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Preleminary Study on Foam Concrete Infill Bamboo as Construction Materials

Muhamad Azani Yahya and Mohammed Alias Yusof
Faculty of Engineering, University Pertahanan Nasional Malaysia, Kuala Lumpur, Malaysia

Abstract: The modification of building materials from locally available raw materials such as agricultural, forest and industrial wastes can contribute to the solution of environmental issue such as logging. One of the suggested materials to replace the uses of timber as the construction materials is Bamboo. This study, is a preliminary study of Foam Concrete Infill Bamboo (FCIB) as a modification on raw Bamboo with infill using foam concrete to be used as the replacement for timber usage in construction. The study is included compression strength, flexural strength, tensile splitting strength and nailing test of the FCIB and raw Bamboo as the control sample. In the nailing test, the pullout strength of the nail where investigates in order to recognize the usage of nail for joining purposes. The design mix of foam concrete was adopted from the existing research that has an optimum weight to the strength ratio. The density of foam concrete is in the range of 700-1000 kg/m^3. In addition, in this research the failure pattern for each test was being analyzed and discussed. Comparison between control sample and research sample were done in order to know the difference and its sustainability.

Key words: Foam concrete, Bamboo, construction material, comparison, sustainability, optimum

INTRODUCTION

Timber housing and furniture demand increase along with the population growth. Due to the increasing of this construction material, in Malaysia itself more and more forest was cut down to fulfill the need. Coupled with widespread of illegal logging, day by day the sources of this type construction material will become less and cause the severe damage to our forest. To restore forest functions as one component of a secure environmental sustainability, the steps need to be done is to stop the logging of forests and reforestation until the forest back to it's nature condition and achieve balance. However to complete solve this environmental problem, firstly it necessary to find another source or materials to replace timber as a construction material. Efforts are being made to find ways by which indigenous raw materials can be fully utilized to produce building materials. The development of building materials from locally available raw materials such as agricultural, forest and industrial wastes can contribute to the solution of this environmental issue. One of the suitable materials to replace the uses of timber as the construction materials is Bamboo. Bamboo usage as construction material still low and people more reliable on timber or other materials for construction. The reason is some of them were not confident with the ability and strength of alternative natural materials such as Bamboo. Therefore, a modification on Bamboo is needed in order to enhance the strength and quality of Bamboo as a construction material. Besides that, the usage of Bamboo as construction material is also a ways to overcome the environmental issue on logging activities. As is known, the only source of timber is from the forest and due to the increasing of population growth the forest was destroyed for development added to the demand for timber in construction. This situation will affect our forest ecosystem and environment in a long period. Bamboo will be a good alternative material to timber provided it and can serve the same purpose Another problem that people always face when using Bamboo is its joining properties. Nails are commonly used as joint in timber in construction. But unlike timber, raw Bamboo has weak nail pullout strength. Therefore, the use of foam concrete infill Bamboo be one of the solution to make it suitable as construction materials.

Objectives: The research objective will be as follows:

- To investigate the compressive strength, flexural strength and tensile splitting strength of foam concrete infill Bamboo
- To investigate the nail pullout strength of foam concrete infill Bamboo on nailing test

Foam concrete infill Bamboo: Bamboo is one of the oldest building materials used by mankind (Huberman, 1959). Bamboo is also another natural constructional

Corresponding Author: Muhamad Azani Yahya, Faculty of Engineering, University Pertahanan Nasional Malaysia, Kuala Lumpur, Malaysia

material and there are over 1500 different botanical species Bamboos in the world. In general, it is believed that the mechanical properties of Bamboo are likely to be at least similar if not superior to those of structural timber. In some studies there are shows that Bamboo is an ideal and safe structural material for many construction applications. Due of it, many of them have been used traditionally as structural members in low-rise houses, short span foot bridges, long span roofs and construction platforms in countries with plentiful Bamboo resources (Mohmod *et al*., 1990). Bamboo is a fast growing species and a high yield renewable resource. Bamboo growth depends on species but generally all Bamboo matures quickly. Bamboo might have 40-50 stems in one clump which adds 10-20 culms yearly (Abdul-Latif and Mohd Tarmizi, 1992). Bamboo can reach its maximum height in 4-6 months with a daily increment of 15-18 cm (5-7 inches). In Malaysia, there are only 12 types of Bamboo are commercially used for their culms and shoots (Azmy and Abd-Razak, 1991). With the revolution of science and technology and the tight supply of timber, new methods are needed for the processing of Bamboo to make it more durable and more usable in terms of building materials.

There are various physical and mechanical testing was carried out for various species of Bamboo. It proves that Bamboo is strong enough to be used as a building material. In certain mechanical properties, Bamboo even overcomes timber and concrete. However, it is difficult to generalize the properties of Bamboo as it differs with the species, age, climatic factors, moisture content and different heights and diameter of the culm. The density of Bamboo is generally varies from 500-800 kg/m^3 (Mohmod *et al*., 1990). Bamboo also possesses excellent strength properties, especially tensile strength. The moisture content can be defined as the total amount of water contain in the wood cells. Few research stated that age, the season of harvesting and the species is influenced varies moisture content of culms. In additions, the moisture content across the culm wall is higher in the inner part than in the outer part. When determining the yield of Bamboo expressed by its fresh weight differences in the moisture content of freshly felled culms have to be considered (Mohamed *et al*., 1991).

Generally, the specific gravity of Bamboo varies from about 0.5-0.8 g/cm^3. The specific gravity increases along the culm from the bottom to the top and the outer part has a higher specific gravity than the inner part. This is due to the increment of vascular bundles in both the outer layer and top portion of the Bamboo culm. The mechanical properties of Bamboo usually correlated with specific gravity. The specific gravity of the nodes is generally higher than that of the internodes due to less parenchyma whereas bending strength, compression strength and shear strength are lower. This is due to the irregularity of the grain, caused by the arrangement of cells. The presence of nodes, thus leads to a remarkable reduction in all strength properties. Due to no standard methods for evaluating the strength properties of Bamboo as in the case of wood, the results are based on different methods of testing and on widely varying dimensions. The 1 year old Bamboo had the lowest compressive stress with an average of 16.1 MPa. Five year old Bamboo had the highest compressive stress with an average of 34.3 MPa. For the effect of height, the top portion of Bamboo had the highest compressive stress while in the bottom and middle portion there was no significant difference. Because it consists of cellulose fibers that are aligned along its length and provide maximum tensile strength and rigidity in that direction, Bamboo is considered as composite material.

Foam concrete is a cement paste or mortar that classified as lightweight concrete, foam or cellular concrete is made from mixing suitable foaming agent to slurry of cement mortar. This action incorporates small enclosed air bubbles within the mortar (Chung and Yu, 2002). To obtain a wide range of 1600-400 kg/m^3, a proper control in a dosage of foam is needed for application to structural, partition, insulation and filling grades. The term foamed concrete is referred to the majority material of foamed concretes containing only fine sand and no large aggregates with the extremely lightweight foamed materials only cement, water and foamed, so the product should be more accurately described as a foamed mortar. In summary, the foamed concrete can be described as materials that have more than 25% air content which differently from highly air entrained materials. In the making of this concrete, the foam is one of the important ingredients that react as aggregate.

There are many types of foaming agent either synthetic or protein base but the protein base is now being used more often in the production of foam concrete and in terms of stable foam it is the key ingredient in the production of foam concrete. The foam is simply created by a machine called foaming generator which consist process of mixing water and foaming agent chemicals to form stable foam. With consists basically of 95% of air content, the stability of the foam enables it to last through the stages of mixing with the mortar slurry (Tewari, 1992). No compaction is required for foamed concrete and it will flow easily over significant heights and distances from a pump outlet to fill restricted and irregular cavities. The 28 days strength and dry density of the material vary according to its composition, largely its air voids content but usually they range from 1-10 N/mm and from 400-1600 kg/m^3, respectively. Generally lower strengths are significant with lower densities. The most commonly specified strength is 4 N/mm^2 (Strengths of up to

40 N/mm^2 have been produced but so far this has been limited to laboratory-based research work). The plastic density of the material is about 150-200 kg/m^3 higher than its dry density.

Foaming agents or air entraining agent is organic materials. When foaming agents added into the mix water, it will produce discrete bubbles cavities which become incorporated in the cement paste. The properties of foamed concrete are critically dependent upon the quality of the foam. There two types of foaming agent, one is protein-based and the other is synthetic. Protein-based foam has a density of around 80 g/L. Protein-based foaming agents come from animal proteins out of horn, blood, bones of cows and other remainders of animal carcasses. This leads not only to occasional variations in quality, due to the differing raw materials used in different batches but also to a very intense stench of such foaming agents. Because of the possibility of degradation of bacteria and other organisms, natural protein based agents (i.e., fatty acid soaps) are rarely used to produce foamed concrete for civil engineering works. Normally, protein-based foam is suitable for concrete densities from 400-1600 kg/m^3. Synthetic foaming agents are purely chemical products that have a density of about 40 g/L. They are very stable at concrete densities above 1000 kg/m^3 and give good strength. Their shelf life is about 1 year under sealed conditions. Synthetic foam has finer bubble sizes compared to protein but they generally give lower strength foamed concrete especially at densities below 1000 kg/m^3 (Azmy and Abd-Razak, 1991).

Foam concrete is a lightweight, free flowing material which is manufactured by adding foam, prepared by aerating a foaming agent solution, to concrete mortar. The production of foamed concrete on a small scale is a fairly easy process whereby it doesn't involve any expensive or heavy machine and in most cases the equipment is already available for normal concrete or mortar production. Curing regime is one of the dominant effects that influence the strength of foamed concrete. A standard curing standard should be established in order for quality control and comparative purpose. The highest strengths were obtained on specimens cured at 50°C and on specimens sealed in plastic bags and held at a constant temperature of 22°C. In addition, specimen in water-cured gave low strengths due to the build-up of pore water pressure in the saturated microstructure of the foamed concrete. Thus he recommended that foamed concrete test specimens be sealed cured such as wrapped in cling film and stored in plastic bags. Variations of this regime include wetting the specimens after demoulding and before wrapping, or storing them in high humidity environment. Three main properties should be controlled in fresh concrete workability, consistency and cohesiveness. On the other hand, for hardened concrete, the strength is the most important property of concrete. The main criteria for foamed concrete are the physical properties that approximately related to its density. Also, it depends on material mix and the way of mix. Several studies investigated the physical and mechanical properties of foamed concrete cast in different densities and with or without fine aggregates in the mix. There are several aspects that reported affecting the strength of foam concrete, the specimen size and shape, the method of pore formation, direction of loading, age, water content, characteristics of ingredients used and the method of curing including other parameter such as cement-sand and water-cement ratios, curing regime the type and particle size distribution of sand and type of foaming agent used.

MATERIALS AND METHODS

The experimental or methodology program of this research is to obtain the mechanical properties of raw Bamboo (as control) and FCIB. The mechanical properties are consisting of compressive strength, bending strength and tensile splitting strength as the most basic type of mechanical properties. A suitable design mix of foamed concrete was adopting from the existing design mix that has the optimum weight to strength ratio. In addition, this research is also looking on nail pull out strength and behavior of raw Bamboo and FCIB when the nail is punched through it. In preparation of sample and conducting test the existing guideline standard was followed. Figure 1 shows the flow of works and activities. All of the testing was conducted at Heavy Structure Laboratory, Universiti Pertahanan Nasional Malaysia.

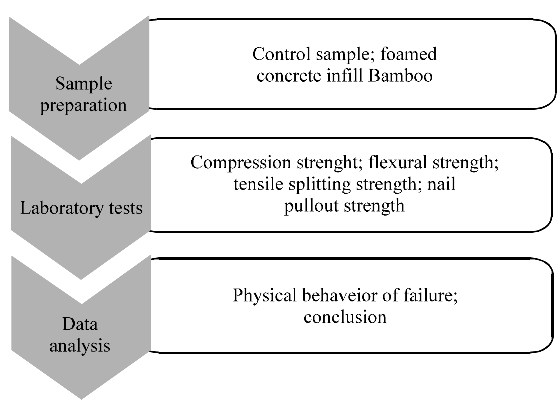

Fig. 1: Flows of works and activities

Bamboo culms were purchased from aboriginal at Gombak, located in Kuala Lumpur. The type of Bamboo that used in this research is Dendrocalamus asper. All culms are almost straight and homogenous in terms of physical appearance. In order to make sure the ease of testing, the culms is make sure to have the same diameter of approximately in average of 100-150 mm and the thickness approximately on average 10-15 mm. Therefore, the size of Bamboo can be neglected. For compression strength and tensile splitting test the height of culms was 300 mm for bending strength test the length of culms was 500 mm and for nailing test the height of culms was 200 mm. In addition, the whole Bamboo culms specimen will be cut with the same number of nodes the sample will be air-dried for several weeks. A total of 4 samples were prepared, 1 for control sample and 3 for infill with concrete foam. In this research there are 4 experiments was being conducted, therefore there are 16 samples was used in this research. In preparation the sample guide from ISO 2215-1 and 2 (Bamboo, determination of physical and mechanical properties Part 1 and 2) were used. The mix design for foamed concrete was adopted from the existing mix design with a density between 700-1000 kg/m^3 that has the optimum weight to strength ratio. A protein base or synthetic foam agent was being used in this mix. After the amount of materials required were obtained, the materials dry was add first starting with the sand and the cement. The mix was constituents for a few minutes and water were added in stages. Then the foam was added to the wet slurry until it totally mixes with the mortar. To know the exactly the design mix after adding the foam, take 1 litter of the foamed concrete from the mix and weight it, the weight of the mix should be 0.7 kg for density of 700 kg/m^3.

RESULTS AND DISCUSSION

According to the first objective, the mechanical properties of Foam Concrete Infill Bamboo (FCIB) being test with 3 experiments:

- Compression test
- Flexural test
- Tensile splitting test

The result shown that there are improvement of mechanical properties when compare to original Bamboo and normal foam concrete. Summary of the result shown in Table 1. For the second objective, test was conducted using Universal Testing Machines with loading rate according to ASTM C234-71 which recommends 22kN/min for steel pullout test in order to determine the pullout of the nail. Pullout strength test results as in Table 2.

Table 1: Summary of results

Samples	FCIB 1	FCIB 2	FCIB 3	Average
Compression (N/mm^2)	6.6	9.7	10.0	8.8
Flexural (N/mm^2)	4.5	4.2	3.8	4.2
Tensile (N/mm^2)	0.5	0.4	0.4	0.4

Table 2: Pull out test result

Samples	Shear area (mm^2)	Pullout strength P(kN)	Stress (N/mm^2)
FCIB 1	723.8	0.346	0.478
FCIB 2	723.8	0.378	0.522
FCIB 3	723.8	0.287	0.400

Fig. 2: Compression test

Fig. 3: Flexural test

The result for compressive test show it is similar to normal foam concrete and less than natural Bamboo. This issue shows that FCIB is not good in compression. For flexural and tensile, the result increased about 40% from natural Bamboo. For the pull out test, the test cannot be done with natural Bamboo because the sample failed during nailing punch. Figure 2-5 show the testing scenario.

Fig. 4: Tensile splitting

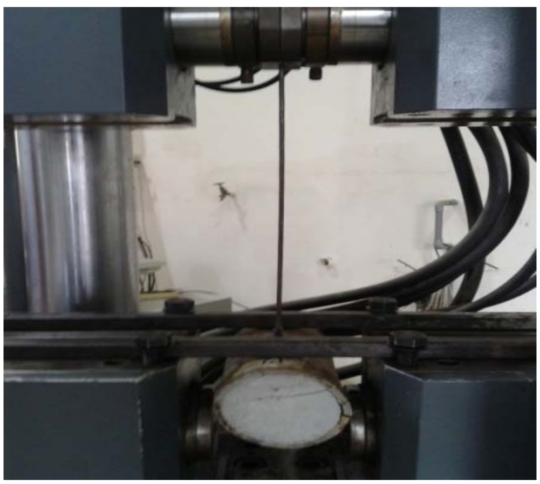

Fig. 5: Pull-out test

CONCLUSION

In this research, the modification of Bamboo with foamed concrete infill method have severely increased the mechanical properties of raw Bamboo. Therefore, the conclusion can be made for modification of Bamboo using the foamed concrete infill method is:

Foamed concrete has reduced the natural splitting behavior of Bamboo and increase the flexural and tensile strength. But in compression test the internal horizontal force from foamed concrete has reduced its compressive strength compared to control sample.

In nailing test, nail pullout strength of FCIB has shown some result that promised the use of nail for joining method. This is because Bamboo is well known for its natural splitting behavior with the present of foam concrete the natural splitting behavior of Bamboo have been reduced and the usage of the nailing method in Bamboo have been improved by using foam concrete inside it.

It is shown that FCIB can be explored further as the construction materials. The usage can offer an option to replace timber as a permanent structure. However, further research also must look into threated Bamboo.

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