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The Performance of Bamboo Fiber as Fine Aggregate Replacement in Concrete

Hamidun Mohd Noh[1*], Nur Atiqah Mohamad[1], Nur'ain Idris[2], Narimah Kasim[1], Rozlin Zainal[1], Sharifah Meryam Shareh Musa[1]

[1]Faculty of Technology Management and Business,
Universiti Tun Hussein Onn Malaysia (UTHM), Parit Raja, 86400, MALAYSIA

[2]Centre of Diploma Studies,
Universiti Tun Hussein Onn Malaysia (UTHM), Hub Pendidikan Pagoh, 84600, MALAYSIA

*Corresponding Author

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Abstract: The rapid growth of construction industry has caused a huge demand on natural aggregate as the production of concrete requires massive use of natural stone materials. Due to the increase of demand of this material, it has affected to the shortage of natural aggregate and increased the cost of construction material. On the other hand, bamboo is one of the materials which have a big population and potential to be used in construction due to its durability, flexibility and strength performance. So, bamboo fiber was used as aggregate replacement material to reduce the cost of construction material and pollution as well as to improve the quality of the concrete. The research objectives in this study are to determine the optimum percentage of bamboo fiber as aggregate replacement in concrete and to compare the compressive strength of the bamboo fiber concrete with standard concrete. There were 4 cube specimens casted for each proportion of 0%, 5%, 12.5%, 10%, 12.5%, 15% and 17.5% of bamboo fiber as aggregate replacement in concrete. Then, the compressive strength test was conducted to find the optimum bamboo fiber contents with the maximum workability and strength of the concrete. The findings showed that the replacement of 5% of bamboo fiber achieved the highest strength with 27.77 N/mm2 and the strength decrement difference is only about 2.38% with standard concrete. Based from the result, the 5% bamboo fiber concrete can be suggested as the optimum percentage of bamboo fiber as aggregate replacement in concrete. This study is not only aim in reducing the cost of construction material but it also can be one of the effectives ways to reduce environmental impact by using natural fibers as aggregates replacement.

Keywords: Bamboo fiber, fine aggregate replacement, concrete

*Corresponding author: hamidun@uthm.edu.my

1. Introduction

Nowadays, bamboo is one of the natural resources which have a big population in Malaysia. There are many advantages of bamboo which have multipurpose of uses include sources of food, traditional and also as a structural member in a building. According to [1], all of the bamboo parts which consists of top-discarded, middle and basal part can be used in producing end-products in manufacturing industry. In fact, the use of bamboo has become familiar since it has been used in 1980's as scaffolding in construction.

Then, bamboo has been used as structural material at construction sites in China, India, Malaysia and other countries, because it is sturdy and affordable [2]. Due to that, the use of bamboo as a structural material has been gaining considerable attention. The use of sustainable material in each and every aspect has been emphasized a lot by the society, especially in the construction industry. This is particularly significant since the construction industry is considered to be one of the key industries contributing to the global emission of carbon dioxide. As a result, sustainable building materials are often invented to replace traditional construction materials.

In construction industry, cost is one of the main criteria for materials selection. In recent years, the used of bamboo in construction has gained a lot of attention due to its high productivity rate and short harvest period compared to other naturally growing resources [3]. In fact, bamboo can be categorized as an economic building material due to the availableness and can be considered as sufficient material that can replace steel and wood since it has becoming reliable structure material with low cost production.

In addition, the high tensile strength and excellent weight-to-strength ratio of bamboo are the prominent characteristics that should be considered as possible building materials. The excellent weight to strength ratio has allowed it to be used against dynamic forces produced by earthquakes and high- speed winds as a highly durable material [4]. Furthermore, it is able to withstand up to 3656kg/cm2 of pressure with these characteristic features.

1.1 Research Background

Gigantochloa Albocilliata or Buluh Madu is one of the types of bamboo that being harvested widely in Malaysia. In fact, this type of bamboo is known as one of the sources of food due to it shoots by the locals. According to [5], Gigantochloa Albocilliata bamboo species has strong physical and mechanical properties as building materials in housing construction. This type of bamboo can be used as one of the housing components that can replace the timber due to their culm form and the bending properties.

Besides, the continuous development of the construction industry will be challenging in ensuring the survival of natural aggregates in the future. This fact was addressed by [1], who highlighted that natural resources decrease as the demand for aggregate to be used in concrete production increases. The high demand for natural resources in developed countries due to rapid urbanization and the issue of agricultural waste disposal has provided opportunities for the use of bamboo in the construction industry. As a result, bamboo has been the focus of research in recent years.

Then based on previous research, [6] has stated that bamboo fibers can be used in concrete as revolutionary fibers to improve concrete strength, enhance concrete ductility and post- cracking load carrying ability. It showed that in the early age of curing itself, the control of concrete specimens became highly distinct. Meanwhile, [7] reported that bamboo can be used as replacement of aggregates which showed that the strength of concrete increased after 7 days of curing up to 56 days. From this research, it enhances the potential of bamboo fiber as building material can be used in construction industry.

Meanwhile, as substitute alternatives for cement, fine aggregate, coarse aggregate and reinforcing materials, many agricultural waste materials are already used in concrete. Therefore, there were some researchers have studied the potential of wastes as aggregate replacement in concrete such as sugarcane bagasse ash [8], rice husk ash [9] and, sawdust [10].

1.2 Problem Statements

The demand on construction materials keep on increasing from years to years. These materials such as fine aggregates and coarse aggregates are very important in construction which the effect of the insufficient or lack of these construction materials can cause a huge problem in construction industry. According to [11], the shortage of building materials has raised the cost of construction, and thus, the responsibility was passed to the end users. Although the availability of natural aggregates has been projected to be sufficient for growth in the next few years, if no control measures are to be enforced, aggressive consumption would reduce non-renewable aggregate resources.

Then, the rapid growth of construction industry has made it as one of the prime sectors which can contribute to water and air pollution especially in developing countries. At present, this environmental issue is growing as one of the key challenges affecting concrete development. A main concern is the consumption of aggregate as the largest component material, since it constitutes 3/4 of the concrete ingredient. The high demand of aggregate for concrete production needs a massive use of natural stone materials which will disrupt the environmental balance due to the quarry activities that have caused pollution [11].

Furthermore, the application of bamboo as sustainable material in the building has gained a lot of interest in construction industry. This is due to the advantages of bamboo properties which can be used as building materials which are known for its low cost, low density, ecologically friendly, sustainable and biodegradable resources [12]. In addition, bamboo's mechanical properties are equal to or even better than wood.

In this study, bamboo fiber will be used as aggregates replacement material to reduce the cost of construction material and pollution as well as to improve the quality of the concrete. The reason of choosing bamboo fiber other than natural fibers due to bamboo has many benefits. Therefore, the replacement of bamboo fiber in fine aggregate proportion will help to reduce the problem above.

Literature Review

2.1 Bamboo Fiber

Bamboo fiber is the natural fiber that are extracted from the bamboo tree. These fibers are focused as substitute in replacing natural fibers since they have many advantages, such as low cost, low density, ecologically friendly, renewable and biodegradable resources [13]. Bamboo is one of the abundant natural resources in polymer composites that is highly competitive with natural reinforcement. Bamboo's mechanical properties are equal to or even stronger than timber. Bamboo also has high mechanical properties as sound absorbing material. [14] has reported bamboo fibers materials have acoustical properties that is similar to glass wool which is a good sound absorber. From this research, it enhances the potential of using bamboo fiber also can improve sound insulation of concrete.

2.2 Waste Management of Bamboo

In Malaysia, bamboo is one of the natural resources that are found in abundance and allocates widely in the forest. Due to that, there is a lot of bamboo factory composed waste by converting bamboo into ash, the active carbon from the burning process has been released. The carbonization process and steam activation in a high temperature reactor has produced the activated carbon from bamboo residues [15]. This method is seen as one of the potential options for minimizing the amount of waste in the landfill and turning it into an adsorbent for the treatment of waste water or other applications [2]. This shows that, by reusing the waste in construction industry is more preferable since it can reduce pollution and also cost saving instead of burning them.

2.3 Advantages of Bamboo

In developing countries, bamboo has great economic potential because it can be replenished in a very short time. It is also known as an environmentally-friendly material for building since the cost of bamboo as an economical material is lower than other building materials, such as steel. It also has comparable strength and less energy is required for harvesting and transporting bamboos. Thus, the cost of manufacturing the bamboos will be much lower compared to steel. It has been proven that bamboo has a high tensile strength. According to [4], bamboo is claimed to have a tensile strength of about 193 MPa, which for mild steel is on par with a tensile strength of 159 MPa. This desirable performance of bamboo has enabled it to be entitled as "green steel". Bamboo is also known as an excellent carbon sequestration agent since it can sequester up to 12 tons of carbon dioxide (CO2) per hectare [16]. Moreover, it also produces about 35 percent more oxygen which is equivalent to trees. From this, it is assumed that bamboo can play a role in mitigating and protecting the environment from climate change.

2.4 Waste Material as Aggregate Replacement in Concrete

(a) Sugarcane bagasse ash

The waste from sugarcane after the juice extraction process is called sugarcane bagasse. The process of crushing and extracting the juice from sugarcane has left the fibrous residue that is known as bagasse (Loh et al., 2013). This bagasse can cause problem to the environment due to direct disposal on the open lands and form garbage heaps in the area [17]. The waste from sugarcane can be an alternative way which is suitable as renewable material in construction. The sugarcane bagasse ash that can be obtained from the burning of sugarcane bagasse can be used as aggregate replacement in concrete. [8] studied the utilization of bagasse ash as a partial replacement of fine aggregate in concrete. The sugarcane bagasse ash was used as fine aggregate at various replacement ratios with 0%, 10%, 20%, 30% and 40%. The results of this research showed that the optimum replacement ratio for aggregate at 10% which increased the compressive strength of concrete (G20, 22 MPa), (G25, 36 MPa) and (G30, 33 MPa) after 28 days.

(b) Rice husk ash

In Malaysia, rice is the main source of food because most of people eat rice. There are many factories that manufactured paddy to produce rice for market growth. Rice husk is agricultural waste that obtained from the rice grains during the processing procedure. According to [18], the rice husk is a waste material that has no useful application which can cause pollution to the environment. [9] studied the properties of autoclaved aerated concrete with rice husk ash as a partial substitute for fine aggregate. The rice husk ash (RHA) was used at different replacement ratios as an aggregate. This study was focused on the use of rice husk ash (RHA) as fine aggregate to replace sand as it was readily available agricultural by-product. RHA replacement ratio for fine aggregate used was 75% and 100%. The optimum percentage of the fine aggregate replacement from this study was 75% of rice husk ash (RHA) with a high compressive strength (7.50 MPa).

(c) Sawdust

Sawdust is composed of small chippings woods which is known as the main component in the particleboard. It has been used in various of practical applications, such as acting as mulch, an alternative to or as a fuel for clay cat litter. According to [19] , the flammability reaction from the sawdust can be dangerous and this has made it one of the hazardous materials in manufacturing industry. In the past few years, the use of sawdust in making lightweight concrete has gained some attention due to reduce the dumping problem and become as alternative renewable material to control the preservation of natural aggregate. [10] studied the use of sawdust as fine aggregate in concrete mixtures. Sawdust was used at different replacement ratios as fine aggregate of 10%, 20%, 50% and 100%. The results of this research showed that the optimum replacement ratio for aggregate at 10% has increased the strength of concrete that containing sawdust.

2.5 Previous Research on the use of Bamboo in Concrete

[6] studied the effectiveness of bamboo fiber in concrete as a strength enhancer. The bamboo ratio used was 0%, 0.5%, 0.75%, 1% and 1.25%. The result shows that, 1% is the optimum fiber content. The maximum improvement of compressive strength and split tensile strength in 28 days was 41 N/mm2 and 4.8 N/mm2. The bamboo fibers addition makes the concrete very resistive in flexure and the maximum improvement of flexural strength was 7.5 N/mm2 after 28 days. In this study, it showed that the workability of fresh concrete was found to reduce with an increase in the fiber content up to 1.25%.

[7] studied on the self-compacting concrete, bamboo as a replacement of aggregates. The bamboo ratio used was 0%, 2%, 4% and 5%. The result shows that 2% is the optimum percentage for the concrete since it has the highest compressive strength in 7 days (14.9 N/mm2), 28 days (28.88 N/mm2) and 56 days (33.41 N/mm2) and the highest flexural strength for 28 days (4.18 MPa) and 56 days (5.17 MPa). In this study, it showed that the workability of concrete is not improved as the bamboo pieces increase. The compressive strength and flexural strength of concrete also decreased when the content of bamboo pieces is up to 5%

3.0 Research Methodology

This chapter explains the method that used which covers the framework, the preparation of experiments, the concrete test, and therefore based on observation the result is carried out.

3.1 Research Framework

Based on the Figure 1 shows the flow of the laboratory work process. The process starts with material preparation, followed by concrete mix design, concrete mix process which includes slump test and curing process and the experimental test of compressive strength test. The final step in the process is collecting data and data analyzing.

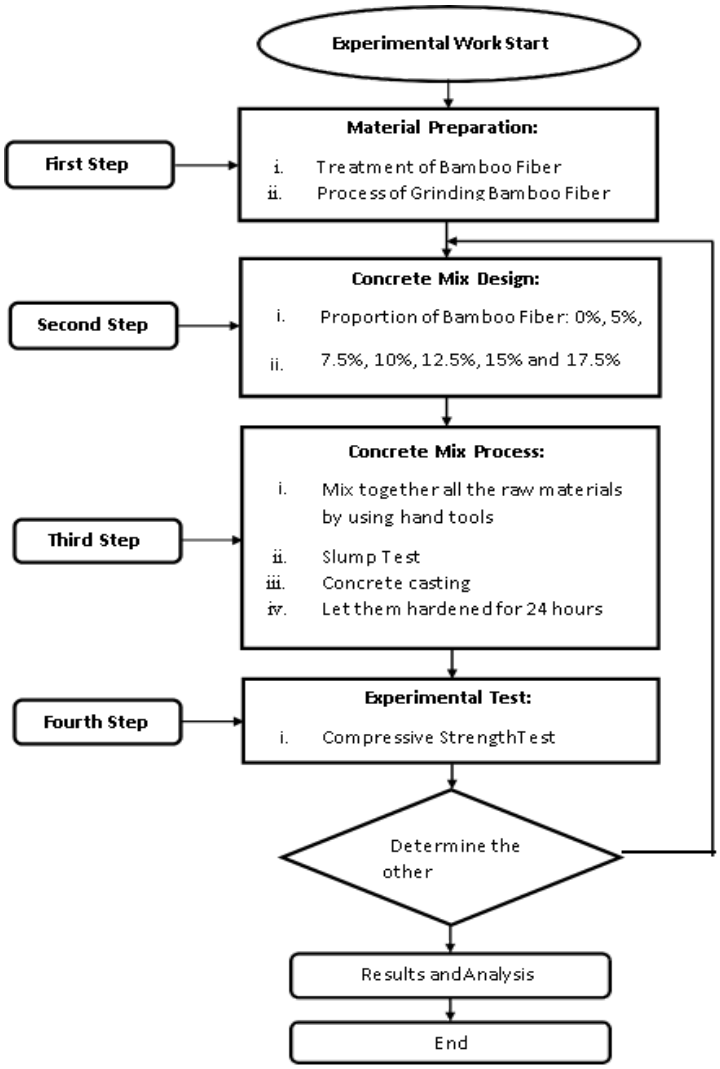
3.2 Experimental Setup

(a) Specimen Details

This research requires a production of some specimens before conducting the laboratory test on the concrete cube. The pilot test is also carried out to determine the proportion of bamboo fiber to be mixed along with the concrete. Therefore, all the materials and equipment has been prepared and ready according to the needs of the research. Based on the Figure 2 below, it shows the size of concrete cube specimen used was 100mm x 100mm x 100mm (length x height x width).

(b) Material Preparation

The material that will be used in this experiment is the bamboo fiber, fine and coarse aggregates, cement and water. The mixture will be mix with the mix ratio of 1:1.5:3 of Grade 20.



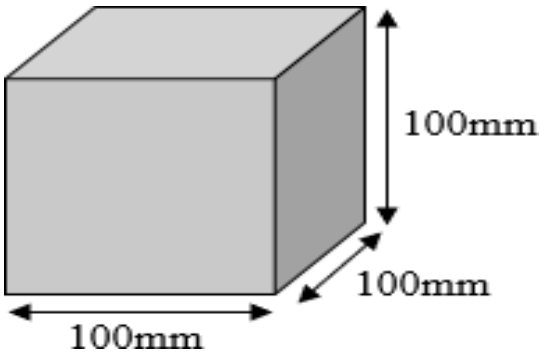
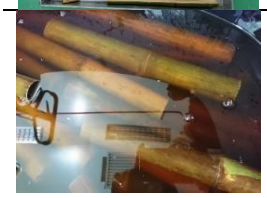


Fig. 2 - Sample of cube

Below in Table 1 and Table 2 are the processes involved in the material preparation of bamboo fiber as fine aggregate replacement.

Table 1 - Treatment of bamboo fiber process

Figure	Description
	a) Bamboo was collected at Parit Raja, Johor. The type of bamboo used is known as "*Buluh Madu*" or in the scientific name is known as "*Gigantochloa Albocilliata*".
	b) The bamboo was cleaned to make sure it was free from debris and impurities.
	c) The bamboo was dried under the sunlight and was cut into half pieces.
	d) Then, the bamboo was treated into borax solution until the water in the tank turned into dark.
	e) After that, the bamboo was dried in the oven at 250°C for 60 minutes to make sure that all of the bamboos were totally dried before went through grinding process.

a. Process of Grinding Bamboo Fiber

Table 2 - Process of grinding bamboo fiber

Figure	Description
	f) All of the bamboo pieces were put into the grinding machine to be grinded until they became small fibers.
	g) Sieve analysis was conducted to bamboo fiber in this process in order to get the right aggregate according to the size.

	h) After the sieve process, the bamboo fibers were ready to use for fine aggregate replacement.

(c) Concrete Mix Design

The concrete mix design used in this study is normal concrete with Grade 20 (ratio 1:1.5:3). The proportion of bamboo fiber that has been determined after pilot study were (0%, 5%, 7.5%, 10%, 12.5%, 15% and 17.5%). Each concrete cube measurements were 100mm x 100mm x 100mm (length x height x width) that went through curing process.

(d) Formwork Design/Casting

The mold was prepared with the measurement of cube was 100mm x 100mm x 100 mm. 28 samples of bamboo concrete cubes were casted. The formwork casting was made to show the compressive strength (at 7 and 28 days) respectively.

Table 4 - Concrete mixing process

Figure	Description
	a) Cement, sand, gravel and bamboo were put into the pan after being weighted on scale along with the water.
	b) All of the materials were mixed together according to concrete mix design. Water was added based on the required amount.
	c) Before casted the concrete into the mold, it is required that the concrete undergo a slump test to check on concrete's consistency.
	d) After that, all the mixed materials were poured into the cube mold in 3 layers. Each of the layer were compacted using steel rod with 25 strokes to make sure that the cube mold was filled.
	e) Then, the concrete cubes were left for 24 hours at room temperature to harden.

3.2 Slump Test

The slump test is an evaluation of fresh concrete's consistency before it hardens. It is used indirectly to verify that the right quantity of water has been applied to the mixture and to carry out an analytical test testing the workability of fresh concrete in compliance with BS EN 12350-2: 2009.

3.3 Curing Process

Curing process has a strong impact on the properties of hardened concrete, proper curing enhances toughness, strength, water tightness, resistance to abrasion, stability of volume, and resistance to freezing and thawing, which affects the time of curing on concrete strength gain. This process is carried out according to BS 8110-1:1997, Structural use of concrete - Part 1: Code of practice for design and construction. The concrete cubes were left at room temperature for curing process by using air for 7 and 28 days in order to increase the strength of the concrete.

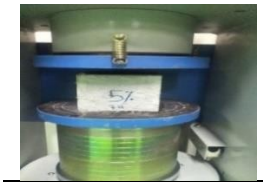
Fig. 3 - Concrete curing process

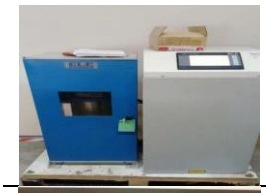
3.4 Experimental Test

(a) Compressive Strength Test

The compressive strength test is conducted to determine the compressive strength of the concrete. It has been conducted after 7 days and 28 days period of curing. Compressive strength test following the BS EN 12390-3 and the process shown in Table 5 below.

Table 5 - Compressive strength test process

Figure	Description
	a) Placed the specimens on trolley after specified curing time.
	b) Next, placed the specimens on the compression plate. Make sure that the position of the specimen at the center of the plate.
	c) Then, set the machine setting according to required dimension of the specimen with 100mm x 100mm x 100mm (length x height x width).

	d) Before run the test specimen, the door must be closed to avoid any unintentional injuries. Press run button and concrete started being compressed.
	e) Then, the concrete has been crushed after being compressed by the load.
	f) After the test done, data has showed and being recorded.

4 Results and Discussion

4.1 The physical properties of the concrete are usually determined by carrying out test on samples. All testing procedures were conducted according to the methodology mentioned in the previous chapter, where all the experimental work has been done. The data obtained from the experiment conducted will be analyzed in this chapter. Data analysis include the compression strength test of concrete cube.

4.2 Results

The concrete cube was tested using the compression strength test machine at the FPTP Laboratory. From there, the compression test data was collected and it becomes the indicator for this experiment in order to get the correct and suitable composition of bamboo fiber to be mixed along with theconcrete.

(a) Compressive Strength of Concrete for 7 days curing

The Figure 4 below shows the compressive strength of concrete for 7 days curing.

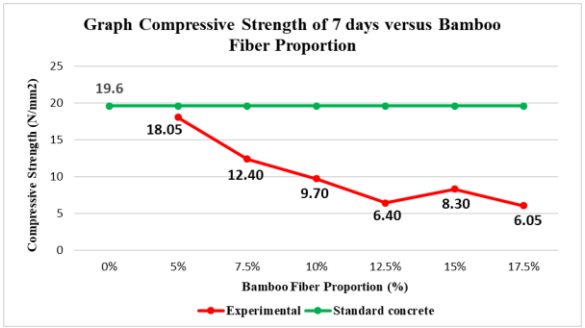


Fig. 4 - Graph compressive strength of 7 days versus bamboo fiber proportion

Based on the Figure 4.1 above, the graph shows that the compressive strength versus bamboo fiber proportion for 7 days curing, there are seven (7) proportions of bamboo fiber replacement in concrete mixture include the 0% proportion for standard concrete. The result shows that the quantity of bamboo fiber in the concrete mixture influence the compressive strength of the concrete. The result for cube with proportion 5% shows that the average value is 18.05 N/mm^2. Meanwhile, the graph decreased at 7.5% where the proportion achieved compressive strength at average of 12.4 N/mm^2. The graph fell down after third composition, which is 10%, achieved compressive strength at average of 9.7 N/mm^2. Then, the graph dropped at 12.5% with 6.4 N/mm^2 of average compressive

strength. Later, the graph shows a slightly increase result at 15%, which the compressive strength achieved the average of 8.3 N/mm^2. Last but not least, the graph again decreased at 17.5% with 6.05 N/mm^2 of average compressive strength.

(b) Prediction of Compressive Strength for 28 days curing

The figure 5 below shows the prediction result of compressive strength of concrete after 28 days curing.

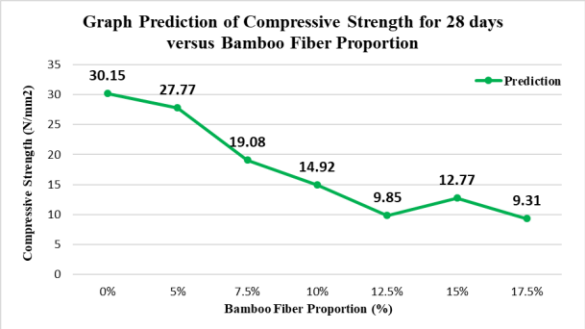


Fig. 5 - Graph Prediction of Compressive Strength for 28 days versus Bamboo Fiber Proportion

Based on the Figure 5 above, the graph shows that the prediction of compressive strength of 28 days versus bamboo fiber proportion, there are seven (7) proportions of bamboo fiber replacement in concrete mixture include the 0% proportion for standard concrete. The result shows that the quantity of bamboo fiber in the concrete mixture, influence the compressive strength of the concrete. The result for cube with proportion 5% shows that the average value is 27.77 N/mm^2. Meanwhile, the graph decreased at 7.5% where the proportion achieved compressive strength at average of 19.08 N/mm^2. The graph fell down after third proportion, which is 10%, achieved compressive strength at average of 14.92 N/mm^2. Then, the graph decreased at 12.5% with 9.85 N/mm^2 of average compressive strength. Later, the graph shows a slightly increased result at 15%, which the compressive strength achieved the average of 12.77 N/mm^2. However, the graph again dropped at 17.5% with 9.31 N/mm^2 of average compressive strength. This result has been obtained based on the percentage strength of concrete at various ages accordance to ASTM C918 / C918M Standard Test Method for Measuring Early-Age Compressive Strength Test and Projecting Later-Age Strength.

(c) Comparison Strength of Bamboo Fiber Concrete between 7 days and 28 days (Prediction)

The comparison at Figure 6 below shows that there is a difference between the average of compressive strength of bamboo fiber concrete between 7 days and 28 days (prediction).

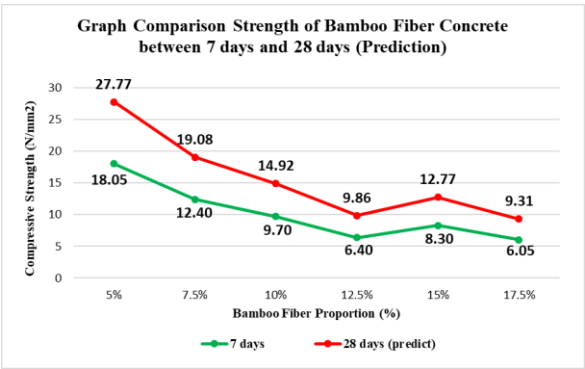


Fig. 6 - Graph comparison strength of bamboo fiber concrete between 7 days and 28 days (Prediction)

Based on the illustration above in the figure 6, the graph represents comparison strength of bamboo fiber concrete after 7 days and 28 days (prediction) of curing. X-axis shows the percentage of bamboo fiber was replaced while y-axis shows the average compressive strength of concrete wall panel. From the graph, the differences of their

compressive strength after undergo the period of curing process can be clearly seen. The average compressive strength of concrete was gradually increased when the specimens reach the curing age from 7 to 28 days.

The average compressive strength of concrete among seven (7) proportions show an increasement after 7 days to 28 days of curing. Based on the graph, it shows that the 5% of bamboo fiber is the highest with the average compressive strength at 18.05 N/mm^2 for 7 days and 27.77 N/mm^2 for 28 days according to the prediction result of 28 days of curing. Meanwhile the proportion 7.5%, 10% and 12.5% of bamboo fiber on the graph indicated a decrease for average compressive strength with 12.4 N/mm^2, 9.7 N/mm^2 and 6.4 N/mm^2 for 7 days and shows the prediction result after 28 days of curing with 19.08 N/mm^2, 14.92 N/mm^2 and 9.86 N/mm^2. However, the proportion 15% of bamboo fiber had initiated a slight increase with 8.30 N/mm^2 for 7 days and 12.77 N/mm^2 for 28 days of average compressive strength prediction result. Then, the graph for the proportion 17.5% of bamboo fiber drastically dropped to 6.05 N/mm^2 at 7 days of curing followed by 9.31 N/mm^2 for the prediction result of average compressive strength after 28 days of curing.

As a result, the workability of the concrete was found to decrease as the bamboo fiber percentage increased. According to [6], bamboo fibers can be used as innovative fibers to improve the strength of the concrete, however the addition of bamboo fiber in concrete can cause the workability of concrete becomes weak when the fibers content percentage is increase.

(d) Comparison Strength between Standard Concrete and Bamboo Fiber Concrete

The comparison at Figure 7 below shows that there is a difference between the average of compressive strength of standard concrete and bamboo fiber concrete.

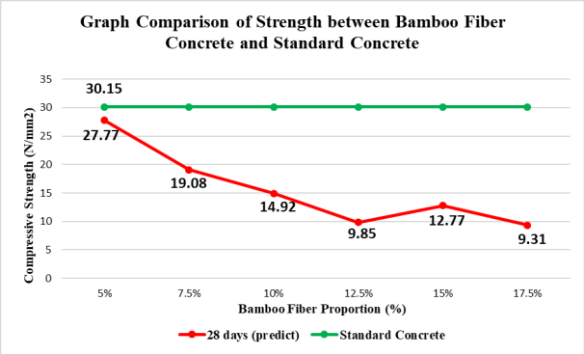


Fig. 7 - Graph comparison of strength between standard concrete and bamboo fiber concrete

Figure 7 above shown a comparison of average compressive strength between standard concrete and bamboo fiber concrete after the 28 days of curing. The relationship between the average compressive strength and bamboo fiber proportion were sketched. Based on the graph, it is clearly shown that the average compressive strength of standard concrete is stronger than bamboo fiber concrete with 30.15 N/mm^2 after 28 days of curing. The highest average compressive strength for bamboo fiber concrete was 5% of bamboo fiber as fine aggregate replacement with 27.77 N/mm^2, while the lowest average compressive strength was from 7.5% with 19.08 N/mm^2, 10% which is 14.92 N/mm^2 to 12.5% with 9.85 N/mm^2, and then at 15% is increasing with 12.77 N/mm^2, before decrease at 17.5% which is 9.31 N/mm^2. However, the highest average compressive strength of bamboo fiber proportion which is 5% with 27.77 N/mm2 are almost to the average compressive strength of standard concrete with 30.15 N/mm2 which the decrement is 2.38%.

This result has showed that the average compressive strength of concrete with 5% is the optimum percentage of bamboo fiber as fine aggregate replacement. Based on the previous study by [8], the percentage of fine aggregate replacement with sugarcane bagasse ash used was 0%, 10%, 20%, 30% and 40%. According to the findings, the concrete's compressive strength decreased after 10% until 40% of sugarcane bagasse ash were added to replace the fine aggregate. This showed that the sand replacement with sugarcane bagasse ash also significantly reduced the concrete strength.

(e) The Strength Reduction of Bamboo Fiber Concrete

The Figure 8 below shows the strength reduction for seven (7) bamboo fiber concrete.

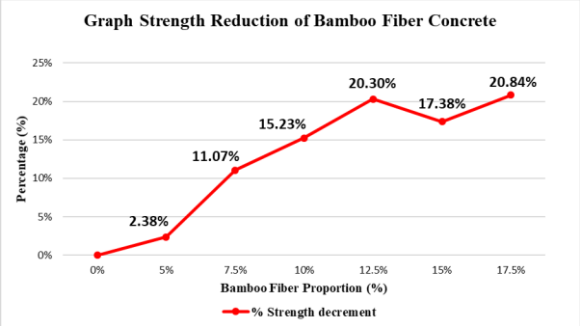


Fig. 8 - Graph strength reduction of bamboo fiber concrete

Based on the Figure 8 above, a graph shown the differences percentage of strength decrement for seven (7) bamboo fiber concrete. The results show that the strength decrement for all of the bamboo fiber concrete is lower compared to standard concrete. It shows that by adding 5% of bamboo fiber in the concrete showed a slightly low strength decrement which is 2.38%. Then, the strength decrement of 7.5% bamboo fiber concrete is 11.07%. Besides, 10% bamboo fiber concrete shows the strength decrement with 15.23%. Meanwhile, 12.5% bamboo fiber concrete has resulted the strength decrement with 20.30%. Furthermore, after added 15% of bamboo fiber in the concrete, the results showed the strength decrement with 17.38%. Although, the 17.5% bamboo fiber concrete has the highest proportion of bamboo fiber but in terms of strength it is low which is 20.84% of strength decrement.

As a result, it is clearly shown that the more the usage of bamboo fiber as a fine aggregate replacement the lower the strength of the concrete. However, the replacement of fine aggregate with bamboo fiber can reduce the cost of fine aggregate production as well as reducing the pollution in order to create a healthy environment in construction industry [20]. Therefore, bamboo fiber seems to have more advantageous in construction industry where the usage of fine aggregate can be reduced and the strength of concrete can be increased with further studies.

4.3 Discussions

Based on the result analysis that was shown in this chapter, it clearly shows that standard concrete shows to have a better performance and able to withstand the load up to 30.15 N/mm^2 before failure mode. Meanwhile, bamboo fiber concrete also shows to an acceptable result. Despite the strength decrement difference is only about 2.38% between 0% and 5% of bamboo fiber, but it has proven that bamboo fiber concrete strength is slightly lower than standard concrete. Based on the observation, the reason for bamboo fiber concrete did not being able to achieve as high as standard concrete is most probably due to the amount of bamboo fiber in concrete. During the process of the research, there are some limitations occurred and recommendations were made for future research.

5 Conclusion

This chapter will describe the summary of the findings, conclusion, limitations and recommendations based on the data was analyzed in the previous chapter. The entire conclusion that will be discuss in this chapter based on the objectives of this research and an observation that was made throughout the research.

5.1 Research Conclusion

Based on the experimental research conducted on bamboo fiber concrete and test result obtained, it can be concluded that the compressive strength with 5% of replacement was the highest compared to other proportion. Hence, 5% of bamboo fiber as fine aggregate replacement is the optimum percentage that achieved the higher strength. Moreover, the 5% bamboo fiber concrete is able to withstand load up to 27.77 N/mm2 while standard concrete able to withstand load for 30.15 N/mm2 while the strength decrement of bamboo fiber concrete of 5% was slightly low with 2.38% compared to standard concrete. This shows that, the standard concrete is better than the bamboo fiber concrete. In fact, the higher the usage of bamboo fiber as fine aggregate replacement, the lower the strength of bamboo fiber concrete.

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