Performance of Beting Bamboo (Gigantochloa Levis) as Partial Replacement for Coarse Aggregate in Concrete

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Abstract. Conventional construction materials are considered as exploitation to natural resources. Thus, numerous alternative materials using natural or waste materials are proposed for concrete production as a response for greener, renewable and biodegradable environments with regard to sustainability. Natural fibre such as bamboo has been rapidly proposed for many applications especially for concrete production in construction. In order to tackle the environmental issues and focusing on sustainability, natural fibre of Beting bamboo is proposed for partial replacement used as supplementary cementitious materials. Current study investigates the partial replacement of coarse aggregate with Beting bamboo in concrete mixtures. The outcome of the study discovers that through the mix design, replacing 5% by weight of Beting bamboo is an ideal % to achieve concrete mixture for structural and nonstructural application. However, with the increase % of Beting bamboo for partial replacement, the strength of the concrete gradually decreased.

1. Introduction
Conventional concrete mixture consisting materials such as concrete, aggregates, and water content is used in both developed and developing countries due to high demand for developments. Globally, building projects in both developed and developing countries consumes about 40% energy [1]. Thus, concrete is widely used in construction because of its cheap cost, wide application and the ability to take any form [2]. However, conventional concrete materials are becoming expensive related to nonrenewability and depletion of natural resources. Due to the environmental concern, green and sustainable material has been considered on the conventional concrete production. Therefore, numerous alternative materials are being proposed for concrete production [3-4]using various alternatives such as fly ash, Cordia millenii ash, and rice husk as admixtures [5] or partial replacement for cement. On the other hand, both fine and coarse natural aggregates have been substituted with materials such as ceramic tiles [6-7] and steel slag [8-9]. From these studies both ceramic and steel slag aggregates have been identified as a good alternative material for making concrete. A low cost and sustainable material like bamboo should be considered as a good alternative material for making concrete [10]. Bamboo is one of the rapid growing plants and is known as perennial grass with woody culm belonging to the family Poaceae and subfamily Bambusoideae. Frequently, bamboo has many advantages as a construction
material, referred as a highly renewable, ecological viable substitute [11], as ‘strong-as-steel’ reinforcement for concrete and high-strength alternative material to timber [12-13]. Past studies conducted researches from the use of full culm bamboo in construction, scaffolding [14-17] to engineered bamboo composites [18-21]. Bamboo on dry state has characteristic strengths at best comparable to high-grade hardwood [2]. Thus, development of bamboo products as a sustainable, cost-effective and as alternative for environmentally partial replacement of construction material should take into consideration. There are many studies substituting materials such as bamboo in novel concrete mixes [23-24]. In order to reduce agriculture waste, current study utilized Beting bamboo as partial replacement of coarse aggregates for concrete structure application. The aim of this study is to understand the integrity of Beting bamboo as partial replacement of coarse aggregate and to find the optimum % which is compatible in concrete mixture for structural and non-structural application. The parameters investigated in the present work are: slump test, compressive strength, density, Ultrasonic Pulse Velocity and the results will be briefly explained.

2. Materials Selection
Bamboo is one of the oldest building materials preferred because of its high strength, light weight, cost effective and it has a rapid growth rate plant. In Malaysia, there are 59 species of bamboo and some of the species generally used for commercial purposes. Current study considered Beting bamboo or known as Gigantochloa Levis as a sustainable material for partial replacement of coarse aggregate in the concrete mixture. In addition, this study focuses on the workability, integrity and compressive strength of Beting bamboo in the concrete. The concrete was designed to achieve compressive strength of 20 MPa at a 28-days. The materials used for these investigations are: cement, aggregates, water, and Beting bamboo. The selected cement was Ordinary Portland cement (OPC) with class of 42.5 to satisfy the requirements in BS12 [25]. For current study, fine sand passing 5mm sieve size opening and crushed coarse aggregate with the nominal size of 20mm in accordance with BS812 [26] as shown in Figure 1. The water used for the experiment was potable tap water, free from any dissolved metal and the concrete mixture was prepared with a water-to-cement ratio of 0.5. As for the mix designs of the concrete, differences % of Beting bamboo chips in accordance with the Department of Environment [27] was estimated. Some portion of the coarse aggregates was replaced with the Beting bamboo chips fibres by weight. The Beting bamboo was cut into the smaller size of 20mm size and undergoes sieving process in order to ensure it suits as partial coarse aggregates replacement. Figure 2 display the Beting bamboo chips was treated with chemicals as studies by Dewi et al., [28] such as Sodium Hydroxide (NaOH), Potassium permanganate (KMnO₄), and Hydrogen peroxide (H₂O₂) to reduce the bamboo to absorb water. Next, the Beting bamboo was dry in the oven for 24 hours at 60°C to remove excessive moisture content. Twenty four concrete cubes samples containing 0%, 5%, 10% and 15% of Beting bamboo were partially replaced with coarse aggregate and cast in 150 x 150 x 150 mm cube specimens. The samples were demoulded after 24 hours and the concrete undergoes curing using immersion curing method. The concrete samples were immersed into the water as the samples were tested at 7 days and 28 days, respectively.
Figure 1: Beting bamboo chips with 20mm size was used as partial coarse aggregates replacement.

Figure 2: Beting bamboo chips after chemical treatment and oven dry

3. Experimental Analyses

Once the materials selection, concrete samples preparation and curing process was completed, experimental analyses were performed on 24 hardened concrete cubes. This section explained types of experimental analyses were conducted accordingly.

3.1 Slump Test

The slump test is conducted to determine the workability of fresh concrete using slump test. Workability is known as the ease with which the concrete can be mixed, transported, placed and compacted. It is a test that is used to determine the consistency of a fresh concrete sample before curing. Thus, the test was conducted as an indication of concrete uniformity.

3.2 Compressive Strength Test

The compressive strength was performed in accordance with BS EN 12390-3 [29] by using the compression strength test machine. The compression test is conducted in order to measure the compressive strength of concrete samples achieved in a certain period of time. The test was conducted on 150x150x150mm cube specimens. The cubes were tested at 7 and 28 day curing ages, respectively.

3.3 Ultrasonic Pulse Velocity (UPV) Test

Ultrasonic Pulse Velocity (UPV) is a non-destructive in-situ test and is conducted to check the quality of hardened concrete. The test was conducted using Portable Ultrasonic Non Destructive Digital Indicative Tester (PUNDIT) using direct transmission because the method is more reliable measuring the transit time of pulse through the concrete sample. It measures the rate pulse traveling across the
sample in order to provide information such as voids and any irregularities in the concrete samples. Thus, the integrity of Beting chips in the concrete without causing any damages to the concrete sample can be obtained. The test was conducted on the concrete samples at the ages of 7 days and 28 days, respectively.

4. Results
The outcome of each experiment analyses conducted in this study are further discussed. Fig. 3-5 summarizes the slump values incorporating % of Beting bamboo as partially replaced with coarse aggregates in the concrete mixture. The results indicated that the amount % of Beting bamboo that was replaced affects the degree of workability of fresh concrete. As for 0% of Beting bamboo, it delivered the highest slump values compared to 15% of Beting bamboo. As for the workability of the fresh concrete, it can be summarized that the highest % of Beting bamboo replacement delivered lowest slump values which specified low degree of workability as presented in Figure 5. Despite the bamboo being treated with chemicals, it can be observed that concrete mixture with the highest % of Beting bamboo suffered dryness due to the poor bond between the bamboo and surrounding matrix. Thus, segregation is inevitable. The chemical treatments are not considered to provide sufficient protection against water absorption. Similar findings was addressed by Liese and Kumar [30] due to bamboo rot with the present of moisture from crack.

Figure 3: Slump test for 5% Beting bamboo replacement

Figure 4: Slump test for 15% Beting bamboo replacement

Figure 5: Slump value with different % of Beting bamboo replacement.
Figure 6 displays the concrete samples were tested with compressive strength on the 7 and 28 days during the curing process. It can be observed that at 28 days, compressive strength of the concrete mixture with % of Beting bamboo increased. However, it can be noticed that the compressive strength of concrete decreased with increased % of Beting bamboo as shown in Figure 7. The reason is due to the amount of Beting bamboo caused by a poor bond between the bamboo and surrounding matrix that led to segregation. In addition, gradation distribution of coarse aggregates due to the partial replacement may also influence the strength of the concrete. Furthermore, replacing coarse aggregate with % of Beting Bamboo resulted in micro cracks as the damage was obvious with the increase % of Beting bamboo. The results show that by replacing 5% coarse aggregate by weight with Beting bamboo is a practicable to be applied for structural and nonstructural application mainly lightweight structure.

![Concrete sample under compressive strength](image1)

![Average compressive strength concrete % test with different of Beting bamboo replacement](image2)

An excellent quality concrete with pulse velocity of > 4.5 km/s should have a lower amount of void in concrete samples [31]. Figures 8 and 9 show the UPV values which 0% of Beting bamboo provides the highest reading of UPV compared with 15% of Beting bamboo. The decrease of UPV values in accordance with the increase % of Beting bamboo. At 28 days concrete, the concrete sample with 0%, 5% and 10% of Beting bamboo is considered as good concrete quality (3.5-4.5 km/s) meanwhile 15% of Beting bamboo is considered as medium quality of concrete is noticed. This indicated that with the increase % of Beting bamboo, significantly lower the UPV velocity due to the hardened concrete consisting of void (due to segregation).

![Average Ultrasonic Pulse Velocity (km/s)](image3)
5. Conclusion and perspectives

Construction industry should initiate and utilize natural resources as alternatives to minimize environmental impact and also deliver awareness on the environment with regard to sustainability. This study demonstrated the use of Beting bamboo as partial replacement of coarse aggregate in concrete mixture. The concrete was designed to achieve compressive strength of 20 MPa at 28-days. This study identifies the effects on concrete properties in rheological and hardened states by substituting Beting bamboo in concrete mixture. The % of coarse aggregate replacement used is 5%, 10% and 15% with control samples (0%). Generally, it can be observed that replacement of Beting bamboo in a concrete mix causes a decrease in slump test, compressive strength and UPV velocity due to the poor bond between the bamboo and surrounding matrix. Hence, the highest % of Beting bamboo led to poor bonding and caused segregation on the hardened concrete is inevitable. Replacing 5% of Beting bamboo by weight is an ideal ratio to achieve the desire concrete mixture for structure and nonstructural application. Despite the highest % of Beting bamboo replacement providing lower results in term of strength, the concrete mixture may be applicable for non-structural application. Thus, higher % of Beting bamboo should be further investigated with the use of admixtures mainly to increase the strength of the concrete. In addition, using sustainable material should be emphasized in future research with regard to the requirements, environment, social and economy mainly towards sustainability.

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