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USE OF WOOD AS COMPRESSIVE REINFORCEMENT IN CONCRETE

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ABSTRACT

A total of forty-two test specimens of wood, pure concrete and concrete-wood cubes of dimensions – 0.15m x 0.15m x 0.15m were made and tested for their compressive strengths. Six tests were for pure concrete. Another six specimens were for woods of different types sawn – parallel to the grain and perpendicular to the grain. The remaining thirty specimens were concrete-wood of same external diameter as pure concrete but with different dimensions of woods placed in them. The woods used were Achi, Melina and Mahogany. The surface of the woods were coated with bitumen and sand blasted. Achi wood was the strongest of all, both parallel to the grain and perpendicular to the grain. Using Achi wood to produce concrete-wood cubes with concrete mix ratio of 1:2:4 and water cement ratio of 0.6, it was found that perpendicular to the grain concrete-wood had the highest compressive strength, higher than that of pure concrete even at different ages.

KEYWORDS: Concrete, Compressive, Melina, Mahogany, Grain, Wood.

1.0 INTRODUCTION

Panshin (1980) worked on the mechanical properties of some woods. He showed that the use of wood can be expanded in construction works when adequate information about a wood is known and followed. On account of being light, been easily obtainable and durable (when properly treated and laminated), wood can be used to reduce the amount of concrete used in construction work. Due to its high compression strength, wood can be used in places were concrete will be used majorly for compressive strength satisfaction. Timber is one of the most sustainable resources available and one of the oldest known materials used in construction. It has a very high strength to weight ratio. It is capable of transferring both tension and compression forces and is naturally suitable as a flexural member (Porteous and Kermani, 2007)).

2.0 LITERATURE REVIEW

On account of being light, been easily obtainable and durable (when properly treated and laminated), wood can be used to reduce the amount of concrete used in construction work. Due to its high compression strength, wood can be used in places where concrete will be used mainly for compressive strength satisfaction. The by-products of wood include sawdust, wood shavings, ash, and also other light weight aggregates (Desch, 1981). Andre,et al., (2012), all of Chamers University of Technology Gothenburg, Sweden carried out a project work on *Timber Reinforcement: Compression Failure Mechanism*. They laminated wood specimens having square and rectangular shapes with a polymer composite, a Carbon fiber reinforced polymer (CFRP). Using an experimental set-up, whereby the woods were conditioned to 12% - 13.3% moisture content for log specimen and no conditioning for beam block specimens, the specimens were seasoned at a temperature of 104^{o}C, with weights before and after drying used to determine moisture contents. In conclusion, they discovered that the elastic moduli of the specimens reinforced with CFRP increased 300% and 200% for mature wood specimen sawn from fast grown and slow grown trees respectively. The difference in terms of stiffness between fast grown and slow grown trees was reduced by 31% when Carbon fiber reinforced polymer was used in compression failure mechanism.

The inherent variability of a material such as wood, which is unique in its structure and mode of growth, results in characteristics and properties which are distinct and more complex than those of other common structural materials such as concrete and steel (Rowell, 1984). Some of the characteristics which influence design and are specific to timber are the moisture content, the difference in strength when loads are applied parallel and perpendicular to the grain direction, the duration of the application of the load and the method adopted for strength grading of the timber (Mcenzie, 2004). The strength of timber is affected by factors such as density, moisture content and grain structure as well as by defects. Density is almost certainly an indication of strength: the denser the timber the stronger it is (Jackson and Dhir, 1988).

3.0 MATERIALS AND METHOD

3.1 Materials

The woods used for the tests are Mahogany, Achi & Melina woods respectively. These woods were gotten from Enugu State, Eastern Nigeria. The aggregates consist of fine aggregates (river sand) and coarse aggregates (granite) from Ebonyi state, also in Eastern Nigeria. The binder material used was the Ordinary Portland Cement. Bitumen was the material used to laminate the wood during casting to prevent it from absorbing moisture.

3.2 Methods

3.2.1 Mix Design: Table 3.1 shows the mix design table for pure concrete cube with nominal mix of 1:2:4. The cube dimension is 0.15m x 0.15m x 0.15m and the total mass of concrete is 8.51kg.

Table 3.2 shows the mix design table for concrete-wood cube with nominal mix of 1:2:4. The cube dimensions of the woods are 0.03m x 0.03m x 0.03m, 0.05m x 0.05m x 0.05m, 0.07m x 0.07m x 0.07m, 0.09m x 0.09m x 0.09 m and 0.11m x 0.11m x 0.11m.

3.2.2 Moisture Content Test: The moisture content is expressed as the weight of water per unit volume of wood. A weighing balance is used to determine the weight of the wood. Next the wood is seasoned in the oven at a temperature of 106^{o}c for 24 hours and weighed after to determine the weight of moisture present in the wood. Then, there is the sawing of the wood into various dimensions. Table 4.1 shows the specimen data for wood before moisture content test

3.2.3 Casting and Testing Of Concrete-Wood Specimens: The woods are then placed at the centres of the concrete cube. The woods here are laminated with bitumen to repel water. The casting uses binder material (cement) and filler materials such as coarse aggregates, fine aggregates and also wood. The proportions of aggregates for the mixes are 1:2:4. A water cement ratio of 0.6 is used to produce a properly mixed concrete (BS 3148:1980). During casting, thirty-six (36) cubes were produced, six (6) for concrete, fifteen (15) for concrete-wood cubes parallel to the grain and fifteen (15) for concrete-wood cubes sawn perpendicular to the grain (BS 1881: Part 108:1983). The curing of the cubes produced was done in the laboratory in a curing tank (BS 1881: Part 111:1983). The curing was done under normal room temperature (23^{o}C – 26^{o}C) for 7, 14 & 21 days respectively. A Universal testing machine was used to determine the compressive strengths of the wood, concrete and concrete-wood cubes respectively (BS 1881: Part 116:1983).

4.0 RESULTS AND DISCUSSION

4.1 Moisture Content Test: Table 4.1 shows the results of moisture content test for woods. A re-weighing was done after seasoning and Achi R_1 was found to have the highest weight. Achi R_2 lost a large amount of moisture (41%). It was noted that Achi R_1 and Melina R_2 lost no moisture as both of them were in their equilibrium moisture state. After moisture content test was completed and re-weighing done, the woods were re-measured. Mahogany R_1 expanded in width while the rest shrank. Achi R_1 increased in height while the rest decreased in height. Melina R_1 expanded in breadth while the rest shrank.

4.2 Compressive Strength Tests

4.2.1 Compressive Strength Tests of Woods

During the compressive strength tests of wood, Achi wood had the highest strength of 17.67kN/mm^2 parallel to the grain and also the highest strength of 20kN/mm^2 perpendicular to the grain (ASTM :1988). For all the woods tested, the perpendicular to the grain condition always gave a higher value than the parallel to the grain condition.

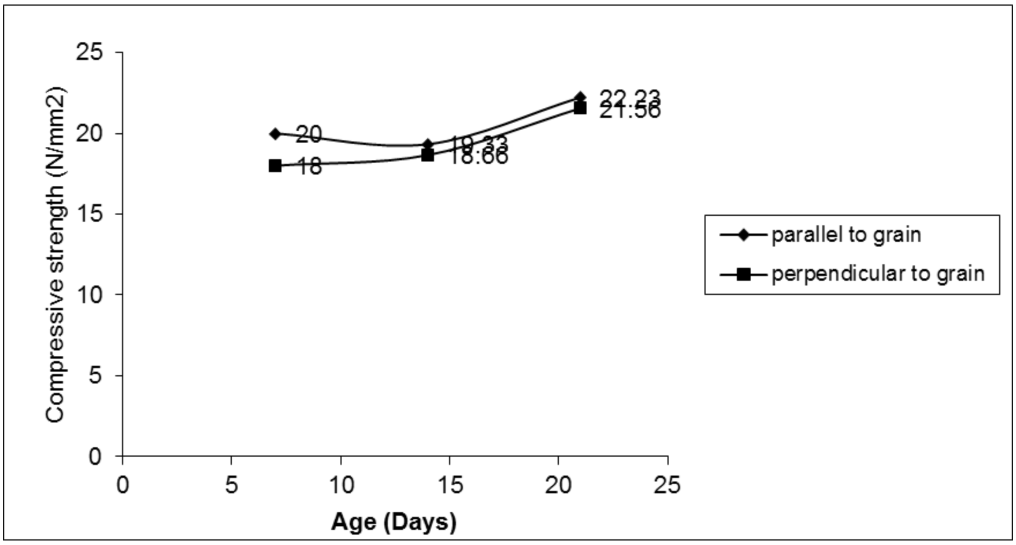

Figure 4.1: Graph of the compressive strengths versus age (days) for wood-concrete cubes with 0.03m x 0.03m x 0.03m wood cubes.

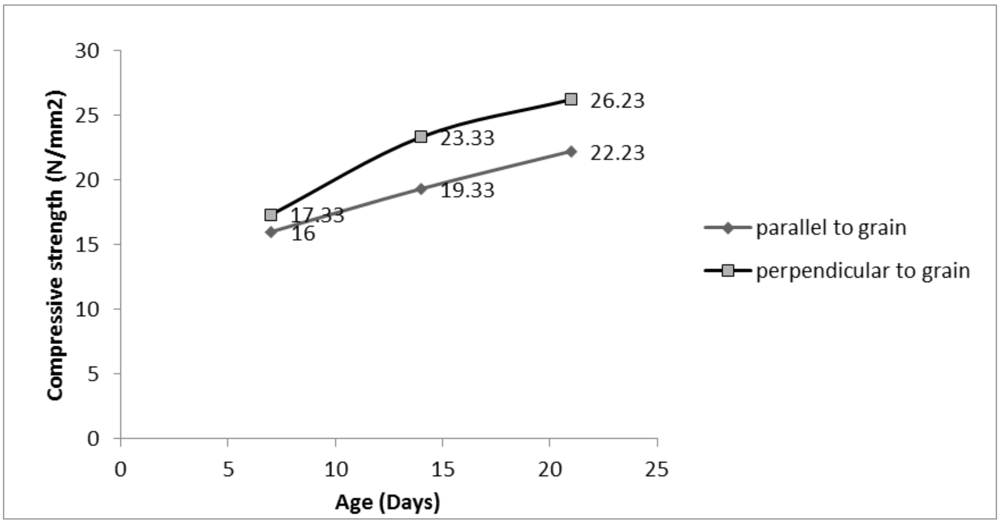

Figure 4.2: Graph of the compressive strengths versus age (days) for wood-concrete cubes with 0.05m x 0.05m x 0.05m wood cubes.

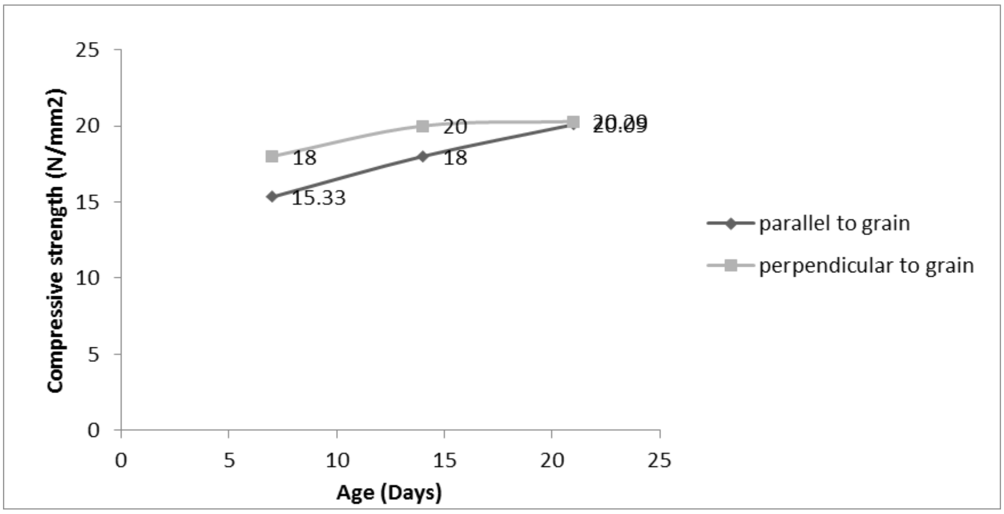

Figure 4.3: Graph of the compressive strengths versus age (days) for wood-concrete cubes with 0.07m x 0.07m x 0.07m wood cubes.

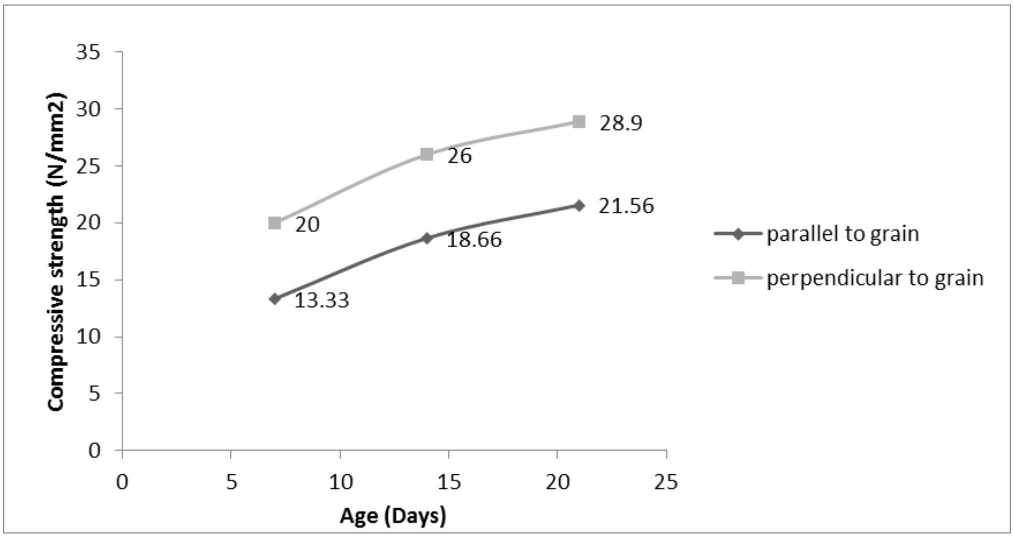

Figure 4.4: Graph of the compressive strengths versus age (days) for wood-concrete cubes with 0.09m x 0.09m x 0.09m wood cubes.

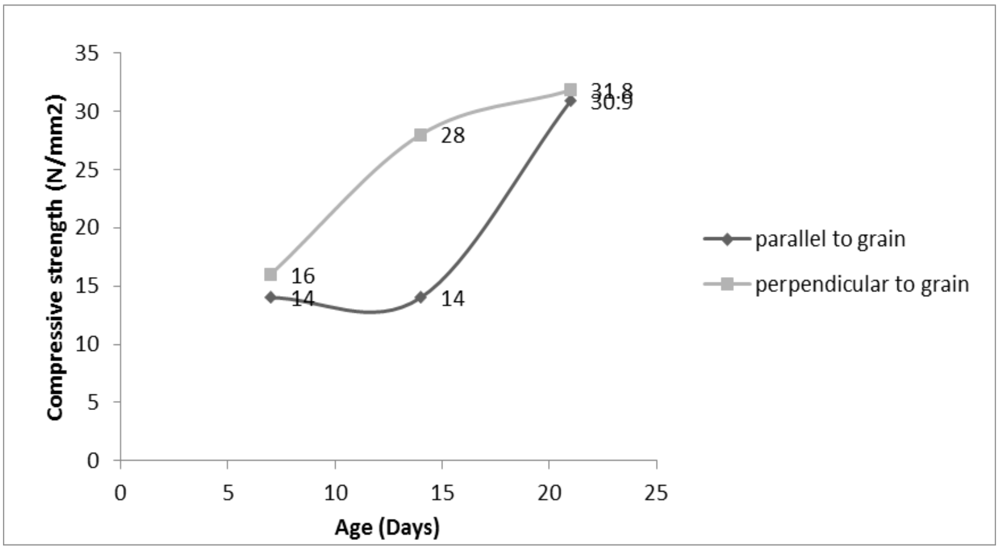

Figure 4.5: Graph of the compressive strengths versus age (days) for wood-concrete cubes with 0.11m x 0.11m x 0.11m wood cubes.

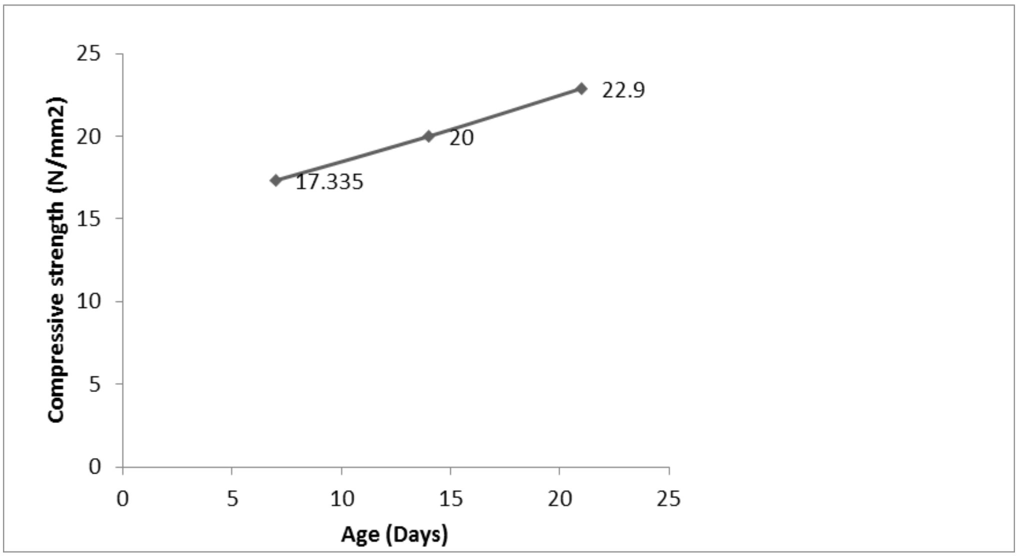

Figure 4.6: Graph of the compressive strengths versus age (days) for pure concrete cubes of dimensions 0.15m x 0.15m x 0.15m.

4.2.2 Compressive Strength Tests of Concrete –Wood Cubes

Figures 4.1 – 4.5 show the graph of the compressive strengths (N/mm^2) versus age (days) of wood-concrete cubes for wood cubes of 0.03m x 0.03m x 0.03m, 0.05m x 0.05m x 0.05m, 0.07m x 0.07m x 0.07m, 0.09m x 0.09m x 0.09m and 0.11m x 0.11m x 0.11m, respectively. The compressive strengths at 7 days of age ranged from 13.33kN/mm^2 - 20kN/mm^2 for 0.09m x 0.09m x 0.09m wood-cubes. This is comparable to the value of 17.335kN/mm^2 given by the pure concrete mix at 7 days. At the age of 21 days, the compressive strengths for the wood-concrete cubes ranged from 20kN/mm^2 for 0.07m x 0.07m x 0.07m wood-cubes to 31.8kN/mm^2 for 0.09m x 0.09m x 0.09m wood-cubes.

Table 3.1: Mix Design Table for Pure Concrete Cube with Nominal Mix 1:2:4.

Dimension of cube (m^3)	Volume of concrete (m^3)	Total mass of concrete (kg)	Mass of cement (kg)	Mass of fine aggregates (kg)	Mass of coarse aggregates (kg)	Total W/C (kg)
0.15x0.15x0.15	337.5×10^{-5}	8.51	1.22	2.43	4.86	2.92

Table 3.2: Mix Design Table for Concrete-Wood Cube with Nominal Mix 1:2:4

Dimensions of wood (m)	Concen tricity	Volume of concrete (m^3) $x10^{-6}$	Total mass of concrete (kg) x 10^{-3}	Mass of cement (kg) X 10^{-3}	Mass of fine aggregates (kg) $x10^{-3}$	Mass of coarse aggregates (kg) $x10^{-3}$	Total W/C (kg) X 10^{-3}
0.11 x 0.11 x 0.11	0.02	8	20.2	3	6	12	10
0.09 x 0.09 x 0.09	0.03	27	68.2	10	19	39	35
0.07 x 0.07 x 0.07	0.04	64	161.3	23	46	92	83
0.05 x 0.05 x 0.05	0.05	125	315.0	45	90	180	162
0.03 x 0.03 x 0.03	0.06	216	544.3	78	155	311	280

Table 4.1: Results of Moisture Content Test for Woods.

Wood name	$W_1 – W_2$ (kg)	% Moisture Content
ARCHI R_1	0	0%
ARCHI R_2	1.3	41%
MELINA R_1	0.1	3.7%
MELINA R_2	0	0%
MAHOGANY R_1	0.1	3.23%
MAHOGANY R_2	0.2	7.14%

Legend: R_1 = Parallel to grain; R_2= perpendicular to the grain

4.2.3 Compressive Strength Tests of Pure Concrete Cubes

The graph of the compressive strengths versus age (days) for pure concrete cubes of dimensions 0.15m x 0.15m x 0.15m is shown in Figure 4.6. The maximum value of the compressive strength was 22.9kN/mm^2 at the age of 21 days.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The use of wood as part replacement for concrete does increase the compressive strength of the cube, most especially when sawn perpendicularly to the grain. The optimum load bearing capacity of concrete-wood cube is higher when the cross sectional area of the wood in the concrete is increased. With an increased dimension of 0.11m x 0.11m x 0.11m of wood sawn perpendicularly to the grain, the strength of the concrete cube was found to be stronger than that of pure concrete for all ages except 7days. Based on the limited number of test conducted, wood can be used as a substitute for volume of concrete used when sawn perpendicularly to the grain.

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