Effect of Sawdust on The Mechanical Properties of Mortar Using Local Materials

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ABSTRACT

In recent years, there has been a great tendency, especially in the field of structural engineering, to use environmentally friendly materials. Therefore, such these materials should be combined with concrete and cement mortar to obtain an environmental and cheaper structural component that has distinctive properties such as lower thermal and sound conductivity and produce lightweight members. In this study, the sand in the cement mortar of the reference mix was replaced by residues of sawdust for different levels ranging between (5, 10, and 15%) by volume. Two methods were used to cure the specimens of this study; the first by immersing the specimens in water, and the second by exposing them to the air under laboratory conditions. Different tests were conducted in order to assess; the air content of fresh mortar, consistency of fresh mortar, compressive strength, flexural strength, and conductivity. From the obtained results, as the percentage of sawdust increased, a significant improvement in sound conductivity was observed. Although the compressive and flexural strength decreased with increasing the percentage of sawdust (up to 15%), this decrease can be considered acceptable for several construction applications. Moreover, the increasing in the percentage of sawdust was noted to be accompanied by an increasing in the percentage of air content. This allows obtaining a lightweight cement mortar with suitable mechanical properties which can be used for various constructions.

Keywords: sawdust; cement mortar; sound conductivity; mechanical properties, air content.

1 Introduction

Many researches have been done on the possibility of using locally available materials to partially or fully replacement to the cement or aggregate in the concrete or mortar. Most of these materials are generally noted to be more expensive constituents. The problem of stacking of unmanaged wastes, especially in developing countries, has resulted in increasing the environmental concerns. Recycling of such wastes appears to be applicable solution not only for pollution problem but also for the economic of buildings design. The growing in the tendency to use environmentally friendly, low-cost and lightweight construction materials in building industry has brought about the need to investigate how this can be achieved and to how this can be benefit to the environment [1].

At the beginning of the 1990s, several studies had been conducted to use the industrial wastes in various forms of concrete productions. For instance, the use of paper waste sludge, glass powder, waste rubber and palm oil fuel ash in concrete mixes has received remarkable interest for the study [2-7]. The waste of sawdust is one of these materials which has used in concrete or cement mortar productions. Sawdust is an organic waste resulting from the mechanical milling or processing of wood into various shapes and sizes [8]. The use of sawdust wastes can not only solve the environmental concerns, but also can protect the natural resources of the construction materials. It has considerable features, such as low bulk density, superior heat preservation and lower thermal and sound conductivity, and can reduce the environmental pollution that resulting from dumping such wastes in close places to the residential communities. The physical and chemical properties of sawdust vary significantly depending on several factors according to the type and specification of the wood [9].

The accumulation of fine sawdust waste in many carpentry workshops, especially in developing countries such as Libya, may cause certain serious environmental problems and health hazards [10]. This study presents an experimental work which investigates the possibility of using the sawdust waste to produce a suitable lightweight mortar. Some of the mechanical properties of mixes that having various levels of sawdust waste have been investigated. The possible successful results in using the sawdust in the construction applications could be open the way for using other agricultural wastes such as the straw, which would achieve more benefits for protecting the environment.

2 Materials and Methods

2.1 Materials

Ordinary Portland cement (OPC) that complies with the requirements of BS EN 197-1:2011 was used in the experimental work of this study. The physical properties and chemical compositions of OPC is provided in Table 1.

Table 1. *Chemical compositions and physical properties OPC.*

Chemical composition (mass %)		Physical properties	
Component	**Value**	**Property**	**Value**
Silicon dioxide (SiO_2)	21.14	Specific gravity	3.15
Aluminum oxide (Al_2O_3)	5.91	Specific surface area(m^2/g)	2926
Ferric Oxide (Fe_2O_3)	3.99	Strength activity index at 3 days (MPa)	25
Calcium oxide (CaO)	61.9	Strength activity index at 28 days MPa	42
Magnesium Oxide (MgO)	2.59	.	
Sodium oxide (Na_2O)	0.18		
Potassium oxide (K_2O)	0.88		
Sulfur oxide (SO_3)	1.11		
Phosphorus oxide (P_2O_2)	0.9		
LOI	0.41		

Natural sand with maximum size of 1.2 mm was used as a fine aggregate which collected from quarries of Zlitan City. The fine sand has a fineness modulus of 2.8, specific gravity of 2.62 and water absorption of 0.83%.

The sawdust was obtained from carpentry workshops in Al-Khums City, considering their purity from stones, dust and the large sizes of husks. The used sawdust has a maximum size of less than 600µm. For the purpose of knowing the grain size distribution, the used sawdust was sieved through a set of sieves of 0.6, 0.425, 0.25, 0.15mm (Figure 1). In this study, sawdust was cured before being used as a fine aggregate in producing the cement mortar. Firstly, it was immersed in water and saturated with hydrated lime for the purpose of getting clear of harmful substances. Then, it was submerged in Kerosene for 24hrs to prevent its liability to water absorption (Figure 2).

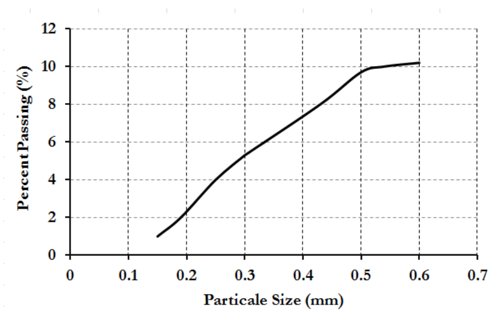

Figure 1: *Grain size distribution of sawdust.*

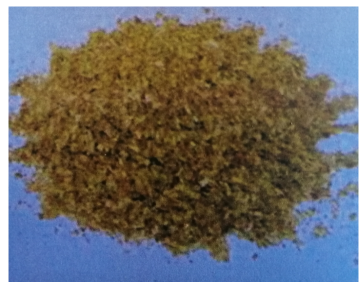

Figure 2: *Sawdust waste after treatment.*

2.2 Mixes Proportions

Due to the remarkable differences in the specific gravities of sand and sawdust, the process of replacing sand by sawdust was done by volume. The replacement percentages of sand by sawdust were 5,10, and 15%. This was done to find out the optimal mix that would give the most appropriate results. The mix of 0% replacement (C) was to serve as reference mix for the other mixes (S1, S2 and S3). The details of mixes are given in Table 2. A 5-liter mortar mixer was used to mix the mortar ingredients at a constant mixing speed of 30rpm. After mixing and casting the mortar into the molds, all specimens were kept in room temperature for 24 hours. After that, the specimens were demolded and cured by following two methods, the first by immersing the specimens in water and the second by exposing them to the air under laboratory conditions. Then, the specimens were left until the day of the test.

Table 2. *Mixes proportions.*

Mix ID	Cement	Water	Sand	Sawdust
C	1	0.4	1.5	0
S1	1	0.4	1.425	0.075
S2	1	0.4	1.35	0.15
S3	1	0.4	1.275	0.225

2.3 Tests Procedures

The Flow Table test aims to find out the effect of using the sawdust on the fresh mortar consistency. Through this test it would be possible to give an idea about the absorbed water by the sawdust. This test was performed according to ASTM C230/C230M- 15 [11].

For determining the percentage of air voids that existing in the fresh mortar which containing sawdust, the Air Content test was confirmed, this test was conducted according to ASTM C185 – 15 [12].

The adopted geometry for the compressive strength specimens was a cube of 7.05×7.05×7.05cm. The cubes were tested at 7, 14 and 28 days, and the specimens were tested under compression by using the standard procedure for testing the cubes of compressive strength test according to ASTM C109/C109M [13]. The test was performed under a load rate of approximately 1.8 KN/m.

The flexural strength of mortar is determined by conducting the test method of ASTM C78/C78M [14] (Third-point loading or 4-point bending test). Prisms with size of 16x4x4cm were tested. The flexural strength at 7 and 28 days were determined by using four-point loading test. The specimens rest on two supports and the half of the load is applied at each of the third of the span length by using a rigid piece of steel. The specimen was loaded at constant rate until the failure.

In this study, Ultrasonic Pulse Velocity test was approved, with a view to assess the effect of replacing sawdust by sand on the acoustic properties such as sound transmission .This test is conducted by passing a pulse of ultrasonic through specimens of cubes and measuring the time taken by pulse to get through the specimens. Higher velocities indicate higher sound conductivity and continuity of the material, while slower velocities may indicate mortar with lower sound conductivity. The calculation of the ultrasonic velocity average was taken according to the age of specimens, and the test was carried out according to ASTM C597- 09 [15].

3 Tests Results and Discussion

3.1 Fresh Mortar Consistency and Air Content

The results of Flow table test of the tested mortars are presented in Figure 3. For all the tested mortars, the flow decreased with increasing the sawdust content. The lower flow in the mortars containing sawdust compared to the control mortar may be attributed to a portion of the mixing water that has been absorbed by the sawdust (although sawdust is soaked in Kerosene to prevent the absorption). In addition, the reason may be due to the roughness of the surface of the sawdust grains which influences the friction between the components of the mortar and causing a lack of flow.

Figure 4 illustrates the effect of replacing the sand by sawdust with different percentages on the air content of the fresh mortar. It can be observed that the increasing in the percentage of sawdust has a significant effect on increasing the air content. By comparing the results of this test, it was observed that the air content in the reference mortar (C) was about 0.36%, and after replacing the sand by 15% of sawdust (S3), the air content became about 1.8%, causing an increase of about 500%. The reason may be due to the difference in the specific gravity of sawdust and sand (S.G of sand 2.66 is much greater than that of sawdust 0.9), this may contribute significantly to the formation of air voids in the fresh mortar containing the sawdust.

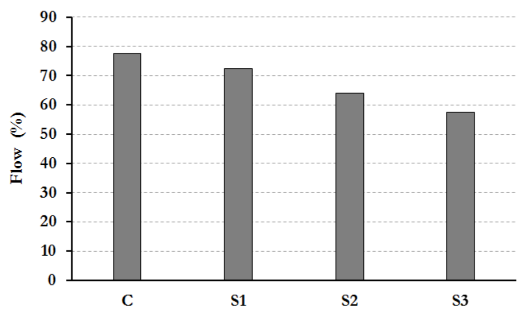

Figure 3: *Flow table test results of mortars with different proportions of sawdust.*

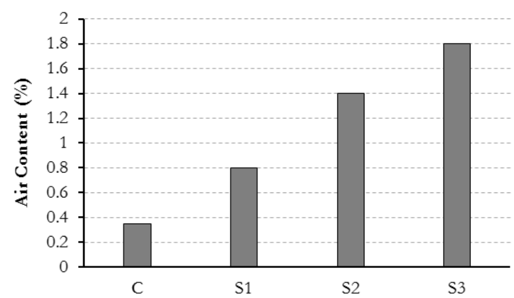

Figure 4: *Air content results of mortars with different proportions of sawdust.*

3.2 Compressive Strength Comparison

Figures 5 and 6 show the results of the compressive strength values obtained from the tests. The average compressive strength values are inversely proportional with the replacement percentage of sawdust cured by water and air under laboratory conditions respectively. The strength dramatically decreases with an increase in the replacement level of sawdust.

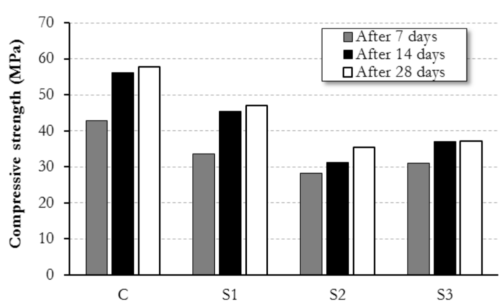

Figure 5: *Compressive strength results of mortars cured by water immersion with different proportions of sawdust.*

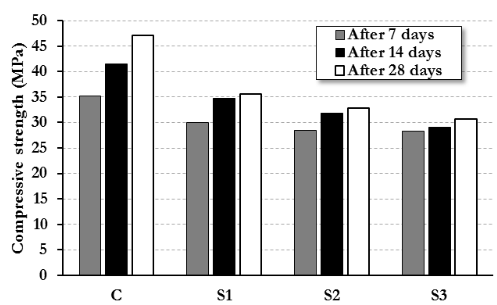

Figure 6: *Compressive strength results of mortars cured by exposing to air with different proportions of sawdust.*

In both methods of curing (air or water), the strength decreases with an increase in the replacement level of sawdust. According to the comparison of compressive strength results that is shown in Figure 5, the strength of the standard mortar that were cured by immersing in water after 7 days was 42.95 MPa, while it was 57.75 MPa after 28 days. However, the specimens with the highest replacement percentage (15%) were 31 MPa and 37.06 MPa after 7 and 28 days, respectively. Wherever, the percentage of decrease in compressive strength was about 39% and 56% after 7 and 28 days, respectively. Through Figure 6, it can be noted that the effect of replacing sawdust on compressive strength for air-cured specimens is not much different from water-cured specimens, but it is lower in the compressive values. Comparatively, the results indicate that sawdust as a partially replacement of sand mortar can achieve the same order of strength as conventional mortars at same curing periods.

3.3 Flexural Strength Comparison

Figure 7 and 8 show the relationship between the average of flexural strength and the percentage of replacing the sawdust with sand at different ages for the tested mortars that cured by air-curing and water immersion. Similar behavior to that noted for the compressive strength was also observed for the flexural strength. However, the flexural values were decrease slightly for the all replacement levels. At the 7 and 28 days water curing period, the range of flexural strength obtained was between 1.63-2.16MPa (for 0% sawdust content) and 1.35-1.34MPa (for 15% sawdust content) as shown in Figure 7. In other words, the flexural strength decreased by 21% and 61% at 7 and 28 days curing period, respectively. However, despite the difference in the water curing period, it can be observed that as the (10% and 15%) of sand was replaced by sawdust, the strength was approximately equal.

The variations of flexural strength for specimens cured by exposing to air under laboratory conditions are presented in Figure 8. The effect of the replacing of sand by sawdust is almost similar for both curing methods. However, the flexural strength was lower compared to that obtained from specimens cured in the water. Generally, the flexural strength test results indicate that the strength decreases with increasing in sawdust content for all the ages and curing methods.

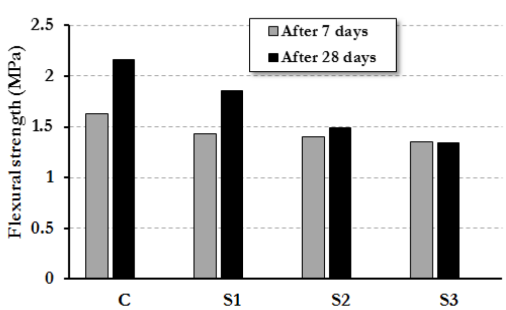

Figure 7: *Flexural strength results of mortars cured by water immersion with different proportions of sawdust.*

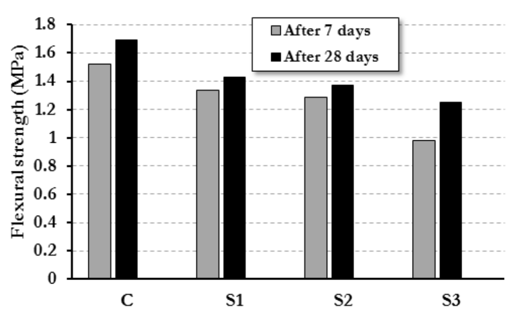

Figure 8: *Flexural strength results of mortars cured by exposing to air with different proportions of sawdust.*

The decrease in flexural strength can be attributed to poor adhesion is present at the interface due probably to increasing quantity of water absorption by the sawdust grains which causes low efficient hydration reaction on the cement matrix. However, the mortars produced by replacing up to 15% sawdust, the strength is still permissible for using in plain construction applications and that can be used as lightweight mortar. According to the conditions of this study, it is expected that using higher contents of sawdust (more than 15%) seems to deteriorate the flexural strength.

3.4 Ultrasonic Pulse Velocity Comparison

Figures 9 and 10 illustrate the effect of sawdust on the ultrasonic pulse velocity of the mortars cured by water and air under laboratory conditions respectively. The test results confirmed that the velocity values are inversely proportional with the replacement percentage of sawdust. For all studied mortars, whether submerged in water or exposed to air, the ultrasonic pulse velocity dramatically decreases with an increase in the replacement level of sawdust. It was observed that for specimens cured by immersing in the water, approximately 19% and 73% as a reduction in the velocity of control mix is obtained from the 15% of sawdust replacement at 7 and 28 days, respectively. On the other hand, the specimens cured by exposing to the air, the reduction was 31% and 30%.

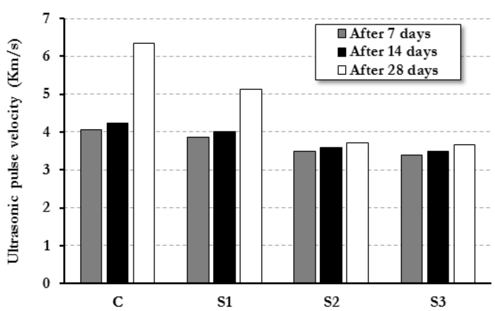

Figure 9: *Ultrasonic pulse velocity results of mortars cured by* water immersion *with different proportions of sawdust.*

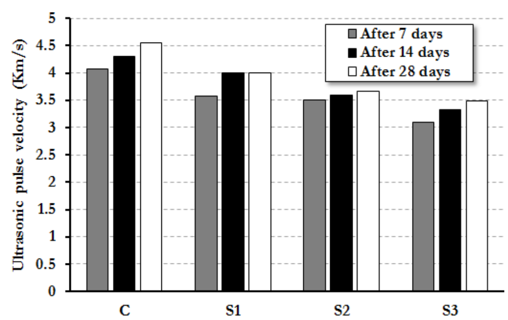

Figure 10: *Ultrasonic pulse velocity results of mortars cured by exposing to air with different proportions of sawdust.*

The decrease in the ultrasonic pulse velocity values can be attributed to the fact that part of the waves was absorbed by the grains of sawdust. In addition, the presence of air voids that increase the cause of the delay in the transmission of the waves. It can also be observed that the curing method had a great role in the effect on the ultrasonic pulse velocity results, i.e. the curing by immersing in water increased the velocity more than the curing by exposing to air. For all the curing ages, it is also interesting to note that there is a convergence in ultrasonic pulse velocity values for mortars containing sawdust and cured by exposing to air. However, the results provided by this test indicated that mortars less sound conductivity could be manufactured by adding sawdust to the mixture.

4 Conclusion

From the obtained results of the conducted tests in this study, the following conclusion can be drawn:

- An increase in the percentage of sawdust is accompanied by a noticeable increase in air content, which in result may increase the chance of obtaining lighter weight mortars. Moreover, this can reduce the transmission of sound and increase the possibility of using this type of mortar in various constructions that need to be loaded with light loads.
- Comparatively between the mortars containing sawdust and the standard mortar, it was concluded that the percentage of flow decreases as the replacement percentage of sawdust by sand increases. This could be explained by the fact that when the sawdust increases, the more mixing water is absorbed by the sawdust grains, which reduces the workability, and leads to an increase in friction hence reduce the flow.
- The flexural and compressive strengths of the prisms and cubes respectively which made with local materials and containing sawdust, decrease with the increase of sawdust level in the mix. However, the strength at a replacement level of 15% by the volume of sand is considered reasonable for various construction applications.
- By analyzing the results obtained from the ultrasonic pulse velocity test, it can be concluded that an increase in the percentage of sawdust leads to a decrease in the velocity. This can reduce the possibility of sound transmission through the structural elements which made with mortars containing sawdust.
- Overall, it can be concluded that adding sawdust to cement mortar produces a mortar with less sound conductivity, lightweight and more environmental and economical.

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