PAPER FIBER REINFORCED FOAM CONCRETE WALL PANELING SYSTEM

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ABSTRACT

One type of a new product for the usefulness of panel wall material containing mixed composite of cement, sand, and recycle paper called as Paper Fiber Reinforced Foam Concrete (PFRFC) as upon of the reinforcement addition is expected can improve materials quality for non load bearing wall. Pursuant to study of paper fiber in mixture of concrete it was produce a strong structure materials, environmental friendly and economical. By that this study have practiced using paper fiber with other mixture of lightweight foamed concrete to search out the good material for lightweight concrete in term of the tension strength, compression strength and absorption of noise. Paper fiber is come from wood fiber which have experienced of crushing process, condensation, and pickling have idiosyncrasy in absorbent strength of sound and strength of tension but it is sensitive to water, slow harden and increase the density of foam concrete specimens. Experimental work of PFRFC have been conducted in the form of prism specimen, panel wall and cube, with water ratio, cement, and sand is 0.45 : 1 : 1.5 and mixed with 5%, 10%, 15% and 20% of paper fiber. The research have shows that, with addition of paper fiber the flexural strength of the Paper Fiber Reinforced Foam Concrete (PFRFC) is increases although the compression strength of PFRFC is not as good as the flexural strength. The strength of wall panel of PFRFC is better compared to Normal Foam Concrete (NFC) wall panel in terms of the flexural strength and noise absorption. The density discovered is less than normal concrete density, which are 2400 kg/m^3. The PFRFC density is appropriate for the lightweight material for wall panel, which is the range of density, are 800 - 900 kg/m^3 for the specimen of PFRFC cube.

Keywords: Paper fiber reinforced foam concrete, non-load bearing wall, lightweight foam concrete, flexural strength, noise absorption, lightweight material.

1.0 INTRODUCTION

Paper Fiber Reinforced Foam Concrete (PFRFC) has an unexploited potential application in building frames due to its possibility of better strength in tension and sound insulation and relatively simple construction technique. To know such potential, the author tries to do any experiment on PFRFC to be contributed in building construction material through experimental investigation and analysis. PFRFC could be an ideal building material because it is economical, utilizing air, unwanted newspapers, magazines, cardboard, junk mail, old bills, and tax records. Now days, natural fiber composites takes an important role in building and construction industry as they have great potential in order to replace timber, concrete, steel and glass fibers. Various types of natural fiber composites include rice husk, coconut husk, groundnut shell, cotton stalk and many more used as building materials for various applications. Natural fiber composites building materials have gained importance and popularity due to their lightweight, high strength and stiffness, corrosion resistance, and lower impact on the environment. These composite are far advanced to any other building material as they are eco-friendly to a larger scope that is today's necessitate and important aspect. The used of fiber from the dispose of recycle paper could be a valuable material in the construction of a composite material that can be used as an internal panel wall in housing construction.

2.0 RESEARCH SIGNIFICANT

In the United States, they discard enough paper each year to build a wall 48 feet high around the entire perimeter of the country. Even though about 45% of discarded paper is recycled annually, 55% or 48 million tons of paper is thrown away or goes into the landfills. Figuring conservatively, it takes about fifteen trees to make a ton of paper. That means that 720 million trees are used once and then buried in a landfill each year (Lorenz, David, 1995). A large amount of recycle paper was disposed in over the world. If the waste cannot be disposed properly it will lead to social and environmental problem. Recycling cuts energy consumption and pollution. Paper recycling can reduce air pollutants by 75% and water pollution by 67%. A ton of recycled paper saves 17 trees and three cubic yards of landfill space (The Environment Paper Network (EPN), 2007). Studying and analyzing the efficiency of using recycle paper fiber to get the good strength to be better quality of building material through the testing of strength of lightweight concrete to determine the effectiveness of paper fiber reinforced foam concrete (PFRFC) as concrete fiber, to find the optimum mix design especially to get the best fiber content to achieve better strength of PFRFC and to determine the basic physical behavior of the recycle paper fiber reinforced lightweight foam concrete wall paneling system.

Generally, this research is to investigate the physical properties of the recycle paper fiber reinforced foam concrete in terms of density (lightweight), strength (bending and compression), and sound insulation. The material that would was tested is a mixture of recycled paper, foam concrete, sand and water. The hypothesis will be that recycled paper can be made into homes in a low cost, low tech way, and better strength of lightweight concrete wall paneling system. All of the tests performed were designed to find the maximum rate of stress that the material could withstand without failure, density test, flexural test, ultrasound test and sound insulation, and then compare those results to the result of lightweight foam concrete without adding any fiber composite.

3.0 EXPERIMENTAL PROCEDURE

The research was conducted through an experimental programme with mortar samples, different in size and shape. Therefore, the influence of the paper fiber in percentages was studied concerning density, velocity of ultrasonic pulse, compressive strength, flexural strength, as well as bond between reinforcement and foam concrete. Additionally, the following were also studied: carbonation, sound absorption and influence of air curing conditions on paper fiber reinforced foam concrete. The experiments were conducted in the laboratories at the School of Housing, Building and Planning, Universiti Sains Malaysia.

Ordinary Portland cement of ASTM type I was used. The cement had a specific surface of 350 m^2/kg and a compound composition C_3S 54.3%, C_2S 17.6%, C_3A 11.6% and C_4Af 6.4%. The sodium oxide equivalent of the cement was 0.59%, while the silica and iron modulus were 2.62% and 2.71% respectively. The fine aggregate was a graded river sand with 5.0mm maximum size and complied with the grading limit of zone 1 of BS 882. The foam concrete mix proportions used in this study were cement: sand: 1:1.5, all by weight with a water-cement (w/c) ratio of 0.45 for the initial mixes. Irrespective of the final w/c ratio used, all the mixes were designed for a slump of 15cm - 20cm.

Paper fiber is added based on percentage of the volume of a cube sized 100mm x 100mm x 100mm. As such, the investigation is expected to have basic characteristic or basic properties of the PFRFC so as load carrying capacity and durability can be established. The information may be very useful for future study and future development so improvement to building materials can be carried out in more detail manner. The mix proportion is shown in Table 1.0.

		5% fiber	10% fiber	15% fiber	20% fiber
		1:1.5:0.45	1:1.5:0.45	1:1.5:0.45	1:1.5:0.45
a. Volume of foam concrete	:target mix	0.024	0.024	0.03	0.024
b. Wet density of foam	:+100 of dry target	1000 kg/m^3	1000 kg/m^3	1000 kg/m^3	1000 kg/m^3
c. Cement to sand ratio	:1:1.5				
d. Water of cement ratio	:0.45	2.95	2.95	2.95	2.95
e. Weight of materials		24	24	30	24
f. Weight of cement		8.14	8.14	10.17	8.14
g. Weight of sand		12.2	12.2	15.25	12.2
h. Weight of water	:+200	3.7	3.7	4.6	3.7
Adding/reduce water		0.3	0.3	1.8	2.7
Admixture (Superplasticizer)		-	-	-	0.407
i.(1) Weight of paper fiber	:% of volume	0.11	0.22	0.4	0.429
i.(2)Total weight		**24.45**	**24.56**	**32.22**	**27.98**
j. Density of mortar	:measure (weight)	2018	1808	1830	1743
k. Volume of slurry	:i/j	0.012	0.014	0.017	0.016
l. Workability of mortar	:	17	17	17	16
m. Foam content in mix	:a-k	0.012	0.010	0.013	0.008
n. Foam volume required additional	:mx 1000+15%	12	10	13	8
o. Foam output	:measure flow rates				
p. Time of pumping	:n/o				
q. Actual density of foam concrete (wet)	:measure (weight)	1048	1099	1043	1091

Table 1.0 : Design mixes for foam concrete specimens

All foam concrete specimens were cast in steel moulds, an external vibrator was used to facilitate compaction and decrease the amount of air bubbles. The samples were demoulded after 24 hours and then cured at air curing condition until the date of test.

4.0 TEST RESULTS AND DISCUSSIONS

4.1 Density

The density is carried in accordance with British Standard BS 5669 : Part 1. The thickness, width, length and weight are measured in order to determine the density. The calculation for density is carried out by using the following equation:-

$$P = M/V$$

Where,

P = density in kg/m^3

M = mass of the test specimen (kg)

V = volume of the test specimen (m^3)

The cube density results of all the mixes tested up to 28 days are presented in Figure 1.0. From the results, the average density of 10% PFRFC decrease compared to 5% PFRFC average density, and 15% PFRFC average density is lower than 10% PFRFC average density. It shows that as higher paper fiber percentage become lower density it has. But contrarily, 20% PFRFC density is increase and got the highest density compared to others.

This situation could be affect by the water content that absorbed by the higher paper fiber percentage. The excessive paper fiber that absorbed the water while mixing it might be kept in the specimen. The water, which absorbed in the specimen, was not dried, and it causes the higher density in the specimen.

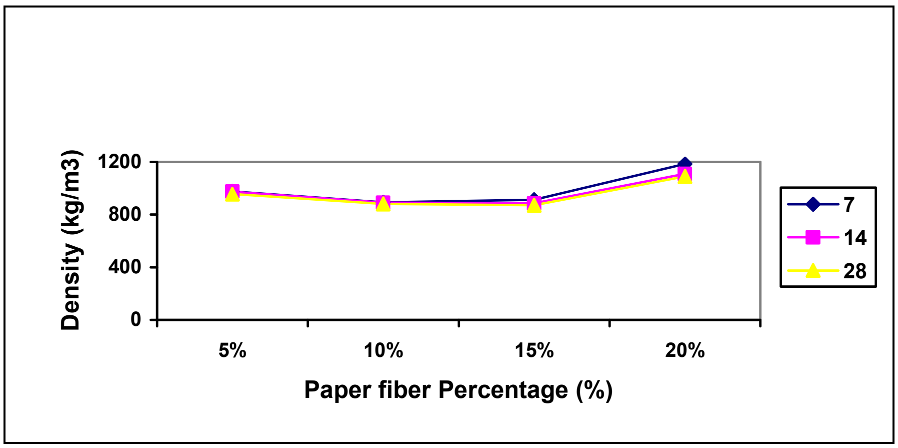

Figure 1.0. : Density with paper fiber percentage of the Paper Fiber Reinforced Foam Concrete (PFRFC).

4.2 Ultrasonic pulse velocity

For ultrasonic pulse velocity measurement, a direct method using a portable ultrasonic non-destructive indicating test (PUNDIT) instrument was adopted in accordance with the British Standard BS 1881 : part 203:1986. The pulse velocity of a foam concrete material depends on its density and the elastic properties of the foam concrete. It is indicative of the quality of the material which relates to the development of its microstructure, denseness and also the presence of internal microcracking. The pulse velocity in foam concrete also depends on the path length, the lateral dimensions of the specimens tested, the presence of reinforcement as well as the moisture conditions of the test specimens. In general, the velocity is increased moisture content.

The result is presented in Figure 2.0. From the test resulted, value of pulse velocity progressive lower along with the increasing percentage of the paper fiber. Value of pulse velocity for 5% PFRFC, 10% PFRFC and 15% PFRFC downward progressively this indicate that over more increase structure fiber of specimen with time not uniform. Inhomogeneous structure can be interpreted there is a lot of air space in specimen and it is expected will decrease as lower as compressive strength.

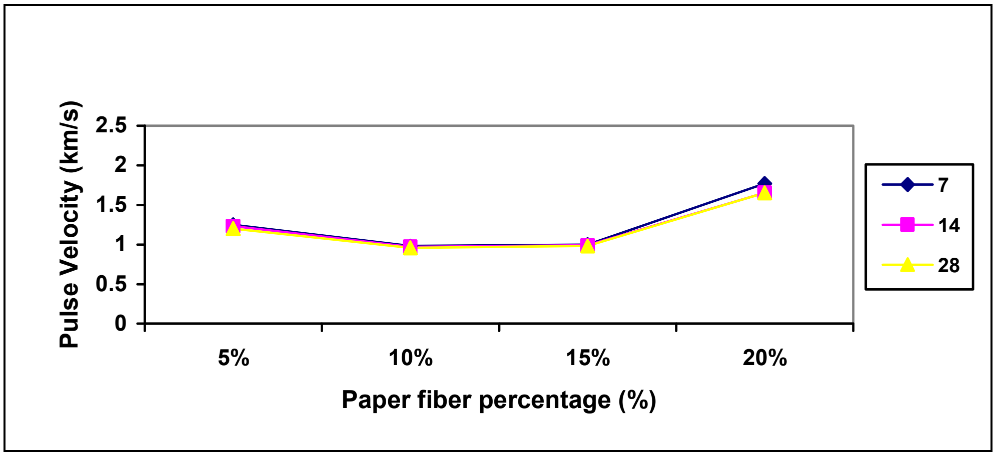

Figure 2.0 : Pulse velocity with paper fiber percentage of the Paper Fiber Reinforced Foam Concrete (PFRFC).

The value of pulse velocity with fiber percentage, 20% for PFRFC showed increase than the value of pulse velocity of 5% PFRFC, 10% PFRFC and 15% PFRFC. This situation affected by admixtures, which have been added in mixture with 20% fiber percentage. Adding superplasticizer has controlled water content to reach the workability or achieve the target slump of foam concrete.

4.3.1 Compressive Strength

The compressive strength of the specimens was determined from method specified in BS 1881 : Part 119 : 1983. The compressive strength results of all the mixes tested up to 28 days are presented in Figure 3.0. From the results, the compressive strength development of paper fiber reinforced foam concrete (PFRFC) was not great enhanced.

The result of Figure 3.0, confirm that PFRFC with 5% paper fiber percentage has generally lower compressive strength compared to the PFRFC with 10% paper fiber percentage. However, the PFRFC with 15% paper fiber percentage has lower compressive strength compared to the PFRFC with 10% and 20% paper fiber percentage.

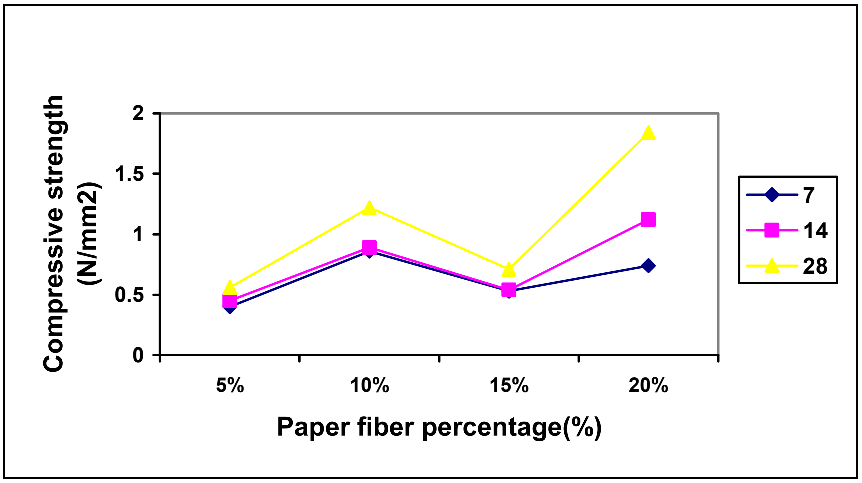

Figure 3.0 : Compressive strength with paper fiber percentage of the Paper Fiber Reinforced Foam Concrete (PFRFC).

4.4 Flexural Strength

The flexural strength is carried out in accordance with British Standard BS 1881 : Part 118 : 1983 "Method of determination of flexural strength". This research is used to compare the result of Paper Fiber Reinforced Foam Concrete (PFRFC) using 5%, 10%, 15% and 20% paper fibers respectively.

The result is presented in Figure 4.0 expected; the flexural strength was strongly affected by w/c ratio. Our mix design reached 0.8 N/mm² at 28 days by 20% PFRFC. The average increment of flexural strength for 5%, 10%, 15% and 20% PFRFC within 14 days increased about 12% compared to day 7. The average increment of flexural strength for 5%, 10%, 15% and 20% PFRFC within 28 days increased about 17.5% compared to day 14.

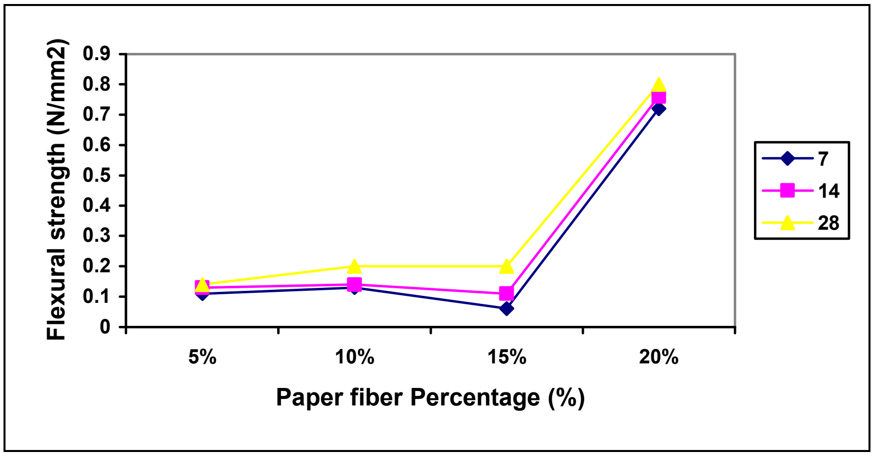

Figure 4.0 : . Flexural strength with paper fiber percentage of the Paper Fiber Reinforced Foam Concrete (PFRFC).

The strength of flexural circumstance is almost equivalent to the compression strength fluctuation result. Which is 10% PFRFC flexural strength progressively increase compacted to 5% PFRFC flexural strength, contradictory for 15% PFRFC strength because it being decreased from the 10% PFRFC, and continuously much differ improvement for 20% PFRFC flexural strength.

The uniformity of paper fiber distribution in the mixture could be affect the flexural strength, improper distribution of paper fiber can caused the flexural strength of specimen was not same for every part or length of the specimen. The good distribution of paper fiber may not exist in the specimen due to lack of proper sampling method and the paper fiber could be crumples and heap in the mixture or specimen.

4.5 Carbonation

The durability of the hardened concrete was to be assessed through external exposure of the prism after flexural test is conducted. Although this will provide reliable results, the durability performance (or any deterioration) has to be monitored over a long period. Since the length of exposure at this is evaluated from 7 to 28 days only it is still too early to obtain a meaningful evaluation of durability. Assessment of extent of the carbonation carried out at this stage is only intended to serve as a starting point for further monitoring. With respect to durability, the importance of carbonation lies in the fact that it reduces the pH value of the pore solution in hardened Portland cement paste. The reduction of pH value to critical value can result in depassivation of the protective oxide film on the steel and thus the initiation of corrosion. In this study, the measurement of carbonation was determined using the common phenolphthalein test.

Based on the comparison of carbonation test, the percentage of paper fiber in foam concrete influencing the carbonation attack. The differences can be seen from the figure of carbonation comparison between four types of PFRFC specimen. 5% PFRFC attack the carbonation most and for 20% PFRFC, it did not show aggression of carbonation. From this view we can conclude that higher paper fiber content has better quality of again the carbonation. In other words that the addition of paper fiber in concrete composite is useful to keep away from of carbonation.

Type of Specimen	Carbonation Picture
5% PFRFC	
10% PFRFC	
15% PFRFC	
20% PFRFC	

Figure 5.0 : The comparison of carbonation with paper fiber percentage of the Paper Fiber Reinforced Foam Concrete (PFRFC).

4.6 The Sound Absorption of Wall Panel of Paper Fiber Reinforced Foam Concrete (PFRFC) and Normal Foam Concrete (NFC).

The amount of sound energy absorbed by a material is determined by a standardized test procedure ASTM C423-90a : Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method. The amount of absorption is expressed as the ratio of the sound energy absorbed to the sound energy incident to the barrier surface.

The equipment for sound insulation test was using Sound Level Meter. There were two methods in testing sound insulation.

Test Type		PFPRFC Panel (dB)	Normal FC Panel (dB)
Indoor test	Test 1 (80-90 dB)	73	75
	Test 1 (70-80 dB)	69.2	70.2
Outdoor test	Test 3 (80-90 dB)	68.9	72.3
	Test 4 (70-80 dB)	57.2	63

Table 2.0 : Average Result For Data Collection Of Wall Panel Performance For Internal Environment (dB)

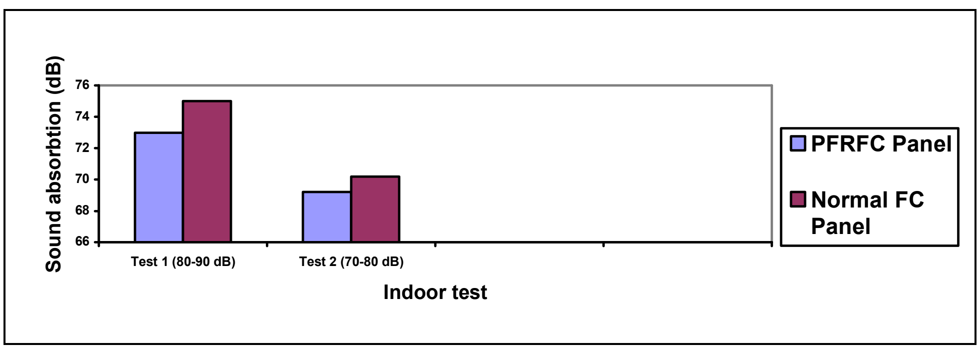

Figure 5.0 : Comparison of sound absorbance of PFRFC panel and normal FC panel (Indoor Test)

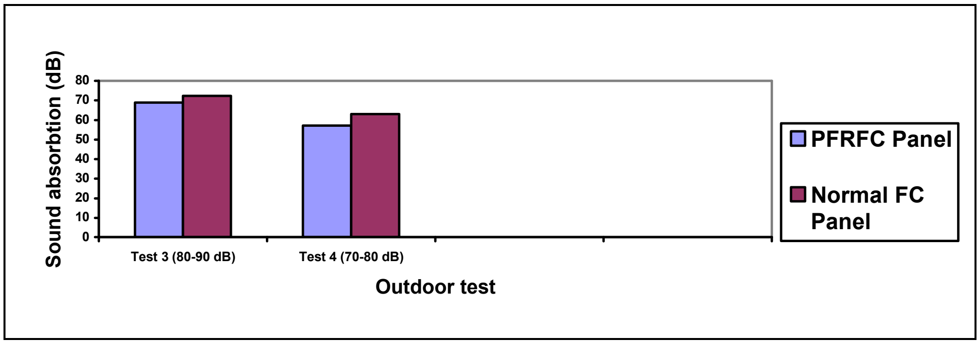

Figure 6.0 : Comparison of sound absorbance of PFRFC panel and normal FC panel (Outdoor Test)

From the Table 2.0, it could be seen that the highest noise absorption is PFRFC panel wall with the average data reading is 67.1 dB, compared to the highest noise absorption of Normal PC panel is got the average data reading is 70.1 dB. This shows that the Normal PC panel has the lower noise diffusing ability, and the panel with paper fiber has the higher noise diffusing ability. Within normal FC panel, the noise is not diffused to the entire surface, and the reading on noise level meter located in front of the wall panel is high.

For both the indoor and outdoor noise absorption test, the PFRFC panel could absorb more noise compared to Normal FC panel, for all four specified noise they are 70-80 dB and 80-90 dB inside the room, and 70-80 dB and 80-90 dB outside the room. This shows that paper fiber has a good ability to diffuse noise. The sound or noise absorption or insulation could be influencing by many other and general factor, for example is effect of wind, temperature, material of room, humidity and air flow.

Paper Fiber Reinforced Foam Concrete has recently been demonstrated to have the potential to reduce the noise that is generated in PFRFC panel. PFRFC is proportioned by gap grading aggregates to develop and interconnected network of pores. This paper investigates the influence of recycle paper fibers on the acoustic absorption of PFRFC. It was observed that addition of fiber reinforcement does not significantly influence the total pore volume of the system; however the acoustic absorption is improved. The improvement in acoustic absorption due to the addition of fiber reinforcement is most prominent in mixtures with larger pore sizes. It is believed that, in these mixtures, the fibers partition the pores. The addition of recycle paper fibers significantly altered the pore connectivity factor, which describes its influence on acoustic absorption.

4.7 The Flexural Strength of Wall Panel of Paper Fiber Reinforced Foam Concrete (PFRFC) and Normal Foam Concrete (NFC).

This testing result was comparison between Paper Fiber Reinforced Foam Concrete (PFRFC) wall panel and Normal Foam Concrete (NFC) wall panel. Both of wall panel were reinforced by the wire mesh and was tested based on BS 5669.

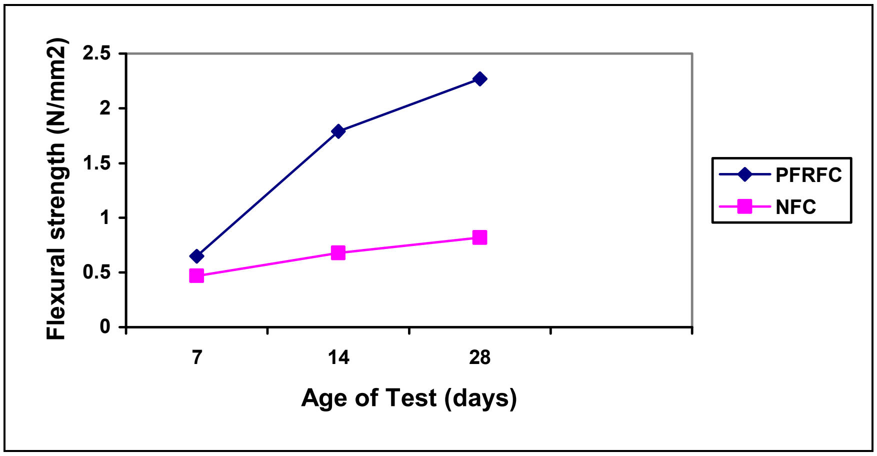

Figure 7.0 : Comparison of flexural strength of the Paper Fiber Reinforced Foam Concrete (PFRFC) wall panel and Normal Foam Concrete (NFC) Panel Wall

All of panel was cured by air for 7, 14, and 28 days. The flexural strength progressively increases according to the days of curing. The PFRFC wall panel is higher in breaking load compared to NFC wall panel. Both of panel, which is reinforced by the wire mesh as the structure. The result of panel flexural test which done for 7, 14, and 28 day test respectively. Based on Figure 7.0, the flexural strength of Paper Fiber Reinforced Foam Concrete (PFRFC) wall panel is higher than Normal Foam Concrete (NFC) wall panel.

5.0 CONCLUSIONS

Various sampling and testing of specimen and identified collected data have been discussed with a purpose to carry objective attainment of this research of study. Marginally the paper fiber provides a lot of benefit to increase the strength of concrete mixture, as new material for the concrete or cement composite to go along with economical construction material, and other excellence competent to be exploited accurately.

From the test, results and the analysis of the experimental work carried out in the study the following are the main conclusions and recommendations:

1. Waste paper is suitable to reinforce foam concrete in term of flexural strength and noise absorption, but it not appropriate for foam concrete caused by increasing the density. The best percentage of Paper Fiber is 10 % of mix volume, because without any admixtures it could achieve the strength almost similar to the strength of 20% PFRFC that have been added by admixtures. Paper Fiber has very high ability in absorption of water. However it absorption ability give the other advantages in absorbing noise.
2. Paper can work along with ordinary mortar or concrete, but paper does not react with foam concrete properly. In the early of moist, paper absorb a lot of water and it would disturb mortar workability because target slump test result must be achieved. Waste Paper Fiber Reinforced Foamed Concrete has lower compression strength and fracture toughness compared to normal foamed concrete without any fiber.
3. Flexural behavior of Paper Fiber is much better compared to plain concrete whether in term of ultimate load, deflection, steel strain, and concrete strain. The paper fiber roles is to reduce the density of specimen, it should not mix together with the high ratio of sand, because the sand can cause the higher density.
4. Water absorbance ability of paper fiber can cause the higher weight if it does not cured properly, the Paper Fiber reinforcement foam concrete should be cured until it dried. Paper Fiber effective to be applied in foam concrete paneling wall system. The present study has explored the possibilities of using paper fiber for lightweight concrete (Foam Concrete) as the reinforcement to be used as wall panel.

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