Strength of two-way Semantan Bamboo reinforced concrete slabs

C B Yong¹*, Ridzuan Ali² and R Mohd Ikmal Fazlan³
¹,²Faculty of Civil Engineering, Universiti Teknologi MARA, Malaysia.
³Faculty of Civil Engineering, Universiti Teknologi MARA, Cawangan Pulau Pinang.
yongchuabon@yahoo.com

Abstract. Steel has been widely known as the essential material for reinforcement. However, many researches have been conducted in order to find an alternative sustainable material to replace steel. In this study, bamboo has been chosen to replace steel as reinforcement is introduced as one of the alternative material for reinforcement of concrete. The Semantan Bamboo (Gigantochloa Scortechinii) splint with a size of 20 mm x 10 mm (Thickness) was used as the main reinforcement. Three samples of two-way concrete slabs were prepared with a dimension of 1200 mm x 1200 mm x 100 mm. One sample will be constructed without reinforcement, while the remaining two samples will be reinforced with 1.5%, 2.5%, 3.5% and 4.5% of bamboo. All the samples will undergo concentrated punch loads and control slab without reinforcement. The results show that the maximum punching shears that the slabs can sustain more 60 kN. The slabs fail by the cracking of concrete at the bottom of the slab under the concentrated load.

1. Introduction
Concrete is a common material widely used in construction. Concrete has high strength in compression but low in tensile strength of plain. However, to improve the limitation, additional reinforced should be added in the plain concrete and steel bars are the most popular reinforce materials. The steel has a good in tension. In fact, the steel has some disadvantages using steel as reinforcement. According to [1], steel is a non-renewable material. In fact, high spending to produce good quality of steel from raw metal. However, in the future, the steel is not usable because of the high cost in the mining process. New material available to replace the steel is more benefits for the concrete strength and more economic. The new materials are low cost on the process of producing, renewable material and able to find from locally.

Steel is one of the famous materials used in the construction industry. The knowledge of steel was explained in the classes, workshops, and conferences. Reference materials are easily available on the internet about steel. An example, developing countries such as Malaysia was used steel bar as a reinforcement bar to overcome the weakness of the concrete in to construct the buildings and structures. Again, steel production is a high cost because the mining industry which consumed high energy and power. According to [2] was explained the process of mining to produce the steel. Based on that 20%-25% only for the cost of steel generated. About 60% of that energy is derived from coal, principally which required as a raw material to produce coke used in blast furnaces to convert iron ore to iron. In addition, to produce the coal-fired power plants, the industry must run through a lot of consumption of electricity. Furthermore, if the ignition continuously happened, the environment would be polluted due to the release of carbon dioxide (CO₂) to the atmosphere which could lead to climate
changes and global warming. This is the reason why there is a need to find a sustainable material such as bamboo in order to replace the bar.

Following on that, replacing steel in construction has attracted researchers to get the substitutes materials. Based on that, bamboo has become popular to be used in construction as an alternative to replacing steel since it can give benefit to most developing countries [1]. One of the advantages of the bamboo is the strength is greater than timber but estimated to be half of the tensile strength of steel. However, corrode problem was solved.

The problem with the use of steel reinforcement is concrete's alkalinity, which causes corrosion. Besides that, some construction cannot tolerate the use of steel. For example, MRI (Magnetic Resonance Imaging) machines have huge magnets and need to be housed in nonmagnetic buildings. Other than that used of steel are not green because the manufacture of steel reinforcement bars for reinforced concrete could be a course of significant energy consumption and a large contributor to (2014), claimed that many researchers do embody Carbon Dioxide (CO2).

Material to replace steel as reinforcement bars for concrete for this study is bamboo. Bamboos are alternative sustainable material available in most area, especially in a rural area. Bamboos are easy to find and handle and carry because it is light compared steel. However, there are only a few researches that have been done related to the behavior of bamboo in two-way slabs which can be the limitation of utilizing bamboo as a construction material. Hence, this study will help to increase the knowledge of bamboo has become popular to be used in construction as an alternative to replace steel since the structural behavior of bamboo as reinforcement in concrete slabs. Therefore, the study of the shear strength of bamboo reinforced concrete is required to determine its structural behavior. For that reason, this study is proposed since there is insufficient study on two-way slabs subjected to concentrated loading. This study has highlighted the uses of in pursuing sustainable construction. As a result, it will also increase it can give benefit to most developing countries [1]. One of the advantages of the chance for bamboo as local material which can cut the cost and not harmful to the environment to be the bamboo is the strength is greater than timber but estimated to be half of the tensile strength of an alternative material to steel.

Bamboo has a possible as a great sustainable structural building material when it is characterized as a renewable, biodegradable and energy-efficient natural resource [3]. Therefore, bamboo has become popular to be used in construction as an alternative to replacing steel since it can give benefit to most developing countries [1]. Bamboo can be found in almost every tropical and subtropical region thus making it easier to access, therefore, the cost of production the bamboo bars and will be reducing. Compared cost of the mining process to produce steel.

Bamboo is one of non-ferrous reinforcing material that commonly suitable to be replacing of steel bars in the slab. Bamboos can fully growth just a few months and just need a few years to reach its maximum mechanical strength. According to [1], bamboo is a type of grass that grows fast, which can grow up to one meter a day and require 3 years to reach its maximum strength. Bamboos are not a tree but classified as giant grasses. They are in a family group of the Bambu-soideae. The bamboo culm Figure 1.1 shows the general part of bamboo that is cylindrical in shape and has nodes that divide the diaphragms. According to [4], because of the orthotropic materials of bamboo shells bamboo that are in the direction parallel to the fibers are higher in strength as compared to perpendicular to the direction of fibers.
In this study, Semantan Bamboo was used and can be differentiating from other species by looking at their culms diameter. Mostly, Semantan Bamboo has a large culms diameter. It can be found at an altitude up to about 1200m and often spread into the disturbed habitat, from lowland to hills area, along streams and rivers, and in valleys. According to [5], the high compressive strength of Semantan Bamboo on the parallel to the grain. Modulus of elasticity and stress at the proportional limit at the middle top with the skin at internode portion.

The development or maturation phase of bamboo growth based on age. The age would be affected by the properties of bamboo. That duration at 0.5, 1.5 and 3.5 years respectively. Bamboo from 3.5 years of age is considered mature and suitable for any purpose [6]. The bamboo achieved its optimum strength at 2.5 and 4 years. [7] and claimed that the strength of bamboo will start to decreases at a later age. Many researchers find that with as the bamboo grow older the strength of bamboo will increase. Besides to prevent the buckling, the nodes also function as axial crack arresters. Besides that, the shrinkage, resistibility, and elasticity of bamboo are also important properties to be looked at.

The height and age of the bamboo culm will determine the mechanical properties of bamboo. Additionally, physical properties of bamboo such as moisture content, density, specific gravity, and shrinkage must be assessed. [8] stated that the density of bamboo growth can vary from place to place based on site conditions, the extent of disturbances and the species. Appearance and texture of bamboo can be studied to determine the physical properties. Therefore, physical properties are important to determine and select the suitability of bamboo to be used in construction industries. Any changes can be seen physically on bamboo and some test might be needed. Physical properties can be studied and measured without changing its composition of matter. If there are any changes happened, its properties will not be the same and this can affect its strength, durability and so on.

[9] said durability and service life of the bamboo-based on the starch content in the bamboo. However, the influence of the decreasing of the durability of the bamboo is strongly related to the chemical composition. According to [10], the distribution of fiber is more uniform at the base than at the top or the middle because maximum bending at the bottom of the bamboo due to wind occur at the top portion of the culm. Other factors are the condition of the forest also was affected the bamboo properties. Bamboo is a heterogeneous and anisotropic material [11]. Culm height, culm location, density, and moisture content influence its mechanical properties which are extremely unstable. According to [12], bamboo such as Gigantochloa scortechinii is suitable for composite materials, laminated board, and plywood. Additionally, to extend the service life of the product, there is a need to treat the bamboo which is chemical treatments. Chemical preservation ensures a longer service life for bamboo products and maintains its [13]. So, a chemical used is crucial for the treatment so that it does not affect the properties of the bamboo.

An experimental study conducted by [14], about the mechanical properties of laminated bamboo strips from Gigantochloa Scortechinii/polyester composites using different thickness of specimen, the
result shows that the strip thickness of the bamboo increasing proportionally to the. Based on that , absolutely, the laminated unsaturated polyester/ bamboo strip composite has superior mechanical properties compared with pure bamboo. Although. [15] was claimed coating method is one of the prevent from water absorption into the bamboo. That also would not affect the strength of the bamboo. Other function of the coating to avoid uneven shrinkage of the bamboo bars. Other problem [16], bamboo has high moisture and difficult to completely dry, in fact, that, easily damaged by fungal infections and poses uncertainties in it. Again, [17] found that there is variation in moisture contents from the bottom to the top portions and horizontally from the outer layer to the inner layers of bamboo. A study conducted by [18], for the 6.5years age of the oldest culm, the result shows that the highest oven-dry density and lowest initial moisture content has the mean of 680kg/m³ and 48.6% respectively. Meanwhile, the study conducted on by [19] to determine the percentage reduction in the moisture content of bamboo, found that beyond 6 hours of oven drying, the weight of the specimen remains the same. Additionally, bamboo is good more in tension other than compression, which was comparable with that of mild steel [20]. The fibers of bamboo run axially. In the outer zone are highly elastic vascular bundles that have high tensile strength. The tensile strength of these fibers is higher than that of steel, but it’s not possible to construct connections that can transfer this tensile strength. Slimmer tubes are superior in this aspect too. Inside the silicate outer skin, axial parallel elastically fibers with a tensile strength up to 400 N/mm² can be found. As a comparison, extremely strong wood fibers can resist a tension up to 50 N/mm². According to [21], the parallel tensile strength was forty time more than the perpendicular strength.

2. Experimental setup

2.1. Concrete and mix proportion

Normal mix concrete with grade 25 with different percentage of bamboo-reinforced slabs. 0% of bamboo is a control sample with dimension 1200mm x 1200mm x 100mm thickness for each samples. Ensure the quality of mixed concrete, a few numbers of cubes are prepared. Each slab were subjected to concentrated load. The results were evaluated by experimentally and theoretically.

3. Results and Discussion

3.1. Load-displacement relationship

Load-deflection curves of the two-way slab that was subjected to concentrated loading for each slab. However, the minimum and maximum of bamboo reinforcement is 1.5% and 4.5% respectively. From Figure 2, the maximum load and the smallest deflection with the minimum bamboo reinforcement content in the sample. However, the maximum content of bamboo reinforcement in the sample was given a different effect on the strength of the slab. Bamboo reinforcement content contained in the sample, it has a better effect compare control sample. Figure 2 shows the value of failure load and deflection at maximum load accordingly to the percentage of bamboo-reinforcement. The load-displacement graph is to illustrate the behavior of slabs specimens under concentrated loading.
3.2. Mode of failure

Failure cracks due to the bending of the slabs are the first develop underneath the slabs as applied loading is gradually increased and the concrete tensile strength is exceeded. However, the strength of the slabs depends on the numbers of reinforcement bars, concrete strength and the effective depth of the slab. Figure 2 was approved more numbers of bars have inside the slab, the slabs able to carry more loads. Again, the crack pattern observed underneath the slab is illustrated in Figure 3. From the figure, it could be concluded that the failure occurred from punching shears failure. Therefore, the punching shear failure mode as can be closely predicted by theoretical analysis.

According to [22] said, the maximum bending moment at the center of the slabs, subjected to the location of the concentrated load. However, failures may a combination of flexure and shear. Hence, each of the effects would be dominated to failure. Cracking will initiate by a small section of flexural concrete crushing and spreading rapidly to the edges of the slab. Therefore, to determine the cause of the slab failure need to expend the study. Fortunately, flexural failure caused by the crushing of concrete and fracture of the tension bars, or punching shear.

From the result was shown a number of bamboo inside the slabs able to increase the strength of the slab. However, during the experimental the cracks appeared under the slabs should be monitored during the load applied. Even the surface of the slab was crushed and cause the crack shows under it. The crack was almost radial on the surface and randomly spread under the slab and towards the support of the edge of the slabs. Extension and expansion of the slab have produced a crack line with a
different length when the load was executed. Cracks were irregularly in shape since it was influenced by the load applied.

4. Conclusion
The purpose of this study was to determine the strength of two-way slabs subjected to concentrated load. The study also to identify the failure modes of the slabs. Besides that, the experimental result that has been found with maximum and minimum strength is 63.8 kN and 34.59 kN respectively. However, the results were approved the bamboo-reinforcement bars able to improve the strength of the two-way slabs. Besides that, a failure mode that has been identified especially the slabs with bamboo reinforcement gives a similar pattern which is randomly spread to the edge of the slab. In fact, expansion and elongation of the cracks are influenced by the load increases on the slabs. The Semantan bamboo able to replace the steel reinforcement bars but the slabs would be installed or constructed at a particular position especially those that hold lightweight. The slab is easy to handle and light weight compared typical IBS slabs with use steel bars. Furthermore, expansion studies on the treatment of the bamboo for prolong the life of the slabs with bamboo-reinforcement bars.

Acknowledgement
The experiments were conducted at the Heavy Structure Lab of Faculty of Civil Engineering, UiTM. The authors acknowledge the contributions of the Heavy Structure Lab staff and the Final Year Project students.

References
[1] Javadian A Hebel D E Wielopolski M Heisel F Schlesier K and Griebel D 2014 Bamboo Reinforcement - A Sustainable Alternative to Steel World SB14 Barcelona, 5(2), p. 34–40.
[2] Bruce A S 1990 Environmental Issues Facing The Iron & Steel Industry, American Iron & Steel Institute, 8(29909), 22926.
[3] Li Y Shen H Shan W and Han T 2012 Flexural behavior of lightweight bamboo steel composite slabs, Thin-Walled Structures, 53, p. 83–90.
[4] Ghavami K 2005 Bamboo as reinforcement in structural concrete elements, Cement and Concrete Composites, 27(6), p. 637–649.
[5] Jusoh N Z Ahmad M and Ibrahim A 2013 Study on Compressive Strength of Semantan Bamboo Culm (Gigantochloa scortechinii), 330, p. 96–100.
[6] Hashim R Hisham H N Othman S Rokiah H Latif M A Ani S and Tamizi M M 2006 Characterization of bamboo Gigantochloa scortechinii at different ages Characterization Of Bamboo Scortechinii At Different Ages
[7] Amanda S and Untao S 2001 Fracture Properties of Bamboo Composites Part B, 32, p. 451-459.
[8] Wong K M 1989 Current and potential use of bamboo in Peninsular Malaysia Journal American Bamboo Society 7(1&2):1-15.
[9] Hamdan H U M K Anwar A Zaidon and M Mohd Tarmizi 2009 Mechanical properties and failure behavior of Gigantochloa scortechinii J. of Tropical Forest Sc., 18(4), p. 336–344.
[10] Ghavami K 2004 Bamboo as Reinforcement in Structural Concrete Elements Cement & Concrete Composites.
[11] Pannipa C 2013 Bamboo: An Alternative Raw Material for Wood and Wood-Based Composites J. of Materials Science Research, 2(2), p. 90–102.
[12] U A Mohd kha run A Zaidon H Ham dan and M Mohd T 2005 Physical and mechanical properties of Gigantochloa scortechinii bamboo splits and strips J. of Tropical Forest Sc.
[13] Kumar S Dobriyal P B 1992 Treatability and flow path studies in Bamboo. Part dendrocalamus strictus nees. Wood Fiber Science, 24(113117)
[14] Rassiah K Ahmad M M H M and Ali A 2014 Mechanical properties of laminated bamboo strips from Gigantochloa Scortechinii polyester composites Journal Of Materials & Design, 57, p. 551–559.
[15] Wibowo A Wijatmiko I and Nainggolan C R 2017 Bamboo reinforced concrete slab with styrofoam lamina filler as solution of lightweight concrete application, *5012*, p. 1–6.

[16] Jansen J J A 2000 *Designing and building with bamboo* The Netherlands. International Network for Bamboo and Rattan.

[17] Li X 2004 Physical chemical and mechanical properties of bamboo and its utilization potential for fiberboard manufacturing. *Agriculture and Mechanical College, Master of*, 76.

[18] Norul Hisham H. Othman S Rokiah H Abd Latif M Ani S and Mohd Tamizi M 2006 Characterization of bamboo gigantochloa scortechinii at different ages. *J. of Tropical Forest Science* 18 (4), p. 236-242.

[19] Daniel A J 2016 Study O N B Ehaviour O F C Ompression M Ember W Ith B Amboo A S R Einforcement A Nd C Oconut S Hell A S A Ggregate, 3(1), p. 1–14.

[20] Subramaniam S and M V 2015 Bamboo Reinforced Concrete Slabs for Fence Walls. *J. of Sust. Dev. 8*(9), p. 1–13.

[21] Sharma B Gatóo A Bock M and Ramage M 2015 Engineered bamboo for structural applications. *Construction and Building Materials, 81*, p. 66–73.

[22] Kankam C K and Odum-Ewuakye B 2006 Babadua reinforced concrete two-way slabs subjected to concentrated loading. *Construction and Building Materials, 20*(5), p. 279–285.