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Utilization of Coconut Coir as an Additional Fiber Reinforcement and Partial Replacement of Sand in Concrete Hollow Block

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ABSTRACT

Conventional Concrete Hollow Blocks (CHB) use sand as an aggregate. However, this research studies the utilization of an alternative aggregate, such as coconut coir, which has potential use for recycled materials. Philippines, as one of the largest coconuts producing country in the world too much coconut waste are being produced every day in our country. Though there are other studies trying to maximize the use of coconut fiber, a large portion of the wastes are left unused or burnt affecting our natural environment. This research explores the possibility of utilizing coconut coir as fiber reinforcement and an alternative aggregate for hollow CMU by replacing a fraction of sand with coconut coir. Tests shows that on seventh day, the proportion A(control) and B (CHB with 1% coir) attained a compressive strength above 3.45 MPa, the minimum value stipulated in ASTM C-129 for Hollow non-load bearing CMU. All the samples comply in the maximum requirements for water absorption and moisture content tests which is 240Kg/m^3 and 45 percent respectively. Not only does the addition of coconut coir improves the durability of CHB, but equally significant are the potential of recycling materials for a better environment and economic impact in communities where coconut production is abundant.

Keywords: Coconut Coir, Concrete Hollow Blocks, Recycling

INTRODUCTION

Masonry is the building of structures from individual units laid in and bound together by mortar; the term *masonry* can also refer to the units themselves. The common materials of masonry construction are brick, stone such as marble, granite, travertine, limestone; glass block, stucco, and tile concrete block. Masonry is generally a highly durable form of construction. However, the materials used, the quality of the mortar and workmanship, and the pattern in which the units are assembled can significantly affect the durability of the overall masonry construction.[1]

Concrete Hollow Blocks (CHB), are one of the most extensively used walling materials in the Philippines. Some of the reasons for this is their relative low cost when compared to other materials and speed of installation by semi-skilled laborers.[2]

Adding fibers prevents the development of cracks in the concrete materials and increase its ductility, which also proved that adding fiber reduces its permeability and bleeding. Moreover, addition of fiber increases the resistance of the material against fracture when stressed.[3]

However, the rapid growth in population has led to an increase in demand for housing residential and commercial building, public and private infrastructures have led the scarce on the raw materials used in Concrete Hollow Blocks (CHB) making and resulted an increase on its price. In addition, transporting the hollow blocks usually have high chance of breaking due to its vulnerability and adds to the loses in construction costs, therefore a growing interest in utilizing coconut coir as fiber reinforcement and alternative aggregates which has potential in easing both problems.

BACKGROUND OF THE STUDY

A concrete block is primarily used as a building material in the construction of walls. It is sometimes called a concrete masonry unit (CMU). A concrete block is one of several precast concrete products used in construction. The term precast refers to the fact that the blocks are formed and hardened before they are brought to the job site. Most concrete blocks have one or more hollow cavities, and their sides may be cast smooth or with a design. In use, concrete blocks are stacked one at a time and held together with fresh concrete mortar to form the desired length and height of the wall. [4]

Concrete mortar was used by the Romans as early as 200 B.C. to bind shaped stones together in the construction of buildings. During the reign of the Roman emperor Caligula, in 37-41 A.D., small blocks of precast concrete were used as a construction material in the region around present-day Naples, Italy. Much of the concrete technology developed by the Romans was lost after the fall of the Roman Empire in the fifth century. It was not until 1824 that the English stonemason Joseph Aspdin developed Portland cement, which became one of the key components of modern concrete. [4]

The first hollow concrete block was designed in 1890 by Harmon S. Palmer in the United States. After 10 years of experimenting, Palmer patented the design in 1900. Palmer's blocks were 8 in (20.3 cm) by 10 in (25.4 cm) by 30 in (76.2 cm), and they were so heavy they had to be lifted into place with a small crane. By 1905, an estimated 1,500 companies were manufacturing concrete blocks in the United States. [4]

These early blocks were usually cast by hand, and the average output was about 10 blocks per person per hour. Today, concrete block manufacturing is a highly automated process that can produce up to 2,000 blocks per hour.[4]

Objective of the Study

The main objective of this study is to assess the potential of coconut coir to produce newly improve fiber reinforced concrete hollow blocks. Specifically, it aims the following:

1. To produce an innovative building materials using coconut wastes.
2. To produce durable but economical Concrete Hollow Blocks
3. To assess the Coconut Coir Fiber Reinforced CHB, if will comply to the required standard for ASTM.

Significance of the Study

The purpose of this research is to establish a concrete study about the assessment of the utilization of coconut coir as an alternative locally available and cheap materials use as an additional Fiber Reinforcement and Partial Replacement of Sand in Concrete Hollow Block.

The study will benefit the students and co-researchers as a reference for their future study related to this topic and if ever in improving this experimental study. The instructors could also use this research in motivating their students in citing good examples of recycled but helpful products that will benefit to the different sectors in the society. This could also help not only the small firm but also the big construction industry in earning additional profit in purchasing this product. Future home owners in having a good house in more affordable price by using these locally available cheap hollow blocks. This research could help the small coconut farmers in utilizing their waste products into cash. Their waste coir, will be used as the cheap material of the concrete hollow blocks as partial replacement for sand. The used of this product will also benefit our economy, the cheaper construction materials used will result a more profit to the different firms and sectors which simultaneously affect our economic growth. And more importantly, this research study could help our Mother Earth in decreasing global warming due to the burnt waste materials such as coconut coir.

Scope and Delimitation of the Study

This study is limited to the following scope:

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Subject content:

Specifically, the present study covers on the research about the Utilization of Coconut Coir as an additional Fiber Reinforcement and Partial Replacement of Sand in Concrete Hollow Block.

Tests on Concrete Hollow Blocks:

The Concrete Hollow Blocks samples are subjected to compression, moisture content and water absorption tests only.

Theoretical Framework

The Concrete Masonry includes all the sizes and kinds of hollow or solid blocks, bricks, and concrete buildings tiles, so long as they are made from concrete and are laid by masons. Hollow CMU or Concrete Hollow Blocks (CHB) are generally not capable of carrying super-imposed loads.[5] Typically, it has a core greater than 25 percent of its gross sectional area. Aggregates normally make up about 90 percent of the block by weight; they have an important effect in the properties of the block. Conventional hollow non-load bearing CMU has a cement-aggregates ratio 1:12. Typical number of curing days is 7.

Compression, Water Absorption and Moisture content tests are performed on hollow CMU such as load-bearing and non-load-bearing blocks in order to determine its strength properties. The tests are important for the evaluation of compressive strength, water absorption and moisture content as basis for acceptance to specific use. In order to establish the quality of the concrete block, its ultimate compressive strength, maximum water absorption and moisture content should meet the requirements according to the American Society of Testing and Materials (ASTM) Standards. In the Philippines, the Department of Public Works and Highways (DPWH) also stipulates its requirements.

ASTM C129 requires the minimum average compressive strength of hollow non-load-bearing CMU to be 4.14 MPa, or a minimum individual compressive strength of 3.45 MPa, the moisture content requires a maximum of 45% and 240 kg/m^3 for water absorption. [6] And the DPWH Item 704 requires a minimum average compressive strength of 6.9 MPa or a minimum individual compressive strength of 5.5 MPa for hollow load-bearing CMU (DPWH 2000).

Conceptual Framework

The study dealt with the utilization of coconut coir as an additional fiber reinforcement and partial replacement of sand in concrete hollow blocks. It showed the great significance of utilizing coconut coir as partial replacement in the mixtures of CHB.

The conceptual framework (Figure 1) illustrates the methodology used in this study, including the material selection and testing phases.

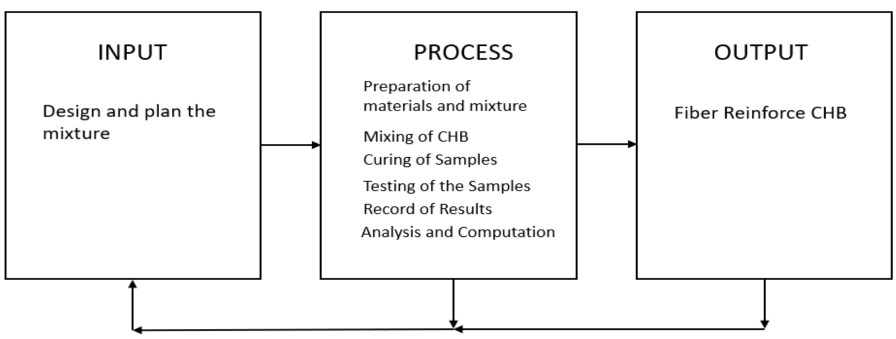

Figure 1. Conceptual Framework

Figure 1 illustrates above shows the conceptual model and process of the study.

MATERIALS AND METHOD

The experimental method of research will use in this study. The experimental method of research is defined as a good method or procedure involving the control or manipulations of conditions for the purpose of studying the relative effects of various treatments applied to member of a sample, or of the same treatment applied to members of different samples.

The basic purpose of experimental research is to discover the influence of one or more factors upon a condition, group, or situation, purpose of which is to discover "what will be?". It describes and analyzes variables in carefully controlled conditions as a basis for inferring or concluding.

METHODOLOGY

The Coconut coir in this experiment was obtained from the coconut Farm in Bulacan. The coir must be approximately one inch in size. The aggregates that were used passed the No. 4 sieve. And Portland Cement Type I was used for the mix. The hollow CMU produced have a dimension of approximately 100 x 200 x 400mm (4" x 8" x 16").

Conventional mix for ordinary hollow CMU in the local market is 1 part cement to 12 parts aggregates. In the research, seven different proportions were designed with 4 samples each and to be tested on the 7th day. The first proportion without coir is 1 part cement and 12 parts aggregates. For 4 other proportions, quantity of the aggregate will be replaced by coir ranging from 1%, 2%, 3% and 4% of the total aggregate volume.

Table 1. Summary of Design Mixes

Design Mix	% Coir By Aggregate Volume
Proportion A	0%
Proportion B	1%
Proportion C	2%
Proportion D	3%
Proportion E	4%

Table 1 shows the summary of the proportion use in making of Concrete Hollow Blocks (CHB). It composed of five proportions A, B, C, D, and E. The percentage of coir by aggregate volume ranges from 0, 1 to 4 respectively.

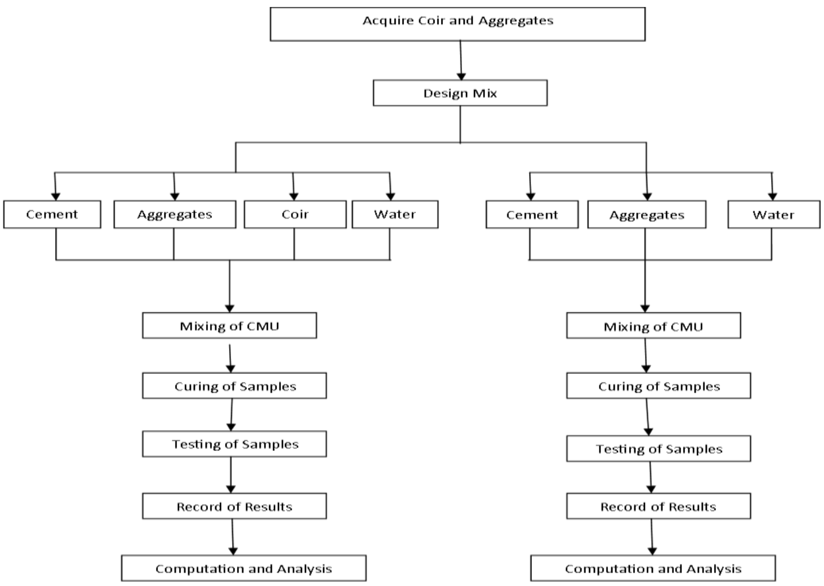

Figure 1. Flow of Activities

Figure 1 illustrates the flow of activities to be conducted to arrive at the results. Starting from acquiring the coir and aggregates, proceed to the design mix, which is the first proportion compose of cement, aggregates, coir and water and the last one is for the control compose of cement, aggregates and water only. Then proceed to the curing of samples in seven days period, and testing the samples, records all the results and compute it.

Materials

It presents the materials used in making the fiber reinforced concrete hollow blocks

1. Coconut Coir
2. Sand
3. Cement – Type I
4. Water

Instrument, Apparatus and Equipment

1. Water Bucket
2. Shovel
3. Meter tape
4. Curing Pond
5. Water Tank (for immersed weight of specimens)
6. Weighing Scale
7. UTM (Universal Testing Machine)

Preparation of Specimen

1. Extracting the coir
2. Mixing cement and sand with coir
3. Pouring of mix in the mold.

Laboratory Procedures

The following specific test procedures are done by the researchers to determine the compressive strength, moisture content, and water absorption of the specimens. The procedures are in accordance to the ASTM C 140-03.

Test Procedures

The specimens for the study of the Utilization of Coconut Coir as an additional Fiber Reinforcement and Partial Replacement of Sand in Concrete Hollow Block are Subjected to the following tests:

A. The proportion of each mix are subjected to the compressive strength test and the results are compared if each passes the compressive strength for non-load bearing hollow blocks set by ASTM C-140-03.
B. The proportion of each mix are subjected to the moisture content and absorption test and the results are compared if each passes the compressive strength for non-load bearing hollow blocks set by ASTM C-140-03.

Compressive Strength Test

A. The dimension and weight of every specimen is determined using meter tape and weighing scale.
B. Every specimen is loaded in Universal Testing Machine to obtain the ultimate load it can hold before failure.
C. Unloading the specimen from UTM.
D. The compressive strength for individual and average of samples is computed using the worksheet as guide.

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Water Absorption and Moisture Content Tests

A. The weight of the specimen is obtained using a solution balance.
B. After obtaining the weight, the specimen is placed in the oven at 110◦ Celsius.
C. Then, the specimen is weighed for oven dried weight.
D. The specimen is submerged in curing pond for 24 hours.
E. The specimen is weighed for saturated surface dry weight.
F. The specimen is weighed while submerge in water to obtain the immersed weight.
G. Computation for moisture content and absorption is done using the data acquired.

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

The result and observation in the test conducted from compressive strength and absorption in the study of Utilization of Coconut Coir as an additional Fiber Reinforcement and Partial Replacement of Sand in Concrete Hollow Block are presented in this chapter.

The coconut coir, has less weight but occupies larger space in the proportion of the mixture thus, the researchers decided to focus on smaller proportion of the coir.

Compressive Strength

Table 2. Test Results for Compressive Strength (Individual)

Proportion	Compressive Strength, Psi (Mpa)		
	Sample 1, Psi (Mpa)	Sample 2, Psi (Mpa)	Sample 3, Psi (Mpa)
0 %	523.59 (3.61)	606.27 (4.18)	681.54 (4.70)
1%	657.00 (4.53)	606.27 (4.18)	540.97 (3.73)
2%	358.25 (2.47)	361.69 (2.49)	379.99 (2.62)
3%	382.36 (2.64)	279.02 (1.92)	339.38 (2.34)
4%	189.46 (1.31)	268.69 (1.85)	229.15 (1.58)

The table 2 shows the summary of test results of compressive strength for individual sample produced by the seventh day period. The result shows that the control or zero percent (0%) and the sample with one percent (1%) coir attained the standard strength for ASTM C-129 which is 500psi. [6]

Table 3. Test Results for Compressive Strength (Average)

Proportion	Compressive Strength, Psi (Mpa)
0 %	603.84 (4.16)
1%	601.41 (4.15)
2%	366.64 (2.53)
3%	333.59 (2.30)
4%	229.10 (1.58)

The table 3 shows the summary of test results of compressive strength for the average of samples produced by the seventh day period. The result shows that the control or zero percent (0%) and the sample with one percent (1%) coir attained the standard strength for ASTM C-129 which is 600psi. [6]

Moisture Content

Table 4. Test Results of Moisture Content (Individual)

Proportion	Moisture Content, %		
	Sample 1(%)	Sample 2(%)	Sample 3(%)
0%	33.33%	40.00%	37.50%
1%	44.44%	44.44%	37.50%
2%	40.00%	36.36%	44.44%
3%	44.44%	44.44%	44.44%
4%	33.33%	30.77%	40.00%

The table 4 shows the summary of test results of moisture content for individual sample produced by the seventh day period. The result shows that the moisture content of all the sample doesn't exceeds the standard maximum value of ASTM C-129 which is 45 percent. [6]

Table 5. Test Results of Moisture Content (Average)

Proportion	Moisture Content, %
0%	36.94%
1%	42.13%
2%	42.47%
3%	44.44%
4%	34.70%

The table 5 shows the summary of test results of moisture content for average of samples produced by the seventh day period. The result shows that the moisture content of all the sample doesn't exceeds the standard maximum value of ASTM C-129 which is 45 percent. [6]

Water Absorption

Table 6. Test Results for Water Absorption (Individual)

Proportion	Water Absorption, kg/m³		
	Sample 1 (kg/m³)	Sample 2 (kg/m³)	Sample 3 (kg/m³)
0 %	120.00	100.00	156.86
1%	191.29	204.55	173.91
2%	200.00	220.00	176.74
3%	155.17	160.71	166.67
4%	210.53	224.14	181.82

The table 6 shows the summary of test results of water absorption for individual sample produced by the seventh day period. The result shows that the water absorptions of all the samples didn't exceed the standard maximum value of ASTM C-129 which is 240 kg/m^3. [6]

Table 7. Test Results for Water Absorption (Average)

Proportion	Water Absorption, kg/m³
0%	125.62
1%	189.98
2%	172.68
3%	160.85
4%	205.50

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The table 7 shows the summary of test results of water absorption for average of samples produced by the seventh day period. The result shows that the water absorptions of all the samples doesn't exceed the standard maximum value of ASTM C-129 which is 240 kg/ m^3[6]

Economical Analysis

Table 8. Percent Reduction of Aggregates

Proportion	Sand(kg)	Cement(kg)	Coir(kg)	% Reduction(Sand)
A	25.00	3.33	0.00	0 %
B	24.50	3.33	0.50	1%
C	24.00	3.33	1.00	2%
D	23.50	3.33	1.50	3%
E	23.00	3.33	2.00	4%

*note: Average Market Price was based on the DPWH Construction Materials Price Data NCR[7]

Table 8 shows the percentage reduction of aggregates by replacing sand with coconut coir. The percentage replaced varies from 0 to 4 percent of coir.

Table 9. COST ANALYSIS

Proportion	Average Market Price (Php)	Price per Unit (Php)	Savings (Php)
A (0%)	Php 22.41	Php 22.41	Php 0.00
B (1%)		Php 22.23	Php 0.18
C (2%)		Php 22.06	Php 0.35
D (3%)		Php 21.88	Php 0.53
E (4%)		Php 21.71	Php 0.70

*note: Average Market Price was based on the DPWH Construction Materials Price Data NCR [7]

Table 9. Shows the cost of conventional CHB compared to the samples with coir mixture. It also shows the saving per unit of each proportion compared to the price of the conventional CHB.

SUMMARY, CONCLUSION AND RECOMMENDATION

Summary

- By replacing portion of coconut coir to the Concrete Hollow Blocks, the water absorption and Moisture Content of all the samples passed the standard of ASTM C-129, which if it fails it will deteriorate the strength of the Samples. The moisture content of conventional CMU was 36.94 and the mixtures with 1, 2, 3 and 4 percent coir attained 42.13, 42.47, 44.44 and 34.70 percentage. The water absorption of 0, 1, 2, 3, and 4 percent proportion attained 125.62, 189.98, 172.68, 160.85, and 205.50 kg/m^3.
- The Percentage with the smallest portion of coir which is one (1) percent attained the standard specification in terms of its compressive strength. 2, 3, and 4 percent proportion attained 366.64, 333.59 and 229.10 Pound per square inch (Psi). While the control attained the highest 603.84 Kg/m^3 compressive strength.
- In terms of its economic benefits. The proportion A, the conventional hollow blocks which uses pure aggregates. The Proportion B, C, D and E decrease the use of aggregates by .5 kg; 1 kg; 1.5; and 2 kg respectively. And by replacing the aggregates in the hollow block mixture we found out that for every 1 percent replacement of coir, an amount of PHP 0.18 will be saved. While by increasing the coir percentage by 2, 3, and 4 percent, the amount save also increases by PHP 0.35, PHP 0.53, and PHP 0.70 respectively. The cost reduction in the unit price upto PHP 0.70 per unit suggests a potential for large-scale savings, particularly in rural or low-cost housing projects. For example, for a typical residential building which uses 3,000 pieces of CHB with normal cost of 67,230 pesos. A savings of Php 2,100.00 or an equivalent of 3.24%. Having more durable property which will result to the

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decrease of wastage due to breakage, here will have a potential savings on the quantity allowance which typically 5% of total, it can be reduce to 2% and save the 3% of the cost.

- In terms of its environmental benefits, the utilization of coconut coir in Concrete Masonry Units will reduce the coconut wastes produce in the country and decrease the bad effects of burning this coconut waste.

Conclusion

After conducting thorough research, tests and analysis necessary for the study of Utilization of Coconut Coir as additional Fiber Reinforcement and Partial Replacement of Sand in Concrete Hollow Block, the following are the findings:

1. By using the coconut waste our group developed an innovative used of coconut coir which is the Fiber Reinforced Concrete Hollow Block.
2. By replacing the aggregates in the hollow block mixture, we found out that for every 1 percent replacement of coir, an amount of PHP 0.18 will be saved. While by increasing the coir percentage by 2, 3, and 4 percent, the amount save also increases by PHP 0.35, PHP 0.53, and PHP 0.70 respectively.
3. By adding coconut coir fiber it improves the durability and becomes not easily breakable when transport.
4. By adding portion of coconut coir to the Concrete Hollow Blocks, the water absorption and moisture content of all the samples did not deteriorate the standard of ASTM C-129.The Percentage with the smallest portion of coir which is one percent (1%) attained the standard specification in terms of its compressive strength.

Recommendation

The researchers propose this study to be further improved by the following recommendation:

1. The use of coir proportion that ranges from 0.5 to 1 percent for the structural partition walls.
2. The use of coir proportion that ranges from 2 to 4 percent for non-structural partition walls.
3. To conduct further investigation in the proportion of the coir mixture due to its long-term curing effects, especially those of the samples failed to the compression tests, such the 14^{th}, 21^{st}, and 28^{th} days curing period. Because there is a possibility that a longer curing period will increase the compressive strength of the Fiber Reinforced Concrete Hollow Blocks.
4. To conduct a study on its possibility to be an earthquake proofing material due to the minimized cracks that Fiber Reinforced Concrete Hollow Blocks exhibit.
5. The researchers also agree that a further investigation can be explored with coir as aggregate to concrete hollow blocks like: The long-term effect or deterioration when exposed to extreme weather conditions, fire and decay vulnerability, and strength on longer curing days with application of appropriate structural tests needed to support the investigation.

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