An Assessment of Bamboo Fiber and Recycled Concrete Fine Grain as Replacement to Sand in Concrete Hollow Blocks

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Abstract: - Concrete hollow blocks (CHB) are widely used in the construction industry due to their strength, durability, and affordability. However, the production of CHB involves the use of large amounts of sand, which is a finite resource and can lead to environmental degradation. In recent years, there has been a growing interest in using alternative materials in concrete production to reduce the environmental impact of construction. This study investigates the use of bamboo as an additive in CHB and the replacement of sand with recycled concrete fine grain (RCFG). The study involved the production of CHB using different ratios of bamboo additives and replacement of sand with RCFG. The physical and mechanical properties of the CHB were then tested and compared to traditional CHB made with sand.

Key Words: — *Bamboo fiber, recycled concrete fine grain.*

I. INTRODUCTION

The construction industry all over the world is progressing. It is a common knowledge that in the society, there are many people who want to live in their respective ideal lives, which most of the people in rural areas are continuously renovating their homes, where the term urbanization comes into place.

The growing demand to reduce waste in the construction industry should focus on reducing the amount of construction waste disposed of in landfills through reusing construction materials, using non-traditional materials, or using common materials in non-traditional ways.

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One-fourth of all sorts of garbage generation is made up of building and demolition waste. In order to achieve sustainable development, reuse of the by-product that will be converted to Recycled Concrete Fine Grain (RCFG) in other sectors of the economy is a positive step. Research and development organizations support the study of recycled materials in the context of sustainable construction. One goal is to use debris in place of natural aggregate recycled concrete made from old concrete buildings.

The Philippines ranks sixth among the world's top exporters of bamboo. The overall area of bamboo stands in the Philippines is between 39,000 and 53,000 hectares, with the majority of these stands naturally growing sporadically or in patches in backyards and along riverbanks in forested areas and on certain private lands, and only seldom in pure commercial stands. An average of 36 million culms per year are predicted to be produced from these bamboo stands each year. Bamboo has been utilized for a variety of uses for years. Bamboo products are actively produced and processed in the Philippines for use in construction, the fabrication of furniture and other handicrafts, food, musical instruments, farm and fishing equipment, pulp and paper, and as a fuel for cooking and heating.

The majority of nations regard the building industry to be their largest energy and material consumer. To maintain the sustainability of future generations, many research projects focus on the use of renewable and sustainable materials in this area. The idea of green and sustainable development has gained a lot of traction around the world, and bamboo fiber technology has made significant strides and entered a number of crucial material applications. In congruence to this, Bamboo scrimber, a composite made from crushed bamboo fiber, has attracted the attention of researchers and manufacturers due to its excellent mechanical properties and design. The findings of analytical and experimental studies showed how different bamboo species, defibering times, heat treatment, adhesives, densities, etc. affect bamboo scrimper performance. Natural fibers can be utilized as a substitute for synthetic fibers as a reinforcing agent due to their accessibility and renewability.

Clemson Agricultural College (South Carolina) had done a lot of testing on using bamboo in Portland cement concrete. Bamboo has been utilized in some regions for millennia as a building material, but before the Clemson study, its usage as a concrete reinforcement had received little consideration. Ultimate strength design procedures were modified to account for the characteristics of the bamboo reinforcement in order to estimate the ultimate load carrying capacity of the precast concrete elements with bamboo reinforcing. A widely used "strong-as-steel" for concrete is made of bamboo, which is a highly renewable and high-strength alternative to timber. Unquestionably, two of bamboo's main advantages are its high rate of biomass production and renewability in plantations that are sustainably managed. However, it is invalid to compare steel favorably in terms of strength. Bamboo is a typically hollow, anisotropic, natural material with high variability of physical and mechanical properties across the section and along the culm. In a dry state, bamboo characteristic strengths are, at best, comparable to that of high-grade hardwood—between 30 MPa and 50 MPa Bamboo is a typically hollow, anisotropic, natural material.

Bamboo is one of the most commercially significant non-timber forest products in the Philippines, and bamboo fiber reinforced concrete is made from concrete that has been reinforced with bamboo fiber (BFRC). The building's structural components, such as supports, columns, roofing, etc., were made of bamboo. Concrete is utilized as the primary material in building. Concrete has a weak tensile strength but is strength in compression. It now participates in the use of natural materials to make concrete. High tensile strength bamboo fiber is anticipated to make a substantial contribution to rapid growth, wide growth distribution, affordable earthquake-resistant building, and seismic retrofit skill, producing vibro-compacted dry-mixed concrete hollow blocks, which are historically used in wall construction, with fine and coarse recycled aggregates from concrete and mixed sources. A reference block, five series of blocks, and several combinations of recycled aggregates and concrete were constructed.

II. METHODOLOGY

The researchers used quantitative research, according to scientific methodologies, it involves deductive reasoning, in which the researchers made a hypothesis, and the focus was on the gathering of data in dealing with the problem of the study. After series of analyses and findings have been shared, using the evidences from the study, results and discussions were demonstrated to check whether the hypotheses were valid or flawed. More so, experimental research which is under quantitative research and qualitative research, will be focusing on collecting and analyzing non-numerical data. To collect authentic data from different perspectives, the researchers conducted the actual experiment in order to have a better understanding of the outcome.

2.1 Sampling methods

The sample for Bamboo fiber and Recycled Concrete Fine Grained (RCFG) were divided into 2 types with different proportions. The proportions mixed with the CHB was bamboo fiber and sand were replaced with RCFG. In the absence of adequate weather protection, these units are appropriate for exterior walls exposed to freezing cycles. To prevent the usage of load bearing units, these units must be clearly marked. According to (ASTM C129) a single unit must have a minimum net area compressive strength of 500 psi (3.45 MPa), whereas three units must have an average strength of 600 psi (4.14 MPa).

Table.1. No. Of Specimen Per Percentage of Samples

Days	Control	1:6 Ratio	Water Absorption (Control and Experimental)

7 days	2	2	4
14 days	2	2	4
28 days	2	2	4

2.2 Materials

Cement: **-** A common type of cement used in construction projects is ordinary Portland Cement, sometimes referred to as Type 1 cement or Portland cement. It is composed of calcareous, or calcium carbonate, and argillaceous or silicates of alumina (clay and shale) (limestone, chalk, and marl). The majority of masonry work and general building use it.

Recycled Concrete Fine Grained: **-** is recycled aggregate used in concrete that contains both coarse and/or fine aggregate.

Bamboo fiber: **-** a regenerated cellulosic fiber that produced from a bamboo.

Water: **-** Microstructure largely develops as a result of curing. Neither salts nor solid particles should be present in the water used for construction or curing. Concrete is typically made using potable tap water. In the course of construction, water is employed in numerous processes.

2.3 Equipment/Apparatus and Utensils

Compression Machine: - are utilized to calculate the compressive, splitting, and flexural strengths. The specimen is subjected to increasing compressive forces until failure occurs, which is most frequently applied to materials with high compression but low tensile strength.

Crusher Machine: **-** In the mining, iron and steel, and quarry industries, crusher machines are used to crush a wide range of materials. They are employed in the quarry sector to crush rocks into granite for use in civil engineering projects and the construction of roads.

Digital Scale: **-** A measuring tool that reads and shows an object's weight is a digital scale. A digital scale is a high-quality scale that provides a more accurate weight reading than an analog balance scale.

Oven: **-** For high-volume thermal convection applications, a laboratory oven is employed. This laboratory apparatus maintains a constant temperature inside the chamber, which is essential for industrial lab processes including annealing, drying, and sterilizing.

CHB Molder: - it is used to design the different types of Common Hollow Blocks

2.4 Constructing a CHB with a mixture of Bamboo Fiber and RCF

For trial Mixture:

- The trial mixture was used to determine the quantity of percentage in every material to be used in making a concrete hollow block by the ratio of 1:6.

For Raw Materials

- The Raw materials contained the quantities that must be solved, and this test was able to determine by the Quantity Test (Q.T) performed by the researchers. The remaining information were based on the American Society for Testing and Materials (ASTM).

2.5 General Procedure

Collection: - The researchers gathered bamboos at San Jose Matulid, Mexico and gained a total of 20 pieces with a length of 2 feet each. The following materials needed to produce a hollow block such as RCFG were gathered from different sites within San Fernando while the cement was provided by the manufacturer.

Mixing: **-** In this process, the researchers utilized a mixer to mix the raw materials needed to produce a 5” hollow block. Likewise, Cement: 4.992 kg, RCFG: 10.008 kg, Water: 3.336 kg were put in the mixer for mixing.

Molding: **-** After the mixture was released from the mixer, the researchers added the bamboo fibers and distributed them evenly on the mixture.

- *Set-up A*: The researchers manually distributed 960 grams of fiber in the mixture to produce twelve hollow blocks with bamboo fibers.
- *Controlled set-up*: To produce a normal hollow block, the researchers put the mixture in the molder without adding any bamboo fiber.

Drying: **-** The researchers were able to produce a total of twelve blocks with bamboo fiber and twelve commercial hollow blocks. The following hollow blocks were dried in a period of seven, fourteen and twenty-eight days.

Curing: **-** The researchers CHBs were typically cured for a minimum of seven days, and up to 28 days, to ensure optimal strength and durability.

Testing: - The researchers conducted a compressive strength test for testing. In this test, the hollow blocks were brought to Unified Testing Center to measure the compressive strength using a compressing machine as well as water absorption test. The authorized personnel recorded the results and printed them out to give the researchers the final copy.

2.6 Compressive Test Strength

Compressive strength was measured on three different occasions, at seven, fourteen, and twenty-eight days. The load capacity, platen sizes, vertical space between platens, and horizontal space between machine columns must be determined by the specimens to be tested (600 x 200 x 125) in mm.

C=P/Area x 1000

C = Compression Strength (MPa)

P = Maximum applied load indicated by the machine at Compress

The compressive strength test on hollow blocks is an important quality control test to determine the strength of hollow blocks before they are used in construction. Here are the details of the process:

- Sampling: Two hollow blocks were sampled randomly from the production line or from the finished product inventory.
- Preparation: The specimens should be dried in air at room temperature for 7, 14 and 28 days.
- Testing: The test was performed using a compression testing machine. The hollow blocks were placed on the machine's lower platen, which should be clean and level, and centered under the loading platen.
- Loading: The load was applied uniformly and continuously at a rate of 14 N/mm2/minute until failure. The maximum load at which the block fails was recorded.
- Calculation of compressive strength: The compressive strength of the hollow block was calculated by dividing the maximum load at failure by the cross-sectional area of the block. The cross-sectional area was calculated as the length times the width of the block.
- Reporting: The results of the compressive strength test should be reported in megapascals (MPa), and the test report should include the block dimensions, date of manufacture, and identification number.

2.7 Water Absorption Test

For 24 hours, three full-size blocks must be completely immersed in clean water at room temperature. The blocks were then removed from the water and allowed to drain for one minute on a 10 mm or coarser wire mesh, with visible surface water removed with a damp cloth and the saturated and surface dry blocks weighed immediately. After weighing, all blocks were dried in a ventilated oven at 100 to 1150C for at least 24 hours and until two successive weighing's at 2-hour intervals showed an increment of loss of no more than 0.2 percent of the specimen's previously determined mass. The water absorption formula is as follow:

Percent =(A-B)/B * 100

Where:

A = wet mass of unit in kg.

B = dry mass of unit in kg.

The water absorption test on concrete hollow blocks (CHB) is a quality control test that measures the ability of the blocks to absorb water. The test can be performed using the following procedure:

- Sampling: Select two pieces of CHBs from the production line or finished product inventory.
- Preparation: The CHBs should be dried in air at room temperature for 24 hours.
- Weighing: Weigh each dry CHB and record its weight as "dry weight."
- Immersion: Immerse the CHBs completely in water at a temperature of 24 ± 1 °C for a period of 24 hours.
- Weighing: Remove the CHBs from the water and wipe them with a dry cloth to remove any surface water. Weigh each wet CHB and record its weight as "wet weight."
- Calculation of water absorption: Calculate the water absorption of each CHB by using the following formula: Water absorption = ((wet weight - dry weight) / dry weight) x 100%.

- Reporting: The results of the water absorption test should be reported in percentage, and the test report should include the block dimensions, date of manufacture, and identification number.

III. Results and Discussion

The hollow blocks had undergone compressive Strength test. The hollow blocks went through a compressing machine for testing. The authorized personnel prepared the machine before testing. When the machine was ready, the CHB with bamboo and fiber and RFCG and Standard CHB compressed to its maximum strength until it broke. As a conclusion for the compressive strength test to compare the efficiency of the

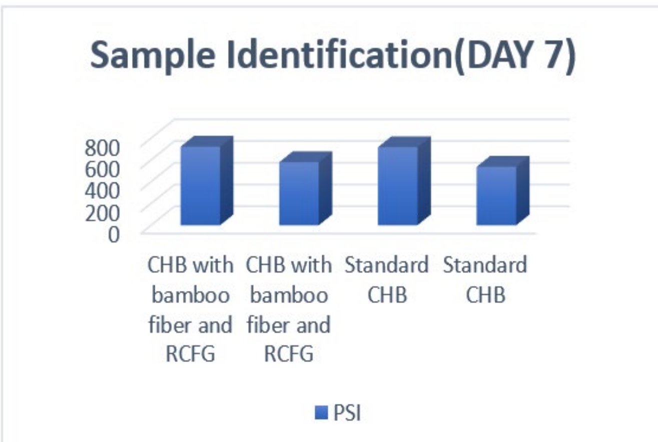

Fig.1. Compressive Strength Test of Hollow blocks

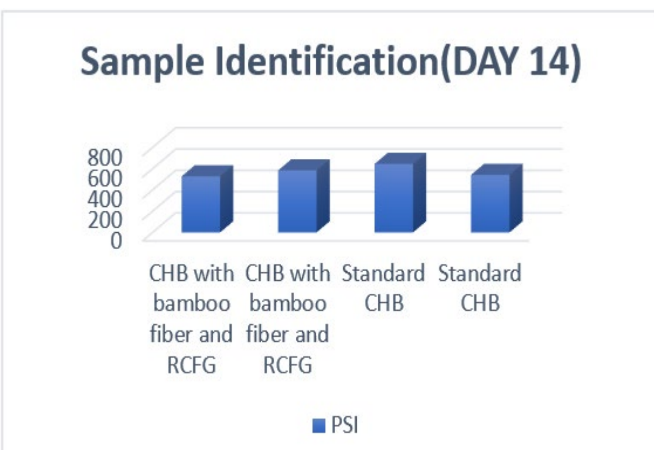

Fig.2. Compressive Strength Test of Hollow blocks

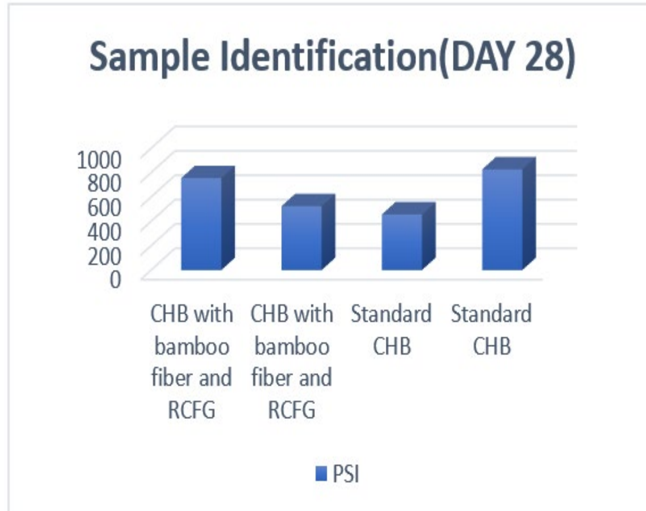

Fig.3. Compressive Strength Test of Hollow blocks

control (standard CHB) and the experimental (Bamboo Fiber-Added CHB) in terms of compressive strength. The CHB with Bamboo fiber and RCFG had a pressure strength of 620.83 psi, while the Control (Standard) had a pressure strength of 615.5 psi. which yields a percentage difference of approximately +0.87%.

The positive sign indicates that the control compressive strength is lower than the CHB w/ Bamboo fiber and RCFG compressive strength. In this case, the Bamboo Fiber-Added CHB has a compressive strength that is approximately 0.87% higher than the standard CHB.

Table.2. Water absorption test for Hollow blocks

Sample	Original weight of sampled, gm	Bulk Specific gravity	Weight of Oven Dry, gm	Absorption %
Bamboo fiber and RCFG 1	9017	10032	8571	17.05
Bamboo fiber and RCFG 2	9139	10133	8790	15.28

Table.3. Water Absorption Test of Hollow blocks

Sample	Original weight of sampled, gm	Bulk Specific gravity	Weight of Oven Dry, gm	Absorption %
Control 1	8718	9269	8434	9.90
Control 2	8638	9387	8462	10.93

The hollow blocks have undergone Water Absorption test. The hollow blocks weigh before putting the CHB to the water. The authorized personnel prepared the oven for drying process and weigh them again for final weight of the CHB and determine the percentage for water absorption of the Bamboo fiber and RCFG CHB and the Standard CHB.

As a conclusion for the water absorption test to compare the efficiency of the control (standard CHB) and the experimental (Bamboo Fiber-Added CHB) in terms of absorption of water. The CHB with Bamboo fiber and RCFG had an average of 16.165% absorption while the Control (Standard) had an average of 10.415% of absorption. which yields a percentage difference of approximately +35.51%.

IV. Summary, Conclusions, And Recommendations

4.1 Summary

The key research findings from each testing instrument were summarized in this chapter. In order to create CHBs (Concrete Hollow Blocks), recycled concrete fine grain, bamboo fiber, and cement were used in place of sand in the following proportions: 25% Bamboo Fiber, 1:6 recycled concrete fine grain, and cement.

First, the researchers tested the sample mixture of bamboo fiber and recycled concrete fine grain to cement using a compressive testing machine in the Unified Geotest Laboratory. The researchers reviewed the results. Therefore, the average dimensions of the commercial hollow block and CHB with bamboo fiber and RCFG are 400 mm in length, 120 mm in width, 48 000 mm in gross area, 19 175 mm in hole area, and 28 825 mm in net area. Prior to the test, the physical dimensions of the Standard Hollow Blocks, CHB with Bamboo Fiber, and RCFG were measured.

The commercial hollow block and CHB with bamboo fiber and RCFG has an average length of 396mm, a width of 120mm, a gross area of 47,520mm, a hole area of 19,685mm, and a net area of 27,835mm. For testing, the hollow blocks were sent through a compressing machine. Before testing, authorized personnel prepared the machine. When the machine is ready, the CHB with bamboo, fiber, and RFCG, as well as the standard CHB, were compressed to their maximum strength until they were broken.

Lastly, the samples of the researchers were examined for Water Absorption to evaluate the sample combination of bamboo fiber and RCFG to cement. According to ASTM C129, the minimum compressive strength requirement for non-load bearing CHBs is 3.5 megapascals (MPa). If the compressive strength of the CHBs is equal to or greater than this minimum requirement, the test is considered passed, and the CHBs are suitable for use in non-load bearing walls.

The maximum allowable water absorption rate for CHBs used in non-load bearing walls is 18% by weight. If the water absorption rate of the CHBs is equal to or lower than this maximum allowable value, the test is considered passed, and the CHBs are suitable for use in non-load bearing walls.

4.2 Conclusion

In conclusion, the study demonstrated that bamboo fibers can serve as an effective additive in hollow blocks to improve their compressive strength. The researchers replaced sand with RCFG and used bamboo fibers as a reinforcement material in Set-up A, while commercially available hollow blocks were tested in Set-up B. The compressive strength of both setups was measured three times in a compressive testing machine. The results indicated that the bamboo fiber acted as a binder and helped maintain the integrity of the hollow blocks, resulting in improved compressive strength. Therefore, the utilization of bamboo fibers as a strengthening material in hollow blocks can be considered a viable option in the construction industry.

4.3 Recommendation

The following recommendations have been provided for the specific improvement of the study "An Assessment of Bamboo Fiber and Recycled Concrete Fine Grain as Replacement to Sand in Concrete Hollow Blocks"

- To further increase the concrete's compressive strength, take into account employing environmentally friendly and sustainable materials.
- Use a Concrete Fine Grain Crushing Machine rather than crushing it by hand to produce more concrete fine grain easier, faster, and with fewer hours of work.
- The consistency and quality of hollow blocks can be increased by using modern production techniques such automated mixing and matching systems.
- To ensure the quality of the blocks, further examinations, like compressive strength tests, and water absorption test should be carried out frequently.
- This work could serve as a guide for future researchers in creating concrete hollow blocks that are more environmentally friendly.

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