Effects of durian sawdust as a partial replacement of fine aggregate in concrete

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Abstract. Recently, many researches all over the world are focusing on ways of utilizing either industrial or agricultural wastes as a source of raw materials for the construction industry. The aim of this study is to determine the optimum proportion of durian saw dust as partial replacement for fine aggregate. These wastes utilization would not only be economical but may also help to create a sustainable and pollution free environment. Durian sawdust is one such fibrous waste-product from durian skin. In this paper, untreated durian sawdust has been partially replaced in the ratio of 0%, 5%, 10% and 15% by volume of fine aggregate in concrete. Fresh concrete tests like compacting factor test and slump test were undertaken along with hardened concrete tests like compressive strength test and UPV test. The result shows that durian sawdust of 5% partially replacement of fine aggregate can be used for structural and non-structural purposes.

1. Introduction
In Malaysia, river sand which act as a fine aggregate in concrete is highly consumed due to the rapid construction activity. Generally, there are few reasons why river sand has been chosen as a fine aggregate in concrete instead of any other material [1]. It is because of its cheap price and readily availability make the river sand as a favoured material in the construction site. River sand has a round particle shape and smooth texture due to abrasion of water toward the sand particle that has been happened for a long period of time. It also contains a very less amount of silt and clay because it has been subjected to years of washing.

Malaysia is known as a developing country which the construction industry has been growing annually especially for structural and infrastructural construction. Thus, the demand for river sand has been increasing in order to satisfy the growth of the construction sector. In contrast, the excessive consumption of river sand caused a serious depletion of river sand. The extraction of river sand from the river bed also has led to various environmental problems such as bank erosion, loss of water retaining sand strata, disturbing aquatic life, lowering the underground water table near the stream and also loss of vegetation on the river bank which will affects the habitat above and below the ground.

Due to this problem, significant research initiative is needed to find alternative, sustainable building materials, cheap materials and low technology methods that result in more sustainable, affordable building that complies with today's comfort standards. In order to achieve this target, adopting green construction materials is an excellent approach. The selection of building materials with minimum environmental costs is useful in this country sustainable development. Building that associated contribution to environmental issues is therefore important and essential. The selection of
environmentally preferably constructive products is an excellent method for boosting environmental performance of buildings.

Natural fibre can be classified into two type: animal-based fibre and plant-based fibre. Animal-based fibre is feathers, silk, wool which are utilized to textile industry as they own certain characteristics which is good insulation properties. The plants fibre can be divided into two part which is wood and non-wood fibre. The example of plant-based fibre types are wool, bamboo, and banana. Natural fibre is a renewable resource and available in the market. Natural fibres are being used in transportation industry, building and construction industries (ceiling, panelling, partition), textile industry, etc. [2]. The natural fibre production causes less environmental problems as compared to the synthetic fibre. In contrast, the synthetic production mostly depends on fossil fuel and needs about ten times higher energy consumption as compared to natural fibre [3]. Due to this factor, the research assured that synthetic fibre productions emit pollutant gas to the environment gradually higher than the production of natural fibre.

According to Vairagade and Kene [4], one example of natural sand replacement in concrete would be sugar cane bagasse ash. This ash is mainly implemented when replacing natural river sand in a normal weight concrete. Moreover, sugar-cane bagasse can be described as a natural fibre waste product of the sugar refining industry. Aluminium ion and silica are contained in the sugar can ash. The researchers have completed a compressive strength of the concrete with different replacement percentage of bagasse ash which are 0%, 10%, 20%, 30% and 40%. As for the results, the specimens with 10% replacement of sugarcane bagasse ash at 28 days were the highest among others [4].

Apart from using sugarcane bagasse ash, Kumendong et al. [5], further introduced and elaborated on the application of coconut sawdust as fine aggregate replacement in concrete. Coconut sawdust are also waste materials which unlikely impacts the environment due to its sustainability. The study concluded that 5% is the optimum percentage of replacement for use in concrete production. In contrast, the concrete totally lost the strength when the researcher fully replaced fine aggregate with coconut fibre [6].

Furthermore, Mohamad et al. [6] emphasizes on the possibility of using Banana Skin Powder (BSF) partial fine aggregate replacement in concrete. This waste product was produced banana skin which undergo drying process by oven at temperature 110°C for one whole day. Then, the banana was grinded and sieved and transformed into a powder. The results showed a very significant compressive strength improvement with the increasing of percentage replacement of natural sand by banana skin fibre. Due to the numerous researches done, the author has good reasoning to use natural fibre waste materials and recycle them for other beneficial uses [6].

Durian is an unpopular material and rarely used in the construction industry but being dumped as agricultural waste which is abundant and do not have any useful utilization most of the time. As the production of durian increased, the agricultural waste of durian also increased and may lead to the environmental problems if this waste is not disposed efficiently. In order to reduce this problem, this agricultural waste can be recycled and reused to produce a new product. Therefore, durian waste can be the solution to prevent environmental issues which is continuously occurred by recycling the waste product and convert it into durian skin fibre. Hence, the study aims to determine the optimum proportion of durian saw dust as partial replacement for fine aggregate.

2. Materials
In this study, there were three materials that involved namely cement, aggregates and durian skin fibre.

2.1. Cement
The cement used for this research was ordinary Portland cement (Type-1). Its physical properties are as given in Table 1.

2.2. Aggregates
Locally available normal graded river sand with 5 mm maximum size was used as fine aggregate, fineness modulus as given in Table 2 and crushed stone with 20 mm maximum size having fineness
modulus as shown in Table 2 was used as coarse aggregate. Both fine aggregate and coarse aggregate designed based on Design of Experiment (DOE).

Table 1. Physical properties of cement.

| Physical property          | Result obtained |
|---------------------------|-----------------|
| Normal Consistency        | 35%             |
| Initial Setting Time      | 45 minutes      |
| Compressive Strength (after 7 days) | 32.5 N/mm$^2$  |
| Tensile Strength (after 7 days) | 2.55 N/mm$^2$  |

Table 2. Physical properties of aggregates.

| Physical tests          | Coarse aggregate | Fine aggregate |
|-------------------------|------------------|----------------|
|                         | River sand       | Durian sawdust |
| Fineness Modulus        | N/A              | 3.04           |
|                         |                  | 2.48           |

2.3. Durian skin fibre preparation

The durian skin fibre investigated in this study was obtained from durian skin waste at local durian stall in Selangor. The process in preparing durian saw dust involved four processes namely cutting, oven-drying, crushing and grinding. The durian skins were dried for 24 hours at 60°C and then ground into smaller size which makes it easier to be mixed with normal concrete. Figure 1 shows the durian saw dust after the grinding process completion.

Fig. 1. Durian saw dust.

Sieve analysis was conducted to determine the grading of durian sawdust and followed the standard grading stated in BS 882:1992. Therefore, sieve analysis was performed because the size of sawdust is larger than 0.075 mm in diameter. The grading of aggregates based on the proportion of particles are different in sizes which is typically 5 mm for fine aggregates and 20 mm for coarse aggregates.

3. Experimental work

The experimental work consists of performing the sieve analysis of durian saw dust followed the standard grading stated in BS 882:1992 and using the results for the mix design to achieve the
concrete of required strength and quality. Thereafter the concrete is tested for workability parameters by performing the slump test and compaction factor test on it, followed by casting the cubes of concrete for further investigations. For carrying out the strength investigations, a total 16 number of concrete cubes were casted and named as M1, M2, M3 and M4. A total 4 numbers of concrete cubes were casted for each mix and were tested for 7, 14 and 28 days at the same time. Based on the ingredients amount of the mixes, the amount of durian saw dust for 0, 5, 10, and 15% replacement by volume of sand were estimated and tabulated accordingly in Table 3. The water cement ratio was kept at 0.50. The casted concrete specimens were placed in the water tank for curing process in the laboratory and tested for 7, 14 and 28 days compressive strength and UPV test, respectively.

Table 3. Properties of fresh concrete.

| Mix No. | Mix proportion | Durian saw dust (%) | Cement (kg/m³) | Free water content (kg/m³) | Coarse aggregate (kg/m³) | Fine aggregate (kg/m³) | Durian saw dust (kg/m³) |
|---------|----------------|---------------------|----------------|---------------------------|-------------------------|------------------------|------------------------|
| 1       |                | 0                   | 410            | 205                       | 1200                    | 600                    | 0                      |
| 2       |                | 5                   | 410            | 205                       | 1200                    | 570                    | 30                     |
| 3       |                | 10                  | 410            | 205                       | 1200                    | 540                    | 60                     |
| 4       |                | 15                  | 410            | 205                       | 1200                    | 510                    | 90                     |

4. Test methods

4.1. Durian skin fibre preparation
At the end of each curing period, a total of 4 specimens were tested for each concrete mix. The compressive strength test was carried out on the 150 mm cube specimens as per BS EN 12390-3. The first mix was considered as the control sample which is normal-weight concrete typically prepared using DOE method. The test was conducted using Digital Compressive Testing Machine available at Civil Engineering Lab, IIUM in accordance to BS EN 12390-3.

4.2. Ultrasonic Pulse Velocity (UPV) test
Apart from testing compressive strength, Ultrasonic Pulse Velocity (UPV) is in favour non-destructive techniques used as an evaluation for determining the UPV values for all concrete produced from the test. The UPV experimental study was conducted at the curing period of 7, 14 and 28 days, subsequently. The UPV results able to determine the quality and consistency of the concrete as well as to check for any damages within the concrete without damaging the specimen. The transducer is located between two points of contact of the concrete member. The pulse velocity V can then be calculated using Equation (1) with the path length L, also known as the distance between the two probes and time of travel, T.

$$V = \frac{L}{T} \quad (1)$$

Concrete which has a high elastic modulus and density will yield a higher pulse velocity. This non-destructive test is in accordance to BS 12504-4.

5. Results and discussion
The results for this study comprise two findings for fresh concrete which are slump test and compaction factor test and hardened concrete namely compressive strength and UPV test.
5.1. Slump test

As the sieve analysis completed, the fresh concrete testing was conducted in order to determine the workability of all four concrete mixes. The slump test is the methods which were employed in this study for measuring consistency of the mix. Based on the slump test results in Figure 2, the slump value of control sample is 90 mm which is being classified as True Slump and has a high workability. On the other hand, the slump value for control mix is actually 100 mm based on design mix calculations which is classified under slump class S3. Moreover, a 5% partial replacement of sand with durian sawdust has a true slump since the slump value determined is 85 mm but it has a low workability. This is because durian sawdust had absorbed the water content for the mix design. After that, it was measured that 10% partial replacement of sand with durian sawdust produced a slump value of 65 mm which being classified as a shear slump with low workability. Finally, it was measured that 15% partial replacement of sand with durian sawdust produced a slump value of 30 mm which being classified as a shear slump with low workability.

![Slump test result](image)

**Figure 2. Slump test result.**

True slump is the most desirable result since the concrete mix was able to maintain the form of the mold and not significantly subsidize. Based on the observation, the control mix and 5% durian sawdust replacement are the only concrete mix achieved true slump. The other two mix designs shown low workability since there is a significant increase of durian sawdust in the concrete mix which increases the rate of water absorption in concrete mix.

5.2. Compressive strength development analysis

The results obtained from compressive strength test for all the mixes are given in figure 3. It was observed that the compressive strength of concrete with durian skin saw dust as partial replacement notably dropped as more composition is being replaced with respect to sand. The control specimen shows a rise in compressive strength conforming to achieving the target mean strength from 29.10 MPa on 7th day, to 34.06 MPa on 14th day, to 38.6 MPa on 28th day.

On the same hand, the concrete with 5% durian sawdust also exhibited an increment in strength from 13.78 MPa on 7th day, to 16.31 MPa on 14th day, to 21.41 MPa on 28th day. This gradual increase in strength from concrete containing 5% durian sawdust gave the most acceptable result which the exceeded M20 strength limit (20 MPa).

In contrast, the concrete with 10% durian sawdust as a partial replacement for sand which exhibited compressive strength results that is significantly decreased from 4.73 MPa on 7th day, to 3.17 MPa on 14th day, and 3.14 MPa on 28th day. Lastly, concrete with 15% durian sawdust partial replacement shows the exact trend as 10% durian sawdust replacement but had the least compressive strength results from 2.19 MPa on 7th day, to 1.52 MPa on 14th day, to 0.94 MPa on 28th day. Based on the
compressive result for 10% and 15% durian sawdust replacement concrete, both samples only can be used as a non-structural component for construction since it is not following the requirement of the target M20 strength.

This issue occurred because of the durian sawdust has a characteristic of high water absorption, which definitely reduced the strength and workability. Nevertheless, this finding cannot be generalized to the rest of the varying samples as more sawdust is removed, there is a higher water absorption level which weakens the bond between concrete constituents. Therefore, the origin of its strength through the hydration cycle from the water-cement paste should exhibit a significant decrease in compressive strength.

This study shows that the compressive strength is directly affected by the amount of durian sawdust replacement. In order to reduce environmental degradation associated with mining of river sand, durian sawdust can be used to replace river sand up to 5% replacement since they have exceeded the target M20 strength at 28 days (20 MPa), which have enough strength and density to be used as a structural component.

Abdullahi et al. [7] explained that there was systematic loss of strength with each subsequent concrete mix as more natural fibre sawdust was being replaced with sand. Even after repeating the tests, the cause for low strength and workability are because of the natural fibre has higher rate of water absorption as compared to the other fine aggregate replacements. In addition, durian sawdust has larger surface area than sand, which indicates that it has a lower density and greater porosity than sand. Thus, durian sawdust has less strength than natural sand [7].

Figure 3. Compressive strength of concrete mixes.

5.3. Ultrasonic Pulse Velocity (UPV) test analysis
Figure 4 indicates the control sample concrete UPV values are 3.70 km/s, 3.92 km/s, and 4.08 km/s for 7, 14 and 28 days respectively. Meanwhile, the UPV values for 5% durian sawdust concrete mix increment was recorded as directly proportional as the concrete age from 2.88 km/s, to 2.94 km/s to 3.13 km/s at 7, 14 and 28 days, respectively. The 5% replacement has the same increasing trend as control sample concrete. Therefore, it can be classified as having a good condition at 28 days [8]. In addition, it also indicates that 5% durian replacement concrete has a good strength and showed little presence of void.

On the other hand, the results values for 10% durian sawdust replacement show a noticeable drop in UPV from 2.45 km/s to 2.27 km/s to 2.10 km/s at 7, 14 and 28 days, respectively which caused by the presence of void and slightly high porosity. The values showed that the concrete is not in a great state but still the condition of the concrete can be considered as fair because the velocity pulse values are still in the range of 2 km/s to 3 km/s.

It can be seen that 15% durian sawdust replacement indicate that the condition rating of concrete had downgraded to very poor concrete as the amount of durian sawdust increase in the concrete. The
result shows concrete containing 15% durian sawdust demonstrated a notable drop in UPV values from 1.40 km/s at 7 days, to 1.21 km/s at 14 days, to 1.16 km/s at 28 days.

This phenomenon occurred because of the consistent appearance of voids and high porosity in the concrete. This also explained that gradual rise on permeability of water in the concrete which reduced both its strength and quality. These results have the similar findings with Abdullahi et al. [7]. Large amount of saw dust content in concrete had caused a gradual drop in UPV values as the density and the quality of concrete decreases when the concrete aging time increases [7].

![Figure 4. UPV values for concrete mixes.](image)

6. Conclusion

The purpose of this study is to conduct a complete research on durian skin sawdust, a natural fibre from waste material to be used as a partial replacement for fine aggregate in the concrete mix. The suitability of the sawdust in concrete was completely tested to measure the possible changes and the causes. The optimum strength for durian skin fibre can be achieved with the maximum replacement of only 5% durian sawdust. From the observation, the strength of concrete mix is inversely proportional with the amount of durian sawdust. The more the amount of durian sawdust, the lower the strength of the concrete. This phenomenon happened due to the high-water absorption of durian sawdust. Therefore, durian sawdust is not suitable to replace river sand as fine aggregate.

7. References

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**Acknowledgments**

The authors would like to express their deep gratitude to Dr. Kamsiah Mohd Ismail, former lecturer from Department of Civil Engineering, IIUM, the financial support of the IIUM Research Acculturation Grant Scheme (IRAGS) from International Islamic University Malaysia (IRAGS18-029-0030), the staff from Department of Civil Engineering and Department of Manufacturing and Material Engineering for their helps in finishing this study and International Islamic University Malaysia for providing the facilities.