Effect of Cement Replacement by Lime on Properties of *Acacia nilotica* Wood-cement Mixture

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Abstract

This research was conducted to study the effect of the pressure levels (0.05, 0.07 and 0.10 kg/cm^2) and cement replacement by commercial lime (0, 10, 20, 30 and 40%) on wood-cement mixture. The wood was extracted for 7 days and calcium chloride was added at 2% based on binder (s) weight. Each combination of the above treatment was replicated four times giving a total of 60 specimens blocks. The specimens were manufactured and its properties were determined. Increasing pressure from low to medium level, resulted in increasing the compressive strength and density when replacing 10, 20 and 30% lime; while the increasing from medium to high level increased the hardness and basic density.

Introduction

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).

The product is used in outdoor and indoor. The panels are used for exterior walls, flooring, roofing, partitions and so on (Stillinger and Wentworth 1977). The product is incombustible, weather proof, fungus and rot resistant and termite proof. The panels can be sawn, shaped, drilled, nailed and screwed and the surface can be painted, overlaid and combined with a wide variety of materials and adhesives. Furthermore, it is durable under extreme sub-zero temperature conditions.

Maloney (1989) noted that the binders used for mineral-bonded products include magnesium sulfate, magnetite, gypsum and Portland cement. The binder type affects the type of the strength of such products.

Lime, which is used in building as a cementing material, is obtained from naturally occurring form of calcium carbonate ($CaCO_3$), which are easily calcinied. Main three groups of lime are classified and used in buildings. The first is non-hydraulic lime or high calcium lime (95% calcium content). The second is semi-hydraulic lime or poor (Lean) lime (15-30% calcium content). The third class is hydraulic lime or eminently hydraulic (Mitchell and Mitchell, 1947).

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Options exist to improve the properties of the composite and the economics of the production. Lime (geer as a local name) has negligible cost compared to cement and is used as a cementing material. The objective of this study was to investigate the effect of pressure and cement replacement by lime on the strength and physical properties of sunt wood-cement mixture.

Materials and Methods

The wood material was collected from 30 *Acacia nilotica* (L.) Willed.ex Del trees selected from Abu Kock forest in the Blue Nile. The experiment was designed to investigate the effect of pressure and replacement of cement by lime in the properties of sunt wood-cement mixture. Lime (calcium hydroxide) was used to replace cement by 0, 10, 20, 30 and 40%. Four replicates for any sample unit has been prepared. Water was added to the wood with $CaCl_2$ and they were first hand mixed, then binder(s) was/were added to the wood-cement mixture. The amount of water was 1200 ml in total for any specimen, 0.23 ml of water for each gram binder (s) and 1.4 ml for each gram of wood (oven-dry basis) was to obtain a homogeneous mixture of wood-cement mixture. The wood-cement mixture was then hand tamped inside a frame mold to prepare the test specimens, which are 5* 10*60 cm^3 in size. Polyethylene sheets were used to cover the mat in the molds to minimize water loss by evaporation. The mixture was kept in the molds for 24 hours and then removed. The removed specimens were kept moistened to cure for 28 days. These specimens were later tested in static bending for modulus of rupture (MOR), compression and hardness using a universal-testing machine (SIEMENS Reg III 6).

Static bending (N/mm^2) was calculated from the formula: $MOR=3Lp\backslash 2bd^2$, where: L was the specimen span, P was the maximum load, b was width and d^2 was thickness (depth). Hardness (per neutons) was measured for each tested specimen (5*10*10 cm^3). Compression and hardness test specimens were prepared from tested static bending specimens.

Density (kg/m^3) for each specimen (5*10*10cm^3) was calculated by formula :
Density = oven-dry weight divided by its green volume**.**

Water absorption test for 2 hours and 24 hours separately were done. Dimension swelling was calculated from change in dimension of the specimen tested.

Results and Discussion

Modulus of Rupture

The effect of replacing cement by lime was highly significant for modulus of rupture (MOR). The results of the means separation test are shown in Tables 1.
Increasing the amount of lime on the expense of cement resulted in a significant decrease in MOR (Table 1). However, replacing cement up to 30% lime did not reduce MOR to a value lower than the specification (1.27 N/mm^2) of the British Standard (BS/1105, 1972).

Hardness Strength

Mean hardness values of the lime percentages are given in Table 1. A significant decrease in hardness values was associated with increasing lime percent.

There was no significant change in strength when replacing cement by lime up to 10% lime (4108N). Also, there were no significant differences between 10% and 20% lime or between 20%, 30% and 40% lime (3608, 3267and 3217N, respectively).

Density

Results of the means separation test are shown in Tables 1. Replacing 10% of the cement by lime caused significant increase in the basic density. Increase the lime in the mixture from 0% to 40% resulted in decreasing the density from 797 to 737 kg/m^3 (Table 1). Decrease of density by increase amount of lime in the sunt wood–cement mixture is positive criteria that preferable in mineral bonded – wood composites.

Water Absorption

As we used the product externally, water absorption had an importance. The great amount (97%) of the absorbed water occurred in the first two hours, while about 3% of the water was absorbed in the remaining 24 hours. There was substantial increasing in water absorption with increasing lime percentages from 0 % to 40 % (Figure1). This means that when amount of cement replacing by lime led to increase of absorbed water.

Dimension Swelling

Dimension swelling (movement) is of importance when wood-cement products are for external use. The results are in agreement with the findings of Miller *et al.* (1989), when used up to 30% fly ash to replace cement. However, the tested specimens showed high dimensional stability in response to water soaking (Table 2). The overall means were 1.36, 0.62 and 0.50% for thickness, width and length swelling, respectively.

Recommendation

Based on the results obtained from this study, replacing up to 30% lime was quite sufficient for manufacturing Sunt wood – cement products, which is used as wall paneling, roofing, partitions and others.

References

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Table 1. Effect of cement replacement by lime on some mechanical properties and density of wood cement mixture.

Properties	**Lime %**				
	0	**10**	**20**	**30**	**40**
MOR (N/mm)	2.12 a	1.78 b	1.39 c	1.33 cd	1.17 d
Hardness (N)	4783 a	4108 ab	3608 bc	3267 c	3217 c
Density (kg/m^3)	797 a	778 b	757 c	757 c	737 d

At the same row means with similar letters are not significantly different at $p = 0.05$.

Table 2. Effect of cement replacement by lime on the dimensional swelling of wood cement mixture.

Dimensional swelling %	**Lime %**				
	0	**10**	**20**	**30**	**40**
Thickness	0.76 a	0.80 a	0.85 a	1.69 a	2.70 a
Width	0.51 a	0.52 a	0.89 a	0.67 a	0.54 a
Length	0.39 a	0.46 a	0.61 a	0.56 a	0.46 a

At the same row means with similar letters are not significantly different at $p = 0.05$.

Fig. (1): Eeffect of cement replacement by lime on the water absorption (%) of wood cement mixure