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SOME ASPECTS OF PHYSICAL AND MECHANICAL PROPERTIES OF SAWDUST CONCRETE

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ABSTRACT: This paper presents experimental results on some physical and mechanical properties of concrete containing sawdust. Concrete specimens having various cement to sawdust ratios of 1:1, 1:2 and 1:3 by volume were made and tested for workability, density, water absorption, strength and modulus of elasticity at different curing periods of 7, 14 and 28 days. It has been found that with the increase in the amount of sawdust, the workability and density of concrete decreased; the water absorption capacity of concrete, however, increased with the increase in volume. Although the strength of sawdust concrete increased with curing period, the strength and the corresponding modulus of elasticity decreased with the increasing amount of sawdust in the mix. The results obtained and the observation made in the short-term investigation suggests that sawdust concrete can suitably be used as a building material in construction.

Keywords: Timber waste, Sawdust concrete, Physical properties, Strength, Deformation.

1. INTRODUCTION

Vast quantities of waste materials and by-products from various sources are generated from the manufacturing process, service industries and municipal solid waste. As a result, solid waste management has become one of the major environmental concerns in the world. With the increasing awareness of the environment protection, significant research has been going on globally on the utilization of waste materials and by-products as construction materials [1]. Recycling of such wastes into new building materials could be a viable solution not only to the pollution problem, but also to the challenge of high cost of building materials currently facing by both the developed and developing nations [2-3]. One of such potential waste material is sawdust which is relatively abundant and inexpensive.

Sawdust or wood dust is an industrial waste obtained as by-products from cutting, sawing or grinding of timber in the form of fine particle (Fig. 1). Sawdust bonded with cement is also known as 'sawdust cement' [4]. Although sawdust consists largely of cellulose (Fig.2), it also contains soluble sugar, acids, resins, oils and waxes, and other organic substances which have an inhibiting effect on the setting and hardening of the cement. Despite setting and hardening problems, most of the softwood sawdust is rendered compatible with the cement if a mixture of lime or cement is used as the binder [6]. The use of cement, sawdust and sand for making floor and wall panels has been fairly common in many parts of the world. Being versatile, this material can be used as eaves, cladding, ceiling, and even roofing with some adaptation and modifications.

Fig. 1 Sample of sawdust used in the study.

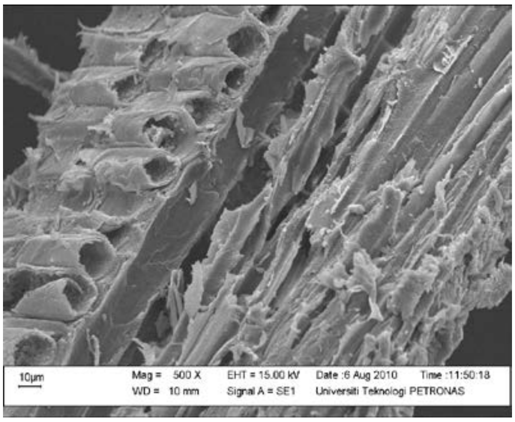

Fig.2 Scanning electron micrograph (SEM) of sawdust particles [5].

Depending on type, sawdust has been identified to be an ideal filler material to produce hollow concrete blocks [7-9]. The strength of concrete, however, reduces with the increase in sawdust volume. Paramasivam and Loke [10] found that sawdust concrete with a cement to sawdust ratio of 1:1 has good bond strength and comparable to the normal concrete. The drying shrinkage, however, is very high; almost 10 times as great as in most other lightweight concretes, and thus greatly limits the usefulness of this material. In spite of the limitations, sawdust concrete has a good insulation value, resiliency, low thermal conductivity and can be sawed and nailed [11].

With the advancement in concrete technology, the utilization of sawdust in the manufacture of building materials has received some attention over the past years. Along with the application in making bricks and blocks, the utilization of sawdust in producing structural lightweight concretes appears to be a unique answer not only to the environmental problem but also to the economic design of sustainable building construction [12]. Considering the availability and the inherent quality of the material, this study aims at exploring further the suitability of sawdust as building material through investigation of physical and mechanical properties of concrete.

2. MATERIALS AND TEST METHODS

2.1 Sawdust and Concrete Mix Proportions

Sawdust used in this study was collected from a local plank and furniture market of Johor Bahru, Malaysia. The sawdust consisted mostly of fine chippings from rubber tree (Fig. 1). In the case of light weight aggregate, it is generally recommended that the proportions are specified in terms of volume rather than by weight because the bulk specific gravities are not in the same order due to different sizes of grain particles [10]. In this study three mix proportions of cement to sawdust in the mixing ratio of 1:1, 1:2 and 1:3 by volume were utilized and the cement used was an ordinary Portland cement (ASTM Type I).

By nature, sawdust particles are porous and absorb most of the water leaving insufficient water for the setting of cement. It is also presumed that if sawdust particles take up enough water during hydration, they could aid the hydration process particularly in the inner parts of concrete that is not possible to cure with water thus eliminating the need for curing since water deposited in sawdust particles are being harvested by cement particles. The water cement ratio of sawdust concrete usually varies from 0.4-1.2 depending on the mix proportions. In this investigation the sawdust particles were treated to saturated surface dry state to reduce the effect of water absorption by the particles. Following several trials, the water-cement ratio of 0.6 was adopted for the study. Throughout the study, supplied tap water was used for mixing of concrete.

2.2 Casting and Testing of Concrete Specimens

Concrete specimen comprising of cube (100mm), cylinder (100x200 mm) and prism (100x100x500 mm) were cast for determining compressive, tensile and flexural strength respectively. The specimens were cast in metal moulds and were demoulded after 24 hours, and cured by polythene sheeting until testing time. Casting and testing of concrete specimens were done in the Structure and Materials laboratory of the Faculty of Civil Engineering, Universiti Teknologi Malaysia. The ambient temperature and relative humidity in the laboratory was 27 ± 3˚C and 85 ± 5% respectively.

The strength tests for compression, tension and flexure were conducted according to BS 1881: Part 116 [13], ASTMC496-05 [14] and BS1881: Part118 [15] standards respectively. While the tests on modulus of elasticity of concrete were conducted in accordance with the standard stipulated in ASTM 469-05 [16]. Along with strength measurement, ultrasonic pulse velocity (UPV) was also measured on the test specimens.

3. RESULTS AND DISCUSSION

3.1 Physical Properties

The physical properties of sawdust concrete are presented in Table 1. The consistency of the fresh mix, tested in terms of slump has been found to vary depending on the amount of sawdust in the mix. In general, higher the amount of sawdust lower was the slump. Slump values of 40, 15 and 5 mm were obtained for mix ratios of 1:1, 1:2 and 1:3 respectively, and were found to fall within the medium, low and no-slump ranges according to Euro code Standard classifications (BS EN 206-1) [17]. Similar observation has been made by Oyedepo et al. [18]

The density of sawdust concrete measured at 28 days for the mix ratios of 1:1, 1:2 and 1:3 are 1450, 1280 and 1065 kg/m^3 respectively. The test results show that the density values are inversely proportional to the volume of sawdust content. By assuming the average density of OPC concrete to be 2400 kg/m^3, the mix proportion of 1:1 provides about 40% reduction in density. This reduction highlights the potentials of sawdust concrete to be used as lightweight building material in construction.

The water absorption, expressed as percentage, was obtained by measuring the amount absorbed against the dry mass. Unlike slump and density, the water absorption of sawdust concrete was found to increase with the increasing amount of sawdust in the mix. This is obvious, because sawdust is relatively porous than the aggregates like sand, stone etc. used in normal concrete mixes [19].

Table 1 Physical properties of sawdust concrete

Mix ratio	Slump (mm)	Density (kg/m^3)	Water absorption (%)
1:1	40	1450	13
1:2	15	1280	15
1:3	5	1065	19

3.2 Compressive Strength

The compressive strength test was conducted on concrete cube specimens (Fig. 3) and the results obtained for the three mixes are illustrated in Fig. 4. The results presented in the figure showed an average strength development of 14.45, 13.60 and 8.40 MPa obtained at the age of 7 days for the mix ratios of 1:1, 1:2 and 1:3 respectively. A slight increase in the strength was found to occur after 14 days.

Fig. 3 Testing of concrete cube specimen for compressive strength.

At the age of 28 days there was a significant increase in compressive strength in all the mixes. Strength values of 18.65, 17.20 and 12.80 MPa, for instance, were obtained for the mix ratios of 1:1, 1:2 and 1:3 respectively. From the results obtained it is clear that the strength of sawdust concrete decreases with an increase in the volume of sawdust in the mix proportions. A somewhat similar observation in the development of strength of sawdust concrete has been made by Akinwonmi [20]. In an investigation on fracture behavior of concrete, a compressive strength value of 15.9 MPa was obtained for 20% replacement of sand by sawdust at the age of 28 days.

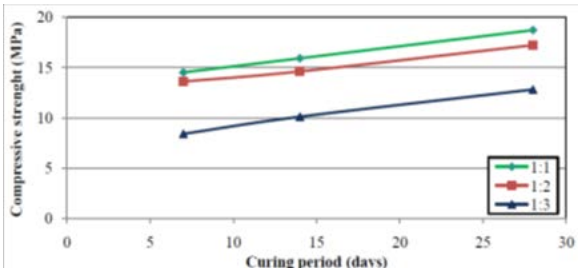

Fig. 4 Development of compressive strength of concrete.

Figure 5 illustrates a liner relationship between the compressive strength and ultrasonic pulse velocity (UPV) of sawdust concrete at the age of 28 days. Even though the UPV values increased with the increase in compressive strength, the highest value of 2620 m/s obtained for 1:1 ratio falls within the low quality range [11].

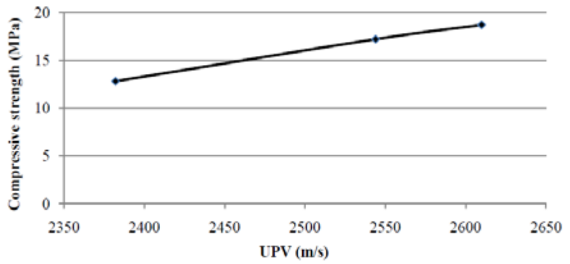

Fig. 5 Relationship between compressive strength and ultrasonic pulse velocity (UPV) of concrete.

3.3 Tensile Strength

The splitting tensile strength of sawdust concrete was also determined (Fig. 6) at the age of 7, 14 and 28 days, and the results are presented in Fig. 7. The development of splitting tensile strength was almost similar to that observed in the case of compressive strength i.e. splitting tensile strength decreased with the increase in the amount of sawdust. For example, at 28 days the strength values of 2.05, 1.95 and 1.30 MPa were obtained for mixes of 1:1, 1:2 and 1:3 respectively.

The relationship between the compressive and tensile strength of sawdust concrete is shown in Fig. 8. It can be observed that the relationship is somewhat liner i.e. compressive strength is proportional to the tensile strength; however, the value of the relationship diminishes with the increase in sawdust mix ratio.

3.4 Flexural Strength

The flexural strength test was conducted on concrete prism specimen (Fig. 9) at the age of 28 days and the results are presented in Fig. 10.

Fig. 6 Determination of tensile strength.

Fig. 9 Determination of flexural strength of concrete

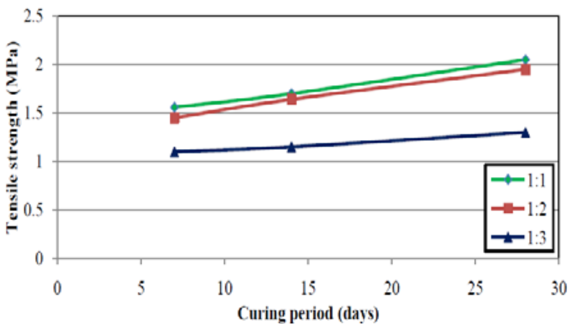

Fig. 7 Development of tensile strength of concrete.

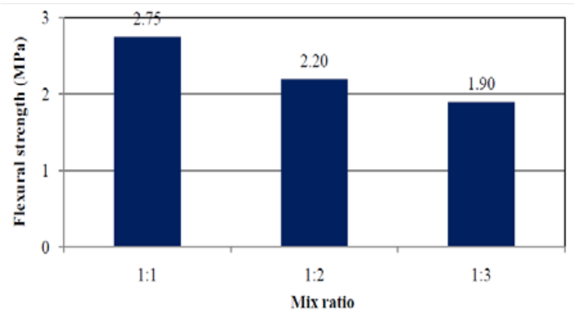

Fig. 10 28-day flexural strength of sawdust concrete.

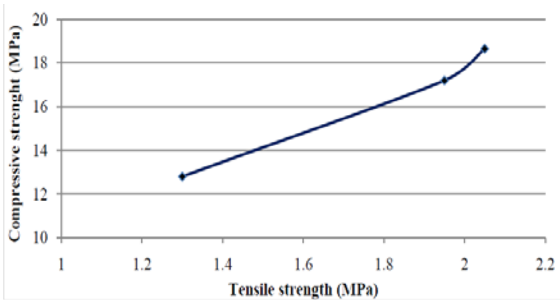

Fig. 8 Relationship between compressive and tensile strength of concrete.

It has been found that like that of compressive and tensile strength, the flexural strength of sawdust concrete also followed the same trend. For example, when the mix proportions changed from 1:1 to 1:2, the flexural strength decreased from 2.75 to 2.20 N/mm^2, which represents a decrease of about 35%. While, a loss of about 30% occurred with the lean mixes from a ratio of 1:2 to 1:3.

The relationship between compressive strength and flexural strength of sawdust concrete is demonstrated in Fig. 11. Although there was a progressive increase in the two parameters, as can be seen in the figure, the relationship is not liner as observed in case of compressive and tensile strength.

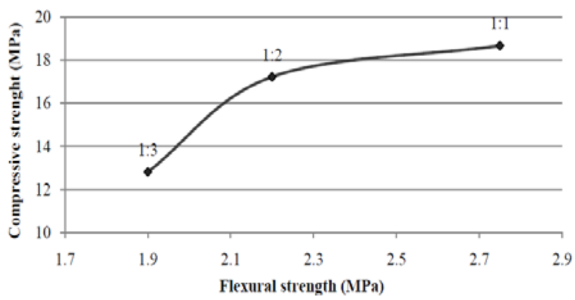

Fig. 11 Relationship between compressive strength and flexural strength.

3.5 Modulus of Elasticity

The modulus of elasticity of sawdust concrete was experimentally determined (Fig. 12) at the age of 28 days. Along with the experimental data, values obtained using theoretical model are shown in Fig. 13. Elastic modulus of 17.10, 16.40 and 11.95 GPa were obtained for the mixes of 1:1, 1:2 and 1:3 respectively while 20.30, 19.50 and 16.0 GPa were calculated using theoretical model for the same mix ratios. Although, moduli of elasticity of theoretical models were somewhat higher, data obtained from the experimental work are quite satisfactory.

Fig. 12 Determination of modulus of elasticity of concrete.

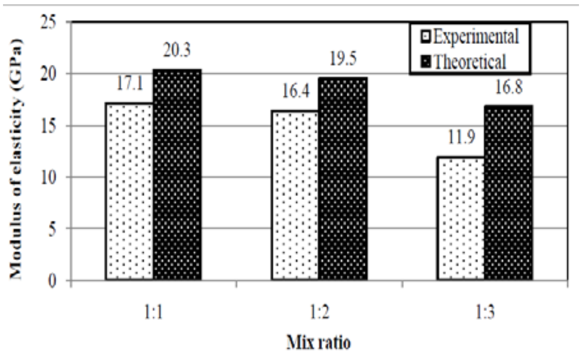

Fig. 13 Modulus of elasticity of sawdust concrete.

4. CONCLUSION

In this study sawdust concrete with various cement to sawdust ratios, by volume was made and the physical and mechanical properties were investigated. This paper highlights the potential benefits of sawdust concrete in terms of physical and mechanical properties. The results obtained and the observations made in this study conclude that sawdust concrete can be used as light weight concrete with a satisfactory strength performance. Long-term strength development including durability aspects has been put forward as recommendation for future study in order to explore better understanding of sawdust as a sustainable building material in construction.

5. ACKNOWLEDGEMENTS

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