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THE FEASIBILITY OF IMPROVING CONCRETE STRENGTH PROPERTIES BY ADDING WASTE WOOD CHIPS

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This paper examines the ability to introduce an industrial waste product, wood chips, in concrete as a partial replacement for fine aggregate. Water was used to treat the wood chips before mixing to prevent them from soaking up the cement hydration water. The research presented in this paper aims to determine the impact of different treatment methods. The first method uses cement paste, and the second is sodium silicate. Twelve trial mixtures were prepared and cast employing water-cement ratios of 0.44 at various replacement levels of wood chippings. Fresh concrete properties tested inclusive slump test. Hardened concrete properties tested inclusively flexural strength, splitting tensile strength, compressive strength, and unit weight. Test results show that the lightening of concrete by wood shavings decreases the strength properties and the unit weight. On the other hand, the value of the slump test increased depending on the level of replacement of wood shaving. The most acceptable mixture and less reduction in the strength properties have been shown at MC10. The results of the tests demonstrate that the disposal of wood chips in concrete is practical and appropriate.

Keywords: wood chipping, composite material, treatment, mechanical strength

1 INTRODUCTION

In many countries, the wood industries generate a large number of waste products. The low costs, the proximity of the sources, and the potential pollution from wood wastes have led to studies into the possible use of wood chippings as aggregate in concrete. In the future, a construction site may face a problem of lack of raw materials. Engineers must select a suitable way to use waste materials instead of conventional materials to overcome this issue. In general, those waste materials harm the properties of concrete when incorporated into mixed concrete. Therefore, to not ignore those waste materials, consider them as useful construction materials, and protect the environment, they need to be treated. Various industrial waste materials, such as scrap steel, rubber scraps, wood chips, steel slag, and fruit fiber from oil palm trees could be incorporated into concrete. Utilizing this debris reduces the need for natural-source aggregate and promotes sustainability. [1, 2]. In Iraq, one of the huge waste materials is considered wood chipping. In addition, wood fibers are naturally degradable [3], which is not negligible in the current context of waste limitation. These types of materials have several potential applications such as acoustic and thermal insulation, fire resistance cladding, etc. One type of lightweight concrete employs waste wood products as its aggregates. A higher strength-to-weight ratio, improved tensile strain capacity, a lower coefficient of thermal expansion, and enhanced heat and sound insulation are all advantages of lightweight concrete. [4–6]. Additionally, composite wood concrete will save construction costs and has the benefit of being a green building material [7]. However, lightweight concrete has certain drawbacks, including a high slump, poor workability, and low indirect tensile strength. To alleviate this problem, by adding admixtures and superplasticizers in concrete, these shortcomings could be dealt with in the mixture to obtain higher workability [8, 9]. Moreover, this composite concrete also exhibits great thermal and insulating characteristics [10]. There are other natural fibers have also been investigated (rice husks [11], hemp [12], or other fibers [13]). Mortar mixes, including these admixtures, impart excellent durability and are considered for coating applications or insulating. Several researchers have investigated the utilization of waste wood products as lightweight aggregates [6, 14–18]. As contrasted to concrete without waste wood, it has been observed that concrete that incorporates waste wood can be built as lightweight structural concrete with excellent thermal conductivity [16]. Additionally, the lightweight concrete composite meets class III RILEM standards and exhibits reasonable durability and strength. [17]. Although adding waste wood to concrete, there are negative effects, such as a decrease in the hardened concrete's strength characteristics' value. have also been registered [6,17]. However, the advice for treating the wood waste before incorporating it into concrete is to minimize the reduction in strength properties [7,17,18]. In Iraq, there was no system for recycling those waste wood. So, this work aims to identify the possibility of using those waste materials after treatment as a partial replacement for fine aggregate. The research focuses on the presence of treated waste wood in the concrete samples in terms of the behavior of the strength properties.

2 SAMPLE PREPARATION

2.1 Materials

2.1.1 Aggregates (sand and gravel), Portland cement

In all mixtures, the cement used was Portland cement 42.5 type II, which complies with the requirement of ASTM 150. The fine aggregate had a maximum size of 4.75mm with a bulk density of 1673 kg/m^3, a fineness modulus of 2.63, 2.41 specific gravity, and an absorption of 1.89%. Crushed stones were used as a coarse aggregate graded at a maximum size of 9.5mm, with a specific gravity of 2.24, a bulk density of 1570 kg/m^3, and absorption of 0.89%. Aggregates in terms of physical properties were conducted according to the ASTM C128 and ASTM C127 for fine and coarse aggregate, respectively.

2.1.2 Wood chipping

The wood used in this study has a specific gravity of 0.258, a bulk density of 210 kg/m3, and 257.34 % absorption. It is obtained from the factory by mechanically processing the raw wood. The waste wood collected from the factory is seen in Figure 1.

Fig. 1. Sample of wood chipping

2.1.3 Sodium silicate

The sodium silicate that was used in this study was powder, white in color as displayed in figure 2. Sodium silicate ((Na_2O)$_x$·SiO_2) has (27.5-29.5%) of Sodium oxide (Na_20) and the Maximum limits of impurities, Chloride (CLCl−) of 0.0%, Sulphate (SO_4−) of 0.05%, and Iron (Fe) of 0.02%. The purpose of using this kind of material is to treat the waste wood in order to improve the bond between the raw materials in the concrete matrix.

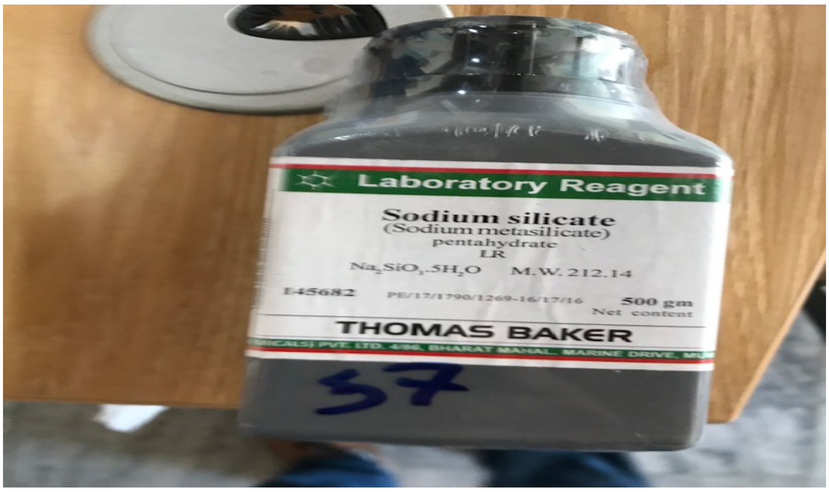

Fig. 2. Sample of the Sodium silicate

2.2 Mixture Proportions

The combination ratio and the initial properties of the concrete were prepared in the laboratory and are displayed in table 1 below. There are 18 types of concrete mixtures, including the standard mix. Waste wood has been added at five levels, with 10 %, 14 %, 18 %, 22 %, and 26 % of the fine aggregate is replaced. Due to the higher water absorption (257.34 %) associated with wood chips, more water is required to create a viable and workable concrete mixture. Table 2 shows the amount of additional water required to calculate how much more water needs to be added.

Table 1. Mix proportions at different mixed concrete

Waste Wood replacement		Cement (kg/m3)	Fine aggregate (kg/m3)	Coarse aggregate (kg/m3)	Water (kg/m3)
%	kg/m^3				
0	0	438	543.0	942	193
10	6.816	438	488.6	942	193
14	9.54	438	466.88	942	193

Waste Wood replacement		Cement (kg/m3)	Fine aggregate (kg/m3)	Coarse aggregate (kg/m3)	Water (kg/m3)
%	kg/m^3				
18	12.27	438	445.17	942	193
22	15.0	438	423.45	942	193
26	17.72	438	401.74	942	193

Table 2. Additional water adds to each mixture of concrete

Wood shaving Replacement by volume (%)	Wood shaving replacement (kg/ m^3)	Mass of additional water (kg/m^3
0	0	0
10	6.816	17.41
14	9.54	24.37
18	12.27	31.34
22	15.00	38.32
26	17.72	45.26

2.3 Saturation treatment

Wood waste has been treated by two different methods:

In the first method, the wood shavings were treated by coating them with cement. A paste was made by mixing cement with water with a mass ratio of “cement /wood” of 2.4. During the process of coating, it is important to make sure that the total surface of wood shaving has been coated. Figure 3(a) displays the waste wood after the cement treatment.

The second method, silica has been used to treat the wood shavings. Sodium silicate was used (100 g/l). The wood was immersed for 24h to be utilized as aggregates in concrete. Figure 3(b) displays the waste wood after the cement treatment.

Fig. 3. (a) waste wood after cement treatment (b) waste wood after Sodium silicate

3 EXPERIMENTAL PROGRAM

Unit weight and slump tests were carried out after the concrete had finished mixing and before it was put into the mold. 100mm cubic samples were utilized to determine the value of compressive strength, for the split tensile test the samples had size150x300mm, and for the flexural strength test the size for the samples was considered 100x100x400mm.

3.1 Fresh concrete tests

The workability of the concrete mixtures was tested according to ASTM C143. The unit weight tests were conducted by following the method mentioned in ASTM C138.

3.2 Hardened concrete tests

Compressive strength is considered the most important property in terms of the mechanical properties of concrete. The compressive strength tests were performed according to the standard of BSEN 12390-3. 100mm cube specimens were utilized to define the amount of compressive strengths. To check the stability of the structures, in this case, use the cylinder mould that has a size of 100x200mm. Prism specimens (400x100x100mm) were used to determine the behavior of bending strength tests that were carried out at 28 days of curing age.

4 RESULTS AND DISCUSSIONS

4.1 Density

4.1.1 Influence of the wood shaving treated by the two methods (cement paste and Sodium Silicate)

The first way of treatment is done by cement paste; it shows a slight increase in density value compared to the second way of treatment. This slight increase can be owing to the light layer over the wood shaving coated with cement paste. For the other treatment method, sodium silicate's influence on wood shaving also has a slight decrease in density. Table (3,4) displays the densities of the treated wood shaving.

Table 3. Densities of wood-concrete treated by Cement paste

Proportion	Density (Kg/m3)
WC0	2195
WC10	2141
WC14	2116
WC18	2083
WC22	2035
WC26	1985

Table 4. Densities of wood-concrete treated by sodium silicate

Proportion	Density (Kg/m3)
WC0	2195
WC10	2162
WC14	2123
WC18	2101
WC22	2058
WC26	2011

4.1.2 Fresh concrete introduce treated wood shaving

Table 5 displays the results of the slump test. Figure 3 shows that the slump increased as the treated wood shaving content increased. The addition of more water to the concrete mixtures could have increased the slump test value. When comparing the two treatment methods with the traditional mixture, the slump test shows an increase in each of them. The slump test results for each treatment approach are shown in Tables 5 and 6.

Table 5. Slump test value for wood shaving treated by cement paste

Designation	Slump (mm)
WC0	65
WC10	108
WC14	137
WC18	168
WC22	181
WC26	194

Table 6. Slump test value for wood shaving treated with sodium silicate

Designation	Slump (mm)
WC0	65
WC10	110
WC14	142
WC18	173
WC22	186
WC26	201

4.1.3 Compressive strength

Using the concrete compression machine that is available in the laboratory of the Civil engineering Department. For each mixture, compressive strength has been measured. Six samples have been tested for each mixture for both methods of treatment three on the 7th day of curing and the other three done on the 28th day of curing. Table 7,8 describes the consequence of the experiment when the sand was substituted with treated wood shaving. The results indicated that when the treated wood shaving was introduced to the concrete mixture, there was a reduction in the strength at all level replacements, especially at high-rate replacement (26%). The compression between the two treatment methods shows that the wood shaving treated with cement paste results in the lowest reduction than the other method of treatment (sodium silicate). In addition, this reduction could be contributing to the weak bond strength between the treated wood shaving and the raw materials. The two mixtures (WC10 and WC14) could be categorized as the best among the overall mixes of the two treatment methods. The amount of reduction is registered as 6.38%, and 10.68%, respectively.

Table 7. Compressive strength for wood shaving treated by cement paste

Designation	f_{cu} (Mpa)		Average of f_{cu} 28th day
	7th day	28th day	
MC0	28.40	41.42	41.11
	29.15	42.27	
	28.85	42.65	
MC10	27.32	40.10	39.42
	25.90	39.50	
	26.44	38.68	
MC14	26.15	37.78	37.61
	25.30	36.96	
	24.90	38.10	
MC18	23.85	36.35	36.17
	24.50	35.40	
	23.65	36.75	
MC22	21.45	34.90	34.85
	22.70	35.45	
	23.30	34.20	
MC26	22.75	32.65	32.58
	20.30	31.90	
	21.15	33.20	

Table 8. Compressive strength for wood shaving treated by Sodium silicate

Designation	f_{cu} (Mpa)		Average of f_{cu} 28th day
	7th day	28th day	
MS0	28.40	41.42	41.11
	29.15	42.27	
	28.85	42.65	
MS10	26.75	37.72	37.85
	25.45	38.34	
	26.65	37.50	
MS14	24.34	36.36	36.15
	25.25	35.45	
	23.86	36.65	
MS18	22.45	35.56	34.91
	23.15	34.75	
	22.20	34.42	
MS22	21.65	33.32	33.34
	22.34	32.67	
	21.16	34.02	
MS26	20.36	31.22	30.95
	19.65	30.12	
	20.65	31.52	

4.1.4 Tensile strength

The split tensile test was executed on samples with a dimension of (150 × 300) mm by following the specification of ASTM C496. Tables 9 and 10 show the average results of all samples that have been replaced by the treated waste wood treatment from both treatment methods. According to the outcomes, the value of split tensile strength decreases as the percentage replacement of wood waste increases. This is accountable for the initial crack development among the wood shaving and the weak bonding of the concrete matrix when the load is applied. Moreover, the first treatment method (cement paste) indicates the least reduction as compared to the second treatment method (sodium silicate). Samples (MC10, MS10, MC14, and MS14) show the lowest reduction, the amount of decrease is not more than 12% in comparison to the control sample.

Table 9. Tensile strength for wood shaving treated by cement paste

Designation	Average of Tensile strength (Mpa) 28th day
MC0	4.05
MC10	3.67
MC14	3.58
MC18	3.38
MC22	3.10
MC26	2.68

Table 10. Tensile strength for wood shaving treated by Sodium silicate

Designation	Average of Tensile strength (Mpa) 28th day
MC0	4.05
MC10	3.59
MC14	3.41
MC18	3.28
MC22	2.92
MC26	2.53

4.1.5 Flexural strength

According to the result displayed in figure 4, it can be deduced that for both treatment methods the value of bending strength decreases as the ratio of wood shaving increases. As make a comparison between the treatment methods, the results show that the first treatment method gives the best result than the second treatment method. This could be contributed to the wood shaving covered with cement paste giving a better bond strength with the matrix mixture.

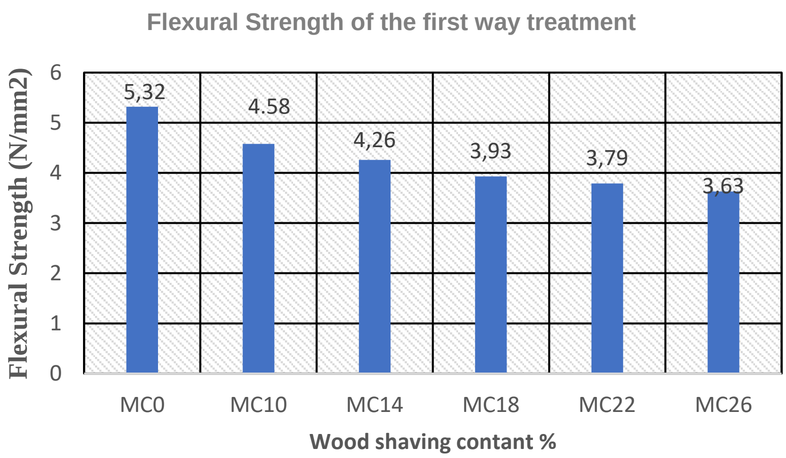

Fig. 4. Flexural strength of concrete containing wood shaving treated by cement paste (28 Days)

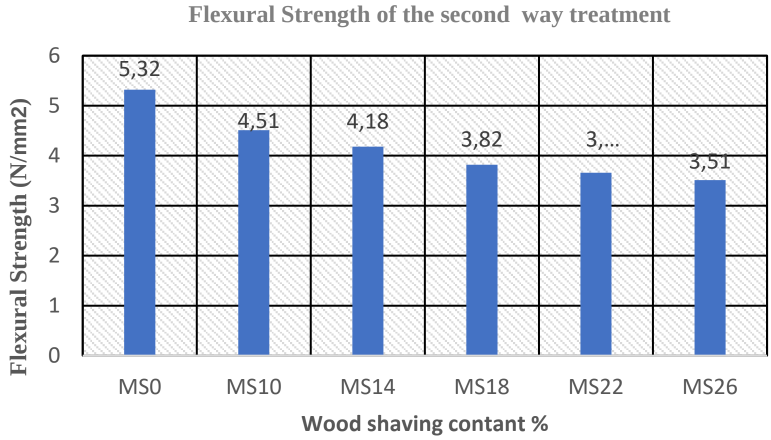

Fig. 5. Flexural strength of concrete containing wood shaving treated by sodium silicate (28 Days)

5 CONCLUSION

Based on the result obtained from this study, the main conclusion can be drawn:

1. The unit weight of fresh concrete containing wood shaving decreases as the wood shaving increase intensity for both methods of treatment.
2. The use of the first treatment method (cement paste) yields an increase in the slump value of the wood shaving concrete. The second treatment method (Sodium silicate), displays that the value of the slump tests more increase.
3. The experiments demonstrate that the split tensile and flexural strength of the first treatment method of MC10 decreased by 9.381%, and 13.90% respectively as compared to the traditional concrete. Furthermore, the second treatment method shows that the sample MS10 decreased by 11.35%, and 15.22% as compared to the control sample, the value of reduction could be more than the first way of treatment.
4. The strength properties of concrete are reduced at all levels as fine aggregate is replaced with treated wood shavings.
5. Compressive strength is considered the most important mechanical property of concrete. The results showed that by introducing the treatment of wood shaving for both treatment methods, there is a reduction in compressive strength and the amount of reduction ranges between (4.11% - 24.71%). Moreover, the least reduction appears in the mixture MC10.
6. It is acceptable and sufficient to use wood shavings in the production of concrete.
7. It is advised to utilize the first treatment method (cement paste) as an attainable and environmentally safe technique to elevate the mechanical properties of wood-concrete mixes.

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