Jurnal
Teknologi

Full Paper

PERFORMANCE OF SAWDUST CONCRETE AT ELEVATED TEMPERATURE

Article history
Received
25 November 2016
Received in revised form
16 June 2017
Accepted
10 October 2017

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Abstract

The aim of this study was to shows the behavior of sawdust concrete at elevated temperature. Sawdust is considered as waste material but nowadays this waste material is utilized in the construction of the building as sawdust concrete. Sawdust is a by-product of wood which is generally used in the production of lightweight concrete, possessing low thermal conductivity. In this study sawdust concrete was made at three different proportions of cement and sawdust 1:1, 1:2, 1:3 by volume. At these proportions, the physical and mechanical properties such as density, workability, strength, fire resistance, mass loss, ultrasonic pulse velocity and residual strength were investigated after 28 days of curing. It was found that with the increment in the amount of sawdust, the workability and strength decreases, however in terms of fire resistance, concrete with lower amount of sawdust performed well. Considering the overall physical and mechanical properties, sawdust concrete can be used in building construction.

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

1.0 INTRODUCTION

The scientific community and construction industry has been getting great interest in using waste products because of uses of waster products, and it was .in this area that a search was made for a spherical or approximately spherical particle (Murray and Liversidge, 1978). In North America, there was an interesting evolution the area of Wood construction because of the large quantity of timber available and widely spread development of much of the country. Native Americans built homes of poles or planks (Phan, 1996).

Sawdust is a waste from timber which is produced in wooden industries. It is obtained from sawing of timber result in the form of as loose particles and into standard useable sizes (Ogunleye, 2009, Onwuka *et al*., 2013). Many previous researches undertaken on the concrete production by utilizing the industrial waste which results are satisfactory to use in construction industry. For instance, over the past years it has taken attention to utilize the waste rubber, glass powder and paper waste sludge in concrete mix. Some research carried out in the past used wood ash in the concrete mix instead of using cement (Elinwa and Mahmood, 2002, Turgut and Algin, 2007).

In many countries Sawdust concrete has been studied and it was used so many years in the construction industry as a light weight concrete. Sawdust is easily available in large amount in tropical countries and cheap, attempts have been made to investigate the suitability of this material for possible use in building construction in the Singapore-Malaysia region. (Adebakin *et al*., 2012, Boel *et al*., 2008, Mageswari and Vidivelli, 2009). Sawdust is composed of fine particles of wood. Because of several factors such as type of wood can varies the physical and chemical properties of sawdust concrete

It was investigated the properties of sawdust in varying properties, where they found the compressive strength to be quite satisfactory. Recently studied in detail the physical and mechanical properties of sawdust concrete (Awal *et al*., 2016). 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 (Aigbomian and Fan, 2014, Aigbomian and Fan, 2013, Ucol-Ganiron Jr, 2012) .

Sawdust concrete must be examined before using it for the construction because of it has serious limitation that is low compressive strength. Despite these limitations, the sawdust concrete as quality of reducing in the weight of overall structure which is transmitted on 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 extended life of formwork. It is easy in handling, mixing and placing as compared with other types of concrete. Sawdust concrete has large void ration which improve the sound absorption property (Memon, 2016). For the sawdust concrete thermal conductivity reduce up to 35% when the wood aggregate varies from 0 to 10 %.(Taoukil *et al*., 2011). For reducing the weight of concrete sawdust has received some attention in past few years, the behavior of sawdust concrete have shown encouraging results (Udoeyo and Dashibil, 2002, Paramasivam and Loke, 1980).

The lightweight aggregates which are used in concrete are mostly porous material whose water absorption is usually higher than that of normal aggregates. The nature of wood is fibrous the arrangement in the tree and the properties of these fibrous cell has effect on the strength and stiffness (Ansari *et al*., 2000), that is why in this research fresh properties, physical properties and mechanical properties of sawdust concrete was investigated in order to achieve best mix proportion for suitable strength for lightweight concrete. Global warming is a major issue nowadays in this 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, so to know the effect of heat on sawdust concrete the thermal behavior of sawdust concrete and find the best mixture proportions for the purpose of heat resistance of sawdust concrete was investigated.

The main scope of this research also to the utilization of wooden sawdust waste in the construction field in order to get benefit as much as possible so we can save our economy and as well as the environment. Implementation of waste sawdust cannot only decrease environmental damage but also save the concrete materials. And 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 are 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.

Figure 1 Wooden sawdust

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

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 determined to know 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 accordance to BS EN 12350-2-2009 for each batch of concrete. Density for the concrete cubes samples were calculated according to ASTM C642. Compressive strength tests 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. Fire resistance test was conducted on the sawdust concrete specimen of cube after 28th days of curing, according to ASTM E119. A non-destructive test using ultrasonic pulse velocity (UPV) was conducted.

2.3 Fires Resistance Test

The test was conducted on the sawdust concrete specimen and control specimen of (100mmx100mmx100mm) cube after 28th days of curing, according to ASTM E119, electric furnace is used for keeping the samples, where temperature increase at the rate of 10 °c/min in order to achieve desire temperature. For one hour, samples kept in furnace after achieving desire temperature which simulating the exposure conditions of real life structures. The power was shut off, for saving from thermal shock the samples are kept in the furnace till temperature comedown to the room temperature (Uysal *et al*., 2012). After the specimens cooled to room temperature, they were removed from the furnace.as shown in Figure 2.

Figure 2 Electric furnace showing concrete specimens

2.4 Ultrasonic Pulse Velocity

Ultrasonic pulse velocity is in the category of non-destructive test which was conducted with the help of apparatus and associated transducer have normal frequency of 55(Awal *et al*., 2015) as shown in Figure 3.

Figure 3 Ultrasonic pulse velocity (UPV) testing apparatus

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, which shows that addition of sawdust tends to decrease the slump value. Thus, the result reveals that sawdust decreased the workability as shown in Figure 4.

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 and for normal weight concrete limit range is 2200 kg/m^3 to 2600 kg/m^3. All the densities of sawdust concrete come 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 5.

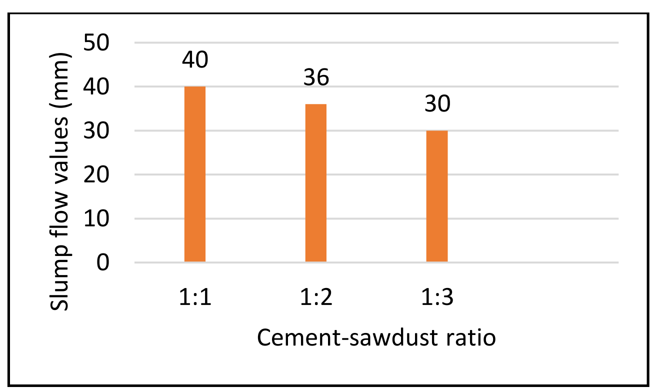

Figure 4 Slump flow values of sawdust concrete

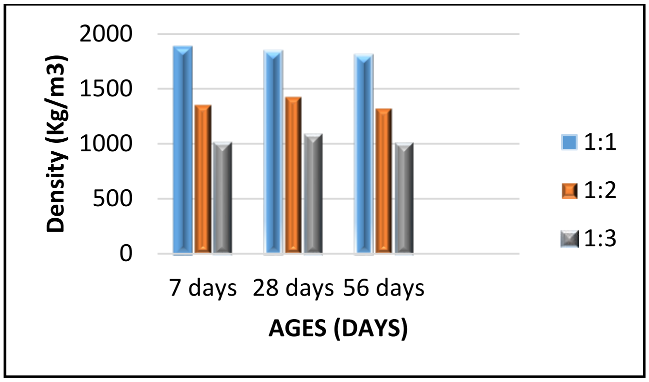

Figure 5 Density of 1:1, 1:2 and 1:3 sawdust concrete at 7, 28 and 56 days

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 6. 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 but it has increased at later age.

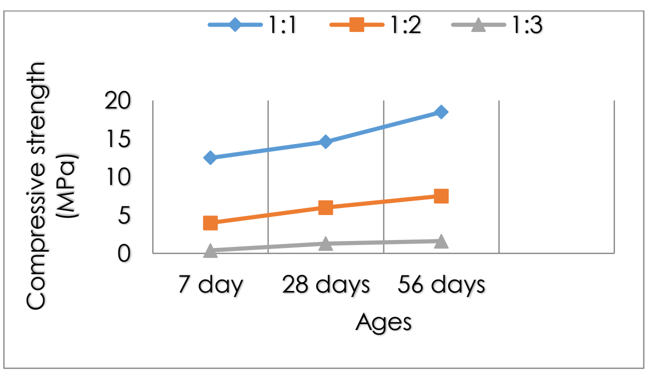

Figure 6 Compressive strength of sawdust concrete

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 7. 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.

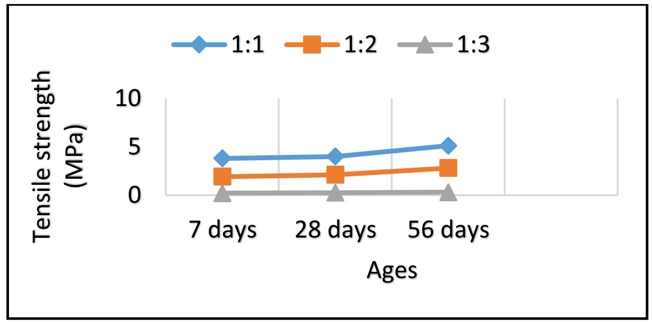

Figure 7 Split tensile strength of sawdust concrete

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 8 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.

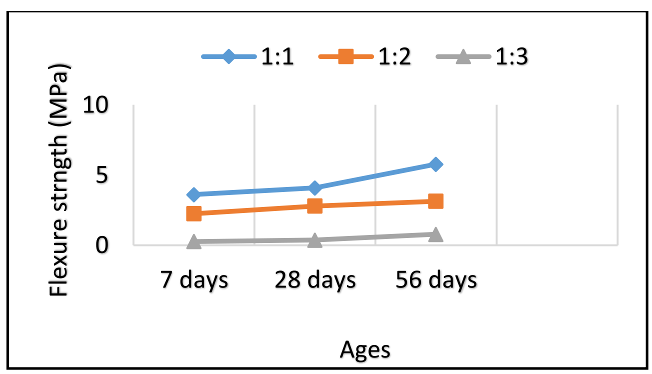

Figure 8 Flexural strength of sawdust concrete

3.6 Fire Resistance Test

3.6.1 Effect on Physical Characteristics of Concrete

In the process of the fire resistance of the concrete specimens, it was observed that the changes occur in color, at surrounding temperature 27°C and 200°C the colors of sawdust concrete was light brown, as shown in

Figure 9. This phenomenon was also same up to temperature of 400°C, as shown in Figure 10. As shown in Figure 11, at 600°C, a dark gray color appeared for the sawdust concrete, without smooth and perfect edges, no cracks in sawdust concrete. At 800°C, sawdust concrete was light gray with ash on the surface which is because of the burning of wood sawdust, with rough edges and large cracks were seen for the samples at 800°C as shown in Figure 12.

Figure 9 Surface texture of the sawdust concrete samples ratio 1:1, 1:2, 1:3 exposed to 200°C

Figure 10 Surface texture of the sawdust concrete samples ratio 1:1, 1:2, 1:3 exposed to 400°C

Figure 11 Surface texture of the sawdust concrete samples ratio 1:1, 1:2, 1:3 exposed to 600°C

Figure 12 Surface texture of the sawdust concrete samples ratio 1:1, 1:2, 1:3 exposed to 800°C

3.6.2 Ultrasonic Pulse Velocity

As shown in Figure 13. UPV value for sawdust concrete ratio 1:1, 1:2 and 1:3 at 27°C was 3030 m/s, 2000 m/s and 1428 m/s respectively which consider as fair, poor and very poor in terms of concrete quality. UPV values vary from 2857 to 2500 m/s,1818 to 1538 m/s and 1250 to 0 m/s were achieved in a temperature between of 200–400 °C, which can be categorized as poor and very poor-quality concrete for sawdust concrete ratio 1:1, 1:2, 1:3 respectively. However, in the 600–800°C temperature range, the results obtained for sawdust concrete are considered very poor in quality wise deterioration in the microstructure of the concrete cause decrease in the change of velocity.

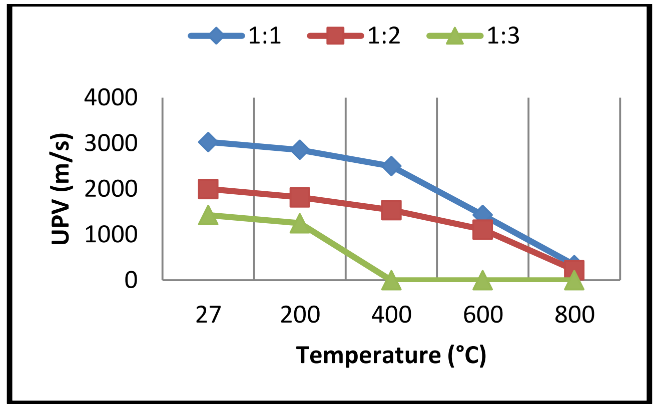

Figure 13 Average UPV values for sawdust concrete

3.6.3 Influence of Temperature on Concrete Weight

As shown in Figure 14. It can be observed that loss in weight increase as the temperature increase of test samples. In the initial region i.e., the loss in weight of sawdust concrete samples is less up to 200^{0}C. The loss observed in this region is due to moisture movement from concrete surface to the surrounding environment. The more weight loss occur in the second region 200–400°C with 15.6% high elevated loss in sawdust concrete 1:3. However, in the last region quick loss of weight occur specially temperature from 600^{0}C to 800^{0}C, where 24.8% was noticed as maximum loss occurred in sawdust concrete 1:3. Change in harden properties of sawdust is due to expose of sample in high elevated temperature. Due to high absorption of water by sawdust particles it causes more loss in weight.

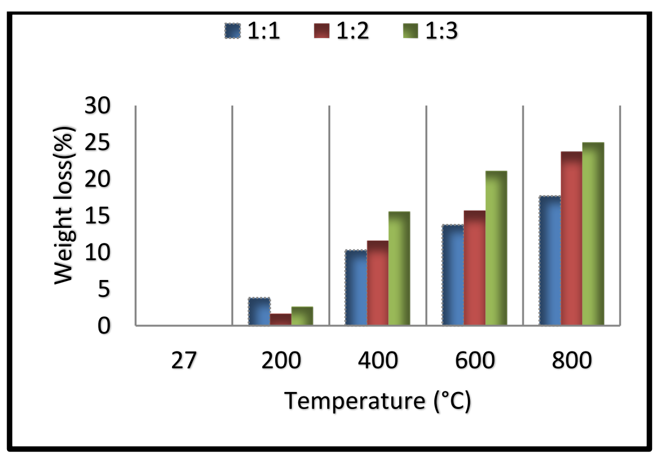

Figure 14 Weight loss of sawdust at elevated temperature

3.6.4 Residual Compressive Strength of Concrete

The results of the residual compressive strength of sawdust concrete are presented in Figure 15. It shows that the residual compressive strength of sawdust concrete, decreased steadily by increasing temperature as at the room temperature the residual compressive strength is 14.6 MPa for 1:1 of sawdust concrete same as it as for the same ratio residual compressive strength is 3 MPa . Considering the outlook of residual compressive strength obtained at elevated temperature the analysis of temperature effect has been divided into four temperature regions namely; region 1, 2, 3 and 4 with temperature ranges of 27–200°C, 200–400°C, 400–600°C and 600-800°C respectively.

These phenomena were observed in the entire cooling regime. In the first region residual strength decreased and second region can be attributed to gradual dehydration within the cement matrix, thus due to transformation from a saturated surface dry state to a dry state, it causes change in its physical properties. In the third region, a huge fall in the residual compressive strength could be due to dehydration of both calcium silicate hydrates (C–H–S) and the decomposition of calcium hydroxides that takes place at temperatures above 450°C(Awal *et al*., 2015).

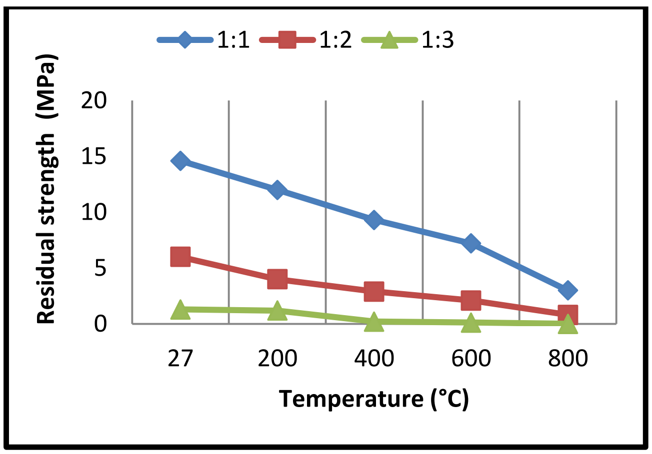

Figure 15 Residual strength of sawdust concrete at elevated temperature

4.0 CONCLUSION

The behaviour of sawdust concrete was investigated based on a set of experiments with various cement to sawdust ratios, by volume was made. The results obtained, and the observations made in this study conclude that sawdust concrete have low workability having slump in the range 30mm–40mm. Density of sawdust concrete is less as compared to normal concrete. Among the three-mix ratio, the 1:1 ratio performed the best result in terms of strength gain. The sawdust concrete with 1:1 mix proportion exhibited best performance in terms of fire resistance, the more the sawdust content lower was the fire resistance. So, it is regarded as light weight concrete with a satisfactory strength and elevated temperature performance. Significance outcome of study is that sawdust material can be used in the construction industry as eco-friendly material.

Acknowledgment

The authors would like to thank the support provided by Universiti Teknologi Malaysia in the form of providing equipment and materials for experimental work.

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