	1014.30
Aerated		2	0.943	0.051	28	943.00
concrete	50%	1	0.880	0.051	7	880.00
		2	0.730	0.051	28	730.00
Standard	-	1	2.25	0.051	7	2250
Concrete		2	2.25	0.051		2250

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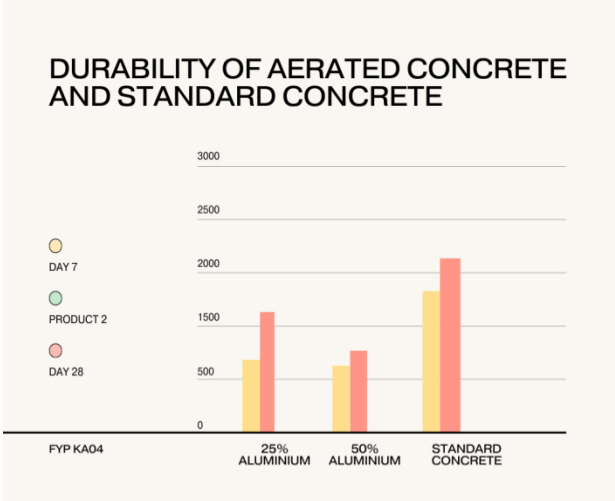

Fig. 1 *Durability of aerated concrete and standard concrete*

Next, based on the objective, this study determines the highest strength of the 2-volume percentage aluminium will add with fiber glass and bamboo fiber. Thus, the compressive strength test was conducted using the compression machine test to determine the highest strength obtained.

Table 3 Durability *of the two different ratio*

Semeliang Bamboo Fiber (SB) and Glass Fiber (GF) (%)	No of concrete specimen	Durability Day 28 (Mpa)
60% GF and 40% SB	1	1.643
	2	0.162
60% SB and 40% GF	1	0.567
	2	1.269

Table 3 shows the results obtained for the compressive strength test for all specimens after 7 days and 28 days of curing. The highest compressive strength of aerated concrete specimens after 7 days of curing is MPa for specimens containing 60% glass fiber and 40% bamboo fiber than other specimens,followed by 60% bamboo fiber and 40 % fiber glass, MPa and specimens. In this study, the semeliang bamboo fiber and glass fiber were added to the AC as replacement material sand to improve the performance and lightweight.

Table 4 *Durability wall panel via rebound hammer test*

No.	Compressive Strength Test wall panel with bamboo fiber and fiber glass using rebound hammer (MPa)	
	60% BF 40% GF	60% GF 40% BF
1	8	12
2	10	12
3	10	11
4	8	11
5	10	10
6	10	10
7	10	14
8	9	10
9	10	10
10	11	11
11	8	14
12	10	15
Average	**9.5**	**11.7**

Analysis Aerated Lightweight Concrete with Fiber Glass and Bamboo Fiber On Wall-panel: After get the best ratio of the aerated concrete, then it will put on the wall panel to test strength using experiment Rebound Hammer.

From the result that show that has proven that wall panel with have fiber glass and bamboo fiber have strength and the material that has use can replaced sand. **Table 4** shows the durability wall panel via rebound hammer test.

Table 5 *Standard reading for rebound hammer test on concrete.*

Average rebound number	Quality of concrete
>40	Very good hard layer
30-40	Good Layer
20-30	Fair
<20	Poor Concrete
0	Delaminated

Based on **Table 5**, which presents the standard reading for the rebound hammer test, the result obtained by the by both AC specimen with different ratio is Poor concrete. This is because the test was conducted on concrete sample and not wall panel.Hence, the result may different.The rebound hammer test work best for close texture concrete compared with open texture concrete. Concrete with high voids and no-fines concrete is not suitable to be tested by rebound hammer. The strength is overestimated by the test when testing floated or trowelled surfaces when compared with moulded surfaces (Gopal Mishra., an article on The Constructor, rebound hammer test on concrete- principle,procedure, advantage & disadvantage 2020). **Fig. 2** represents the average rebound index number for AC sample.

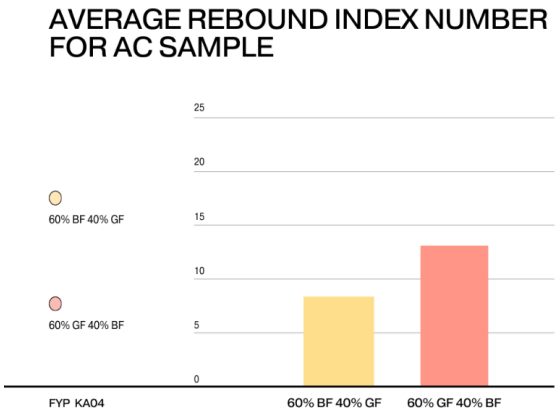

Fig. 2 *Average rebound index number for AC sample*

4. Conclusion

The outcomes of the experiment show that this study's objectives have been accomplished. Data collected proved that concrete formed without aggregate can also produce a high level of strength with the help of fiber glass and treated Semeliang bamboo fiber. However, it is still considered weak due to several factors. 60% of fiber glass and 40% of bamboo fiber is an ideal ratio to enhance the AC's strength with 25% of aluminium powder. The values for compressive strength after a concrete curing process for days 7 and 28 can be done either by rebound hammer test or compression machine test to analyze the effectiveness of the fibers. In other word,this study should have a lot of improvements in terms of the selection of bamboos type and most important, the way AC sample and wall panel was prepared.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design, data collection, draft manuscript:*** *Azizul Mustaqim Abdul Latiff, Lutfil Hazim Selamat Sainudin, Mohamad Fazrul Monkahar,;* ***draft***

manuscript preparation: *Azizul Mustaqim Abdul Latiff, Lutfil Hazim Selamat Sainudin, Mohamad Fazrul Monkahar, Nur' Ain Idris. All authors reviewed the results and approved the final version of the manuscript.*

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