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MECHANICAL AND THERMAL PROPERTIES OF SAWDUST CONCRETE

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Abstract

Industrialization in developing countries has resulted in an increase in agricultural output and consequent accumulation of unmanageable agro wastes. Pollution arising from such wastes is a matter of concern for many developing nations. The aim of this study is to investigate the behavior of lightweight concrete and the utilization of sawdust as waste material in concrete. This paper focuses on the manufacturing of concrete which possess long duration heat transfer by using sawdust waste. In this research, cement to sawdust ratio of 1:1, 1:2 and 1:3 by volume was prepared for sawdust concrete, and the ratio of sand was kept constant that is 1. At these ratios, the mechanical and thermal properties like density, workability, strength and heat transfer were measured after, 7, 28 and 56 days of air curing. The tests results show that with the increase in the amount of sawdust, the workability, compressive strength, tensile strength and flexural strength decreased. It also resulted in reduction of heat transfer of sawdust concrete. Taking into account the overall physical and mechanical properties, sawdust concrete can be used in construction technology.

Keywords: Sawdust, lightweight concrete, mechanical properties, heat transfer

1.0 INTRODUCTION

The sawdust technology first research was carried out in the period of 1930's, and the research on sawdust was also carried out and applicable in the United State of America, Germany United Kingdom and also Singapore and Malaysia[1]. In tropical countries, sawdust is available in bulk within cheap rates; researches have been made to check the appropriateness of this material for possible applicable in construction of building in the Singapore-Malaysia region[2, 3] and sawdust can be obtained from almost every wood factory tree. The type of sawdust depends on the variety of wood from which it is obtained and the particle size of sawdust[4]. Waste sawdust material has been widely used as partial replacement of sand for making sawdust concrete but ensure that strength of overall structure is strong and secure without reliance on the sawdust cement infill [5].

Sawdust concrete must be examined before using it for the construction because of it has serious limitation of low compressive strength. In spite of this limitations, the sawdust concrete provides benefit by reducing the weight of overall structure which is transmitted to the base (Foundation) of structure. As compared to high economy, sawdust concrete has benefit over normal weight concrete. Because of its lightness in weight it reduces damage and extends the life span of formwork. It is easy in handling, mixing and placing as compared to other types of concrete. Sawdust concrete has higher percentage of void which improve the sound absorption property[6, 7]. For the sawdust concrete the thermal conductivity was reduced up to 35% when the use of sawdust as wood aggregate vary from 0 to 10 %. [8]. For reducing the weight of concrete, sawdust has received some attention in the past few years, the behavior of sawdust concrete have shown encouraging results[10].

In economic development, the reason for applying recyclable material in the construction industry is due to increase in environmental awareness of societies and ecological[11, 12] and renewable materials within a human life period[13]. Due to the decreasing deposits of natural aggregates which are used as basic building materials, as well as environmental reasons with the use of waste materials, such as sawdust and shaving [14, 15] and organic materials, such as hemp and straw, is becoming justified in concrete technology [16, 17]. For many years, large number of researchers have used tree waste and plant fillers in lightweight concrete[18].

The lightweight aggregates, which are used in concrete are mostly porous material, whose water absorption is usually higher than that of normal aggregates[19]. The nature of wood is fibrous; the arrangement in the tree and the properties of these fibrous cell has an effect on the strength and stiffness.[6]. That is why in this research the fresh properties, physical properties and mechanical properties of sawdust concrete were investigated in order to achieve the best mix proportion for suitable strength for lightweight concrete. Nowadays, global warming is a major issue of the world and green materials are in priority aspects for material use consideration. For saving the energy consumption for building, it is necessary to decrease the heat transfer of the roofing system and member of structures. A number of advantages of wood-crete over other conventional wood composite materials include better insulation properties, resistance to water absorption, fire performance and strength properties [20]. Therefore, the effect of heat on sawdust concrete, the thermal behavior of sawdust concrete and finding the best mixture proportions for the purpose of saving the energy (heat transfer) were investigated.

The main scope of this research is also the utilization of wooden sawdust waste in the construction field in order to get as much benefits as possible so that the cost of construction can be reduced as well as problem to the environment and also make the residential area cool inside because due to climate change temperature of environment is increasing. Implementation of waste sawdust not only decreases environmental damage but also saves the concrete materials. The implementation of waste sawdust could also be generalized to the use of straw in a countryside, which could lead to an environmental saving profit.

2.0 METHODLOGY

In this study, Portland cement was the basic ingredient of concrete and Type I cement was used. The chemical compositions of the cement is expressed in percentages by mass of the constituent oxides are shown in Table 1. The tap water, which was available in laboratory was used. The fine aggregate used in this study was natural beach sand with 100 percent passing ASTM Sieve No. 4.75 mm. Sand was also dried in oven to reduce the moisture. The sawdust, which is used in this research as shown in Figure 1, was obtained from local wood factory in Johor Bahru, Malaysia. It has very fine Particles whose density is 174 kg/m^3.

Table 1 Chemical and physical properties of OPC

No.	Oxide composition by mass (%)	OPC
1	SiO_2	21.03
2	Al_2O_3	6.16
3	Fe_2O_3	2.58
4	CaO	64.47
5	MgO	2.62
6	Na_2O	0.34
7	K_2O	0.61
8	LOI	1.73
9	Specific gravity	2.94

Figure 1 Wooden Sawdust

2.1 Sample Preparation

Three concrete mixtures were prepared with cement to sawdust ratio of 1:1, 1:2 and 1:3 with the water cement ratio of 0.65, 1.00 and 1.40, respectively and the ratio of sand was 1 among all mixtures. Before mixing, the sawdust was treated. The treatment for sawdust was done by soaking the sawdust in container filled with water for one hour and then it was kept 15 minutes on mesh in order to drain the water from sawdust. After batching all of the constituents, sand, cement was placed inside the mixer and first mixing sand and cement then the sawdust was introduced into the mixer. They were mixed until all the constituents were mixed uniformly before the addition of water.

2.2 Test Methods

The tests for the fresh and hardened properties of concrete were conducted to determine the deformation behavior of sawdust concrete. Slump test was conducted during concrete casting to measure the workability of the fresh concrete. This test was performed in accordance to BS EN 12350-2-2009 for each batch of concrete. Density for the concrete cubes samples was calculated according to ASTM C642. The compressive strength test was conducted on the cubes according to BS 1881-116. The split tensile test was performed on the standard test cylinders according to ASTM C496. Flexural strength test was done according to BS EN 12390-5 on prism specimen. Heat transfer test was conducted on cylindrical specimen, which was carried out by non-standard test following previous researchers.

2.3 Heat Transfer Test

Heat transfer test was conducted on cylindrical specimen of 150 mm diameter and 300 mm height. After casting for 28 days drying surfaces of samples, the specimens were covered with a thin plastic sheet to prevent excessive entranced of water. In order to protect the thermocouple against sudden impacts, a PVC pipe with 2 cm diameter was used. All samples were placed in the water tank while temperature of water was kept about 34 °C. Water temperature was gradually raised to 100 °C. The first measurement of samples when the test was started and recording the temperature was continued up to 100 °C inside the whole samples. Then it was turn on the boiling water tank and record the inside temperature of samples by K thermocouple, data logger and computer. When the sawdust concrete was put into the water tank, heat was raised by the heater that subsequently increased the temperature of the water. This increase in temperature was monitored with close intervals during the first 24 hours until 100 °C. As shown in Figure 2.

Figure 2 Equipment of heat transfer test

3.0 RESULTS AND DISCUSSION

3.1 Workability

From the results, all the slumps of fresh sawdust concrete were within the limit range between 30 – 60 mm. It can be seen that addition of sawdust tends to decrease the slump value. Thus, the result reveals that sawdust decreased the workability as shown in Figure 3. Workability is reduced due to addition of lightweight aggregate that is sawdust

3.2 Density

Cube sawdust concrete specimens with the dimensions of 100mm ×100mm ×100 mm were made to determine the 7-days, 28-day and 56-days density of the sawdust concrete using different cement sawdust ratio of 1:1, 1:2 and 1:3. The objective was to find the sawdust concrete with a higher density which can leads to better mechanical properties for the lightweight concrete. The lightweight aggregate density range limit is 300 kg/m^3 to 1800 kg/m^3. All the densities of sawdust concrete comes in the range of lightweight concrete but the cement sawdust ratio 1:1 has higher density among all in 7 days, 28 days and 56 days that is 1876 kg/m^3, 1837 kg/m^3 and 1800 kg/m^3, respectively as shown in Figure 4. In the ratio 1:2 and 1:3 decrease due increase amount of lightweight aggregate sawdust.

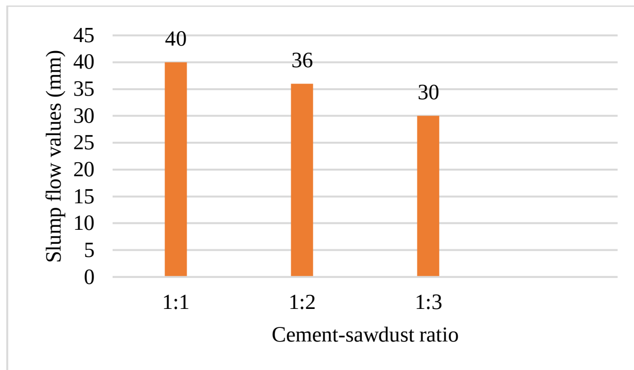

Figure 3 Slump flow values of sawdust concrete

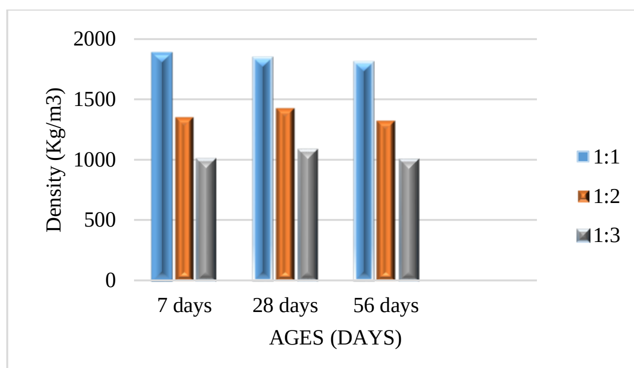

Figure 4 Density of 1:1, 1:2 and 1:3 sawdust concrete at 7, 28 and 56 days

3.3 Compressive Strength

The increment strength with age could be as a result of continuity of hydration process. This indicates that compressive strength is lowered with the addition of more sawdust at the earlier age but it will be increased on a later age of concrete. A 100 mm x 100mm x100 mm cubes were prepared using 1:1. 1:2 and 1:3 cement sawdust ratio with water/cement ratios of 0.65, 1.00 and 1.40, respectively. The relationship between average compressive strength and curing period of concrete with 0.65, 1.00 and 1.40 water/cement ratios are shown in Figure 5. The maximum average compressive strength of 19.53 MPa was recorded for 1:1 cement sawdust ratio sample at 56 days. Significant amount of strength reduction was noted for the samples containing 1:3 of cement sawdust in earlier stage due to high ratio of sawdust but it has increased at later age.

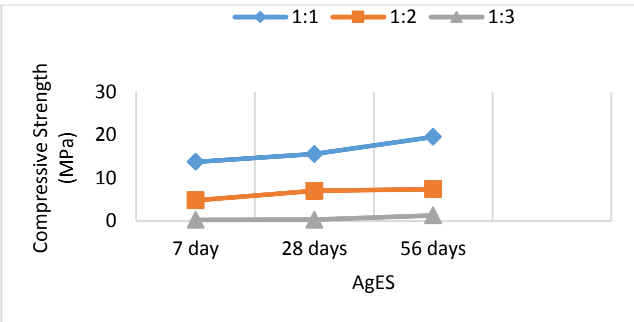

Figure 5 Compressive strength of sawdust concrete

3.4 Splitting Tensile Strength

Cylindrical Specimens of 100 mm diameter and 200 mm height were tested to determine the indirect tensile strength of sawdust concrete. The tensile strength test results of sawdust concrete cylinder at 7 days, 28 days and 56 days are shown in Figure 6. A similar trend to the compressive strength was observed for split tensile strength development in sawdust containing samples. The split tensile strength of sawdust concrete was significantly low. However, samples with 1:1 of cement sawdust showed good strength. Highest strength of 4.1 MPa was recorded for 1:1 of cement sawdust with 0.65 water/cement ratio.

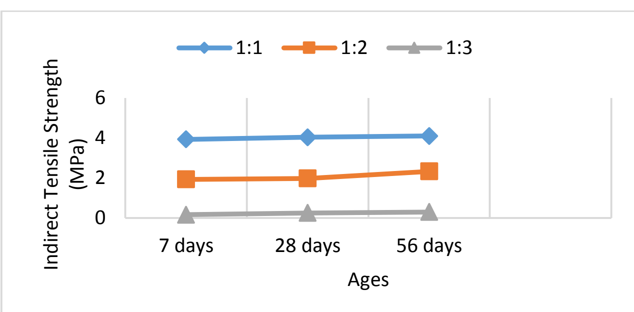

Figure 6 Split tensile strength of sawdust concrete

3.5 Flexural Strength

The test was done by using 100x100x500 mm prism specimens. The maximum load sustained was recorded and the average flexural strength was calculated at the age of 7, 28 and 56 days. Figure 7 shows the gain in strength with 0.65, 1.00 and 1.40 water/cement ratio. Similar to compressive strength and tensile strength, the flexural strength of concrete specimen also followed the same trend; the higher the amount of sawdust the lower the flexural strength. However, the graph shows rapid increase tendency of 1:1, 1:2 and 1:3 ratio of cement sawdust concrete at later ages. Highest strength of 5.77 MPa was recorded for 1:1 ratio cement sawdust and lowest strength of 0.77 MPa was recorded for specimen containing 1:3 ratio cement sawdust at the age of 56 days.

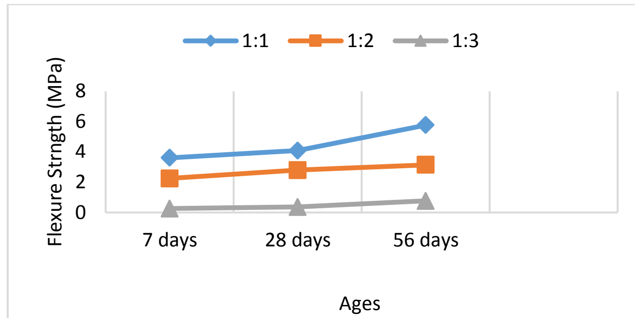

Figure 7 Flexural strength of sawdust concrete

3.6 Heat Transfer Test

It has been observed that during the initial stage, the temperature rises due to heat of hydration of all the specimens and was approximately equal as shown in Figure 8. However, as the age of concrete increased the influence of sawdust on heat transfer was observed. The specimens containing 1:3 cement sawdust demonstrated lower temperature rise as compared to the 1:1 and 1:2 sample. Sawdust concrete with 1:3 cement to sawdust ratio successfully reduced the total temperature rise compared to the 1:1 and 1:2 cement to sawdust ratios. Although the initial temperature of the water was approximately same, more heat transfer was considerably obtained from the 1:1 sawdust concrete during the period of experiment.

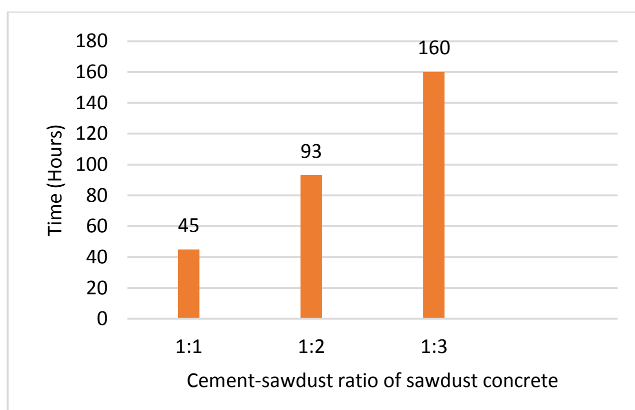

Figure 8 Heat transfer hours of sawdust concrete

4.0 CONCLUSION

The thermal and mechanical properties of sawdust concrete were investigated based on a set of experiments. Based on this study the following conclusions can be drawn:

- Sawdust concrete have low workability having slump in the range of 30 to 40 mm
- Density of sawdust concrete is less as compared to normal concrete hence it can be regarded as light weight concrete.
- Among the three mix ratios, the 1:1 ratio performed the best result in terms of strength gain.
- Despite lower strength gain, the concrete with 1:3 mix proportion exhibited the best performance in terms of heat transfer; the more the sawdust content the lower was the heat transfer.

Significance outcome of study is that sawdust material can be used in the construction industry as eco-friendly material to environment.

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