Effect of some Physical and Chemical Treatments on Mechanical and Physical Properties of *Acacia nilotica* Wood-cement Mixture

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Abstract

The study investigated the effect of some factors on the properties of *Acacia nilotica* (sunt) wood-cement mixture. Wood slabs were obtained from 30 sunt trees in Abu kuk Forest. Portland cement was used. The experiment was carried out to study the effect of cold water extraction for (0, 7 and 14 days) in addition to six levels of calcium chloride (1, 1.5, 2, 2.5, 3 and 3.5 %, based on cement weight) on the properties of the wood-cement mixture. In total, 72 specimen blocks (5*10*60cm^3) were prepared using metal molds. Although the effect of extraction duration on the mechanical properties and water absorption was dependent on the level of calcium chloride, extracted wood had significantly higher strength and lower water absorption than non-extracted wood; there is no need for extraction more than 7-days. No significant differences in 2 hours water absorption and swelling were found between the six levels of calcium chloride when using non-extracted wood (control), increasing the level of calcium chloride in the mixture was associated with a decrease in strength properties and an increase in water absorption. When the wood was extracted, increasing the level of calcium chloride was associated with an increasing trend in the strength properties and a decrease 2-hours water absorption; the level at which the strength properties start to increase varied among properties and extraction levels.

Introduction

The use of other organic or inorganic materials in combination with wood particles offers chances for the development of new composites with improved properties. Inorganic cement is used as a binder in wood-based products since 1920. Using mineral cement as a binder in particleboard manufacturing is gradually gaining importance in many countries of the world.

The wood-cement product has some desirable characteristics such as fire and biological and weather resistance and dimensional stability. The product has no serious environmental problems, however, the basic materials and chemicals used are neither toxic nor inflammable and they are in no danger of explosion. New characteristics of the product achieved are light weight, permeability, thermal and noise isolation. The product can be used for exterior (outdoors) and interior (indoor) building materials.

Developing useful products from industrial residues material is vital for getting rid of the problem of disposal waste. There is a great amount of wood waste remaining

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from manufacturing of *Acacia nilotica* (sunt) wood, as species considered to be one of the most important tree species under management in the Sudan. It is the most dominant hardwood species on the banks of the Blue Nile and White Nile (El Amin, 1990). The dominance of this species allowed establishing sawmills plants at El Suki and Wad en Naial. The plants produce mainly railway sleepers, other sawn products and firewood. The production of such products introduces great amounts of residues. These need different types of utilization systems, probably for slabs and sawdust. Utilizing a part of sunt waste in cement-bonded wood product can justify the mentioned properties.

Research work aiming at studying and improving the compatibility of some Sudanese hardwood species with local Portland cement started during the first half of the 1990s (Ibrahim, 1995).

Cement-bonded wood products are generally produced in two groups: Cement particleboard (high-density smooth- surfaced) and cement excelsior board (low-or medium density porous-surfaced). The former is produced in Europe and Asia for various applications. The latter is produced in Europe, Asia and the United States for roof decking and acoustic ceiling (Dinwoodie and Paxton 1984; Lee 1984 and Lee and Hong 1986). In 1928, cement-bonded wood wool building slabs were produced. The bonding strength between wood and cement depends primarily on the wood species selected (Lee and Hong, 1986). Sandermann *et al.* (1960) found that starch, sugar, tannin and certain phenols were inhibitory in nature. Lignin has been reported to affect the setting of the cement (Vermass, 1974).

Wood can not combine well with cement unless it has been pretreated. Moslemi and Lim (1984) studied 12 hardwood species treated by hot water, and they found that hot water treatment encountered for remarkable improvement of compatibility of the most studied species. Gnannaharan and Dhamodaran (1985) studied the effect of cold water, hot water and sodium hydroxide extraction in 13 tropical species and reported that extraction with cold water is sufficient to remove the inhibitory extractives from most of the species studied.

The specific objective of this Study was to study the effect of water extraction and addition of calcium chloride on the strength and physical properties of sunt wood-cement mixture.

Materials and Methods

The factorial experiment was conducted to study the effect of some important factors on the properties of wood-cement mixture. The wood material was collected from 30 *Acacia nilotica* (L.) Willed.ex Del trees selected from Abu Kock forest in the Blue Nile. Planer shavings were prepared from the slabs of the 30 *Acacia nilotica* (sunt) trees. The shaving particles were screened using standard sieves (DIN4188). Only the particles passing through a 4 mm-mesh screen and remaining on a 1 mm-mesh screen were used in this study. Portland cement (1600 g) and screened wood particles (800 g oven dry basis) were weighed using an electronic balance (METTLER SUR M55 426 Type PJ 6000) to fulfill the cement/ wood ratio of 2:1 in all specimens. Mold size was 5*10*60 cm^3. Calcium chloride was used as the chemical additive. It has been recorded to be one of the most effective and commercial accelerators for cement hydration and is expected to enhance the strength of the mixture. Four specimens have been prepared for each combination of pretreatment level and calcium chloride level.

The experiment was designed to investigate the effect of extraction duration and the addition of six amounts of calcium chloride. In addition to control (untreated wood), two extraction treatments of the wood were done, namely the extraction of wood with cold water for 7 and 14 days. The chemical additive used was commercial calcium chloride (77-80% $CaC1_2$ content). The ratios of calcium chloride to the binder weight were 1, 1.5, 2, 2.5, 3 and 3.5%. Cold water extraction has been used to eliminate the amount of the sugars and water-soluble extractive in the wood, which are reported as poisons or retardant agents in the wood or cement setting. In total, 72 specimens were prepared. Pressure was applied to all specimens, a concrete cube weighing 30 kg was put on a sheet of wood placed on the top of the specimen to distribute an equal load (0.05 kg/cm^2) to the mat in the mold for 24 hours.

Results and Discussion

The results of the means separation test were significant at the probability level ≤0.05. However, all variables means separation test was based on Duncan's multiple range tests.

Modulus of Rupture

Modulus of rupture (MOR) strength is an important characteristics when the products are used as panels, e.g. in ceiling and roofing. Except for untreated wood (control) all the specimens tested for MOR in this experiment exceeded the requirements (1.27 N/mm^2) of the specification of the British Standard (BS/1105, 1972). Results of the analysis of variance showed that the effect of extraction and the interaction term (extraction*calcium chloride) were significant. The coefficient of determination (R^2) was 0.94 1, which means that 94.1% of the variation in MOR could be explained by the main factors and their interaction.

The results of the means separation test are given in Table 1. In the same percent of calcium chloride, there was a significant difference between the extracted and unextracted wood; however, there were no significant differences between the means of the two levels of extracted wood for 7 and 14 days. These results agree with the findings of Gnannaharan and Dhamodaran (1985) that cold water extraction removes the inhibitory extractives from tropical species.

Hardness

Hardness strength test is required if the products are used in flooring or paving or as bearing blocks. Hardness values in this experiment ranged from 200 to 9200 N with an overall mean = 5022 N. Results of the analysis of variance showed that the effect of extraction and the interaction term were significant, which indicate that the effect of the factors are on each other .

The results of the means separation test are given in Table 2. At all levels of calcium chloride, there were significant differences between the extracted and non-extracted wood mixture. Only at 1% calcium chloride, there were significant differences among the three levels of extraction .In control (unextracted wood) there was a significant decrease in hardness means with increased calcium chloride percent. When the wood was extracted for 7 days, hardness strength showed an increase with increased calcium chloride. However, there were no significant differences between 1.5% up to 3.5% levels and also no significant differences between 1, 3 and 3.5%

calcium chloride (Table 2). Wood extracted for 14 days showed that the hardness of the specimens with 1 and 1.5% calcium chloride were significantly lower than the specimens with 2, 2.5 and 3% but not different from that with 3.5% calcium chloride. From the above results it can be concluded that the amount of calcium chloride to be added to the sunt wood-cement mixture should be 1%, 1.5% and 2% for the unextracted (control), 7-days extracted and 14-days extracted wood, respectively.

Water Absorption

Water absorption is important when the products are used externally (out door). Tests for water absorption were done for 2 and 24 hours.

Water absorption for 2 hours

About 94% of the water was absorbed in the first 2 hours of soaking. Results of the analysis of variance shows that the effect of the two main factors (extraction and calcium chloride) and their interaction term were significant.

Results of the mean separation test are presented in Table 3. At the same calcium chloride percent, unextracted wood (control) absorbed significantly higher amount of water than the extracted wood, except in 1% calcium chloride there was no significant difference among the three levels of extraction. This may be due to different setting of wood-cement; more porous of the non-extracted wood mixture compared to the extracted wood mixture, caused more water absorption. When the wood was extracted for 7 days, there were no significant differences in 2 hours water absorption among all added calcium chloride percentages. If the wood was extracted for 14 days, then increasing the calcium chloride percent led to a decrease in the 2- hours water absorption. So, there were no significant differences between the calcium chloride percents from 1 to 2.5 and from2.5to 3.5 (Table 3). The values of the means of the various treatments combinations ranged from 44.3 to 63.2%.

Water absorption for 24 hours

Soaking the specimens in water for 24 hours increased the amount of absorbed water by an average 6% compared to soaking for 2 hours. Results of the means separation test are given in Table 4. At all calcium chloride percentages, except 1%, there was a significant difference between extracted and unextracted wood. When the wood was extracted, there were no significant differences in water absorption among all percentages of added calcium chloride. Water absorption for 24 hours had values ranging from 43 to 67% with an overall mean equal to 52%.

Dimension Swelling

For external uses, dimension swelling was important. Results of the analysis of variance showed that the effect of the two main factors (extraction and calcium chloride) and the interaction term were not significant on the dimension swelling. That is to say that the extraction and the calcium chloride did not influence the thickness, width and the length swelling. The tested specimens showed high stability in dimensions with the overall mean equal to 1.28, 0.78 and 0.98% for thickness, width and length swelling, respectively. This was less than the thickness swelling in Bisons, but less or equal to the 2-hours and equal to or more than the 24-hours swelling in Duripanel results.

Conclusions

- Treatment of the sunt wood with cold water extraction, in wood-cement mixture, significantly affected all the studied properties.
- Increasing the percentages of calcium chloride for unextracted wood resulted in adverse effects in strength properties. Water absorption for 2-hours, the only property that affected significantly by the increasing calcium chloride percentages.

Reccommendation

Acacia nilotica (Sunt) particles is suitable for manufacturing wood–cement products, which is used as wall paneling, roofing, partitions and others. The most suitable duration of cold water extraction was 7 days within the range of calcium chloride percentages with cement: wood ratio 2:1.

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Table 1. Effect of cold water extraction and addition of calcium chloride on the modulus of rupture (N/mm^2) of wood – cement mixture.

Calcium chloride (%)	Extraction time (days)		
	0	**7**	**14**
1	B 1.21 A	a 2.57 B	A 3.19 B
1.5	b 1.19 A	a 3.07 AB	a 3.25 B
2	b 0.97 A	a 3.58 A	a 3.46 AB
2.5	b 0.64 B	a 3.52 A	a 3.38 AB
3	b 0.62 B	a 3.76 A	a 3.64 AB
3.5	b 0.54 B	a 3 .43 A	a 3.94 A

At the same row, means with the same upper case letter(s) are not significantly (P≤ 0.05) different.

At the same column, means with the same lower case letter(s) are not significantly (P≤ 0.05) different.

Table 2. Effect of cold water extraction and addition of calcium chloride on the Hardness (N) of wood cement mixture.

Calcium chloride (%)	Extraction time (days)		
	0	**7**	**14**
1	c 2775 A	b 4400 B	a 6250 B
1.5	b 2600 AB	a 6775 A	a 6550 B
2	b 1950 BC	a 6650 A	a 8000 A
2.5	b 1750 C	a 6575 A	a 7765 A
3	b 1000 D	a 375 AB	a 7975 A
3.5	b 350 D	a 6225 AB	a 7500 AB

At the same row, means with the same upper case letter (s) are not significantly ($P \leq 0.05$) different.

At the same column, means with the same lower case letter (s) are not significantly ($P \leq 0.05$) different.

Table 3. Effect of cold water extraction and addition of calcium chloride on the 2-hours water absorption (%) of wood – cement mixture.

Calcium chloride (%)	Extraction time (days)		
	0	**7**	**14**
1	a 50.88 D	a 53.24 A	a 48.69 A
1.5	a 52.16 DC	b 49.86 A	b 48.24 A
2	a 53.51 DC	b 50.71 A	b 46.75 A
2.5	a 55.53 CB	b 50.80 A	b 46.35 A
3	a 57.78 B	b 49.56 A	b 47.31 A
3.5	a 63.21 A	b 51.93 A	b 47.14 A

At the same row, means with the same upper case letter(s) are not significantly (P≤ 0.05) different.

At the same column, means with the same lower case letter(s) are not significantly (P≤ 0.05) different.

Table 4. Effect of cold water extraction and addition of calcium chloride on the 24 -hours water absorption (%) of wood – cement mixture.

Calcium chloride (%)	Extraction time (days)		
	0	**7**	**14**
1	a 54.56 CB	a 48.46 A	a 47.98 A
1.5	a 57.40 CB	b 46.38 A	b 47.19 A
2	a 58.29 CB	b 45.83 A	b 46.25 A
2.5	a 58.98 CB	b 46.69 A	b 45.40 AB
3	a 61.21 AB	b 44.72 A	b 44.46 B
3.5	a 64.84 A	b 47.97 A	b 44.40 B

At the same row, means with the same upper case letter(s) are not significantly (P≤ 0.05) different.

At the same column, means with the same lower case letter(s) are not significantly (P≤ 0.05) different.