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Recycling of Waste Coconut Shells as Substitute for Aggregates in Mix Proportioning of Concrete Hollow Blocks

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ABSTRACT

Due to the environmental and economic crisis, this study focus on generating product using agricultural waste as well develop an alternative construction material that will lessen the social and environmental issues. It also paved the way to the recognition of using coconut shells and fiber as a substitute for aggregates in developing concrete hollow blocks. As a whole, the study' main concern is the environment and the construction and building technology to enhance natural world as well as building materials. This also aims to design a technical specification of concrete hollow block using coconut shell and fiber as aggregates that will meet the ASTM requirements in order to help contribute to the industry in saving the environment, to encourage the government to find solutions regarding the disposal to landfills of waste materials and save the environment, to provide new knowledge to the contractors and developers on how to improve the construction industry methods and services by using recycled coconut shells and fibers, and to sustain good product performance and meet recycling goals. A conventional concrete hollow block was compared to concrete hollow blocks with coconut shells and fibers of the same proportions. Observations from the tests performed were conducted in the laboratory where precise data were gathered and completely attained. Some of the interesting insights of the study are: (a) coconut shells and fibers are applicable as a partial substitute as coarse aggregates for concrete hollow blocks. (b) the good indicators of coconut shell and fiber quality as aggregate of concrete hollow blocks are particles, shape, and texture, resistance to crushing, absorption and surface moisture, grading, resistance to freezing and heating and light-weight.; (c) coconut shells and fibers are classified as miscellaneous material used for wall panels and partitions and (d) a non-load bearing type of hollow block because the compressive strength gained higher than the conventional concrete hollow blocks after 28th days

***Keywords*:** Coconut shells, construction materials, hollow blocks, recycled materials, technical specification

1. INTRODUCTION

The use of aggregates for construction is one of the most important parts of construction for it will add strength to the concrete. Finding a substitute for the aggregates used today is a task that is worth studying because the quarrying of aggregates from rivers and mountains harms the environment. If a substitute for aggregate can be obtained naturally and the source is abundant and can be regenerated, obtaining the aggregate would deplete its source.

The use of coconut by-products has been a long time source of income for some people in the country. The coconut has many uses. The fruit itself is used in many industries not only as food but for other uses as well (Reddy, 2015). The energy industry has also seen the potential of the coconut as the coco-diesel was created as an alternative to the fossil fueled oils the Philippines import. Aside from its ornamental use, the shell has been powdered and used as glues and its charcoal form was used as activated carbon and used as a filter material for masks and air-conditioning systems (Esquenazi, 2002). In the construction industry, the husk is used as a mat in preventing the erosion of soils. Boards are created from the husk of the coconut by acquiring the fibers from the husk (Babel, 2004).

As a tropical country, Philippines are one of the world's largest producers of coconut products such as coconut oil, copra (dried coconut) and desiccated coconut. Historically, Southern Tagalog, Bicol regions of Luzon and Eastern Visayas were the centers of coconut productions of land with coconut trees and its population was at least partly dependent on it for their livelihood yet, a large amount of agricultural waste was disposed of. Poor management of disposing of may lead to a social and economic problem.

Recycling of the disposed of material is one method of treating the agricultural waste. The used of coconut fiber and coconut shell could be a valuable substitute in the formation of composite material that can be used as a housing construction, such as concrete hollow block (Achaw, 2008)

Coconut is famous as a multi-function plant that all parts of its plant can be used for various activities. The use of this agricultural waste due to an assumption is that it can replace the existing material used in the commercial product in order to reduce cost or improve mechanical properties of the composite material (Yang, 2003). Industrialists in most of the coconut producing countries hail the economic, environmental and technological benefits of utilizing coconut farm wastes (Buck, 1977). On the farmers' side, agricultural residues can be a source of extra income. Traditionally, coconut farmer’s dispose of the husks, spate, petiole and leaves by burning or allowing these farm wastes to rot in the field (Cazetta, 2011). However, worldwide interest in using farm residues for value-added products means that farmers can generate ad-additional income aside from amassing environmental dividends.

Studies have shown that burning of agricultural wastes causes air pollution, soil erosion and even a decrease in soil biological activity that can eventually lead to decreased soil fertility (Chin, 2008). On the other hand, allowing farm residues to rot in the field may improve the productivity of the soil but the process of decomposition is very slow leading to accumulation of piles of agricultural wastes that can cause sanitary problem to the coconut plantation, since decaying debris is ideal breeding place for coconut pest like the rhinoceros beetle (Del Coz Diaz, 2011)

Using agricultural and forest residues for industrial purposes is a much more environment safe and friendly more than any other method of wastes disposal being commonly adopted nowadays. Research and development in the construction industry are shifting towards an exploration of cellulose farm wastes and forest residues processing and production for building materials (Eighmy, 2000). The tremendous potential of agricultural and forest residues can be a solution to the problem of inadequate supply and a high cost of conventional timbers and dependence from imported building materials (Poon, 2004). Current research and development efforts in the field of building materials should be supportive of policies of most governments that are aimed at the promotion of import substitution schemes, employment generation and self-reliance (Etxeberria, 2007). The enormous amount of residues that shall be generated from the farm and forest plantation would then make a stable source of alternative materials for the purpose of building affordable housing units for the majority of the country's population (Rao, 2007).

Considered the most useful tree in the world, the coconut palm provides food, drink, clothing, shelter, heirloom history, and financial security (Evangelista, 2007). Hardly an inch of the coconut palm goes to waste in countries such as the Philippines where families rely on the coconut palm for survival and refer to it as the "tree of life" (Schroeder, 1994).

The shell, husk, roots, fronds, flowers, and wood of the trunk also become useful products. Charcoal filters used in gas masks and cigarettes are made from coconut shells that are burned, leaving pure carbon behind. Charcoal has the ability to trap microscopic particles and impurities and prevent absorption (Ganesan, 1992). Charcoal made from coconut shells produces filters of exceptionally high performance (Lacsamana, Ganiron Jr & Taylor, 2004).

One-third of the coconut's make-up is the hairy husk that is soaked in salt water until it is soft enough to spin into rope or twine that is known for its durability (Ganiron Jr, 2016). The rope, called coir but pronounced coil, is highly resistant to salt water and does not break down like other fibers including hemp (Ganiron Jr, 2015) The coconut husk has household practicality in tropical countries where coconuts are part of almost every cuisine. The husk provides fuel for cooking as well as fiber for making clothing (Sousa, 2010).

Building materials from agricultural and forest wastes are ideal for socialized or low-cost housing since these are generally cheaper than conventional materials (Golce, 2004). For example, residues from coconut plantation like husks, fronds, and space can be processed and transformed into excellent stabilized cement-bonded boards or wall panels and corrugated roofing sheets at a much-reduced production cost than the conventional cement blocks, galvanized iron sheets, asbestos panels or plywood sheets (Xiam-wen, 2002). Likewise, rice hull/straw, corn stalks, abaca wastes and sugar cane bagasse are locally available materials that can be readily used in manufacturing cement-bonded boards (Treloar, 2003). In addition, indigenous and small diameter trees like "bagalunga" and giant "ipil-ipil" are abundant in coconut plantations particularly in Mindanao, Philippines, either as intercropped or naturally-grown, which can be economically processed into cement-bonded boards (Hansen, 1983).

The availability of suitable materials is intimately linked to the development of a new product, such as producing a concrete hollow block using coconut fibers and shells. Generating this product using agricultural waste will introduce alternative construction materials with a low production cost and lessen the social and environmental problems (Kirubakanan, 1991). Modern construction technologies being developed, respond to ecological and social issues of excessive use of raw materials from nature (Tsamba, 2006). The main objective of this study will give a partial replacement for the aggregates and will determine the ability and benefits to the concrete hollow block when substitutes. The simple concrete block will continue to evolve as architects and block manufacturers develop new shapes and sizes. These new blocks promise to make building construction faster and less expensive, as well as result in structures that are more durable and energy efficient (VanDam, 2004). Some of the possible block designs for the future include the biaxial block, which has cavities running horizontally as well as vertically to allow access for plumbing and electrical conduits; the stacked siding block, which consists of three sections that form both interior and exterior walls; and the heat soak block, which stores heat to cool the interior rooms in summer and heat them in winter (Kamar, 2003).

The researcher made this study to explore the use of coconut shells and fibers as an aggregate. Analyze the performance and the effectiveness of the coconut shells and fibers as aggregates in concrete hollow blocks in terms of physical properties like color, texture, size, and density and by mechanical properties like compressive strength, modulus of elasticity, absorption, thermal conductivity and fire resistance to obtain a design technical specification of concrete hollow blocks (Kamar, 2002)

In the preparation of technical specifications, it is essential that the engineer should possess a comprehensive and detailed knowledge of the qualities and characteristics of the various materials to be used and the practical limits to which the quantities necessary for the work in question should be restricted.

2. EXPERIMENTAL INVESTIGATION

2. 1. Project Design

The experimental program covers series of physical property tests like sieve analysis, specific gravity, moisture content and mechanical property test such as compressive test were undertaken in accordance with the ASTM The coconut shell and fiber used in this research was taken along Rizal province. As shown in Figure 1, the materials gathered were screened discarding foreign materials then placed in a container and sealed to preserved and retain its natural conditions in order to achieve an accurate data for the experiment. As the production starts, the required amounts of sand, coconut shell, fiber and Portland cement are measured to obtain the proper amounts of each material. After the dry materials are blended a small amount of water is added. The concrete is then mixed for six to eight minutes. Once a load of concrete is thoroughly mixed, it is dumped into an inclined bucket conveyor and transported to an elevated hopper. On top of the block machine at a measured flow rate, the concrete is forced downward into molds. The molds consist of an outer mold box containing several mold liners. The liners determine the outer shape of the block and the inner shape of the block cavities. When the molds are full, the concrete is compacted by the weight of the upper mold head coming down on the mold cavities. Most block machines also use a short burst of mechanical vibration to further aid compaction. The compacted blocks are pushed down and out of the molds onto a flat steel pallet. The pallet and blocks are pushed out of the machine and place them in a curing rack. The blocks are pushed off the steel pallets, and the empty pallets are fed back into a block machine to receive a new set of molded blocks.

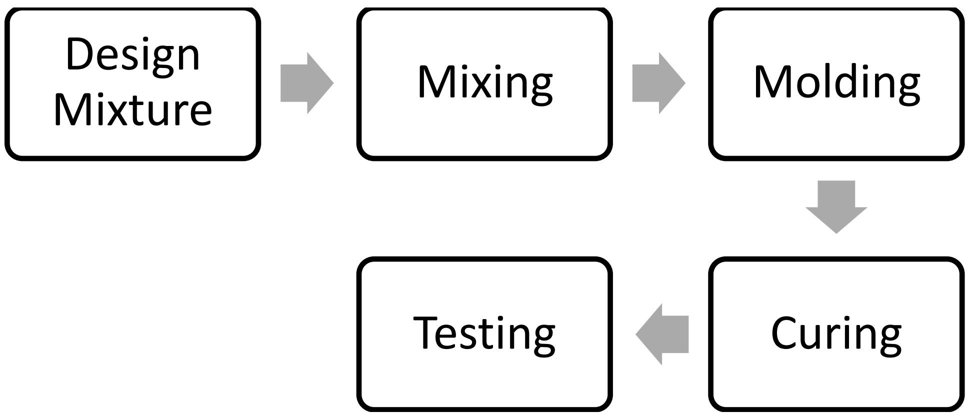

Figure 1. Project Design

2. 2. Project Development

As shown in Figure 2, the researchers develop this experiment through collecting coconut shells and fiber. If gathered materials are wet, it will undergo drying process, or if dry it will be directly screened to discard foreign materials. Shells are crushed and fibers are stripped from coconut husk, after crushing and stripping it will be screened again to discard foreign materials. Physical property is observed through sieve analysis if it will confirm with the standards. Concrete hollow block sample is done by mixing crushed coconut shell and fiber, sand and cement. The mixture is poured into the machine to form a 4 inches concrete hollow blocks. The next stage is curing the specimen for 7, 14 and 28 days. On the said dates the specimen will undergo laboratory tests such as compressive strength test, moisture content, and absorption

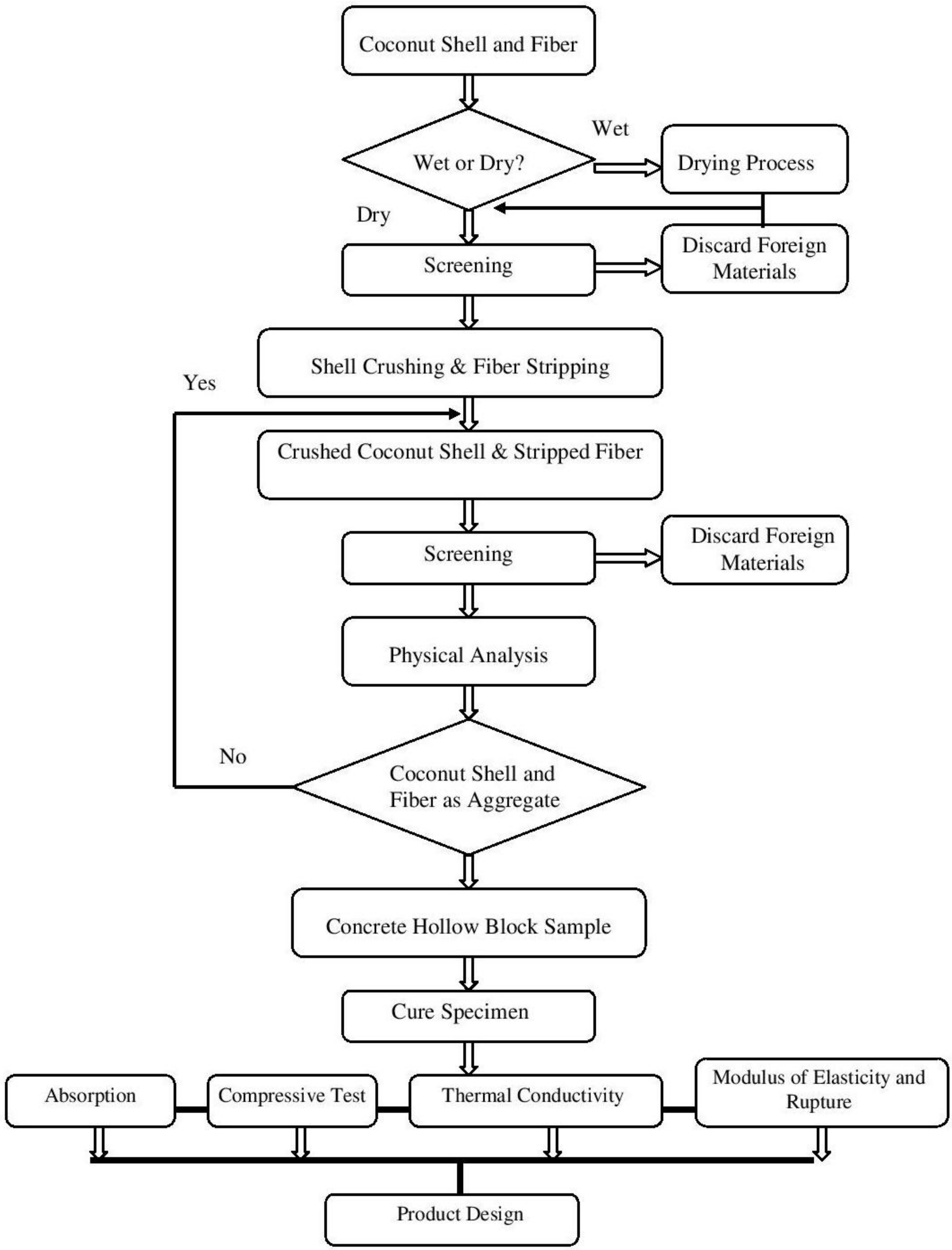

Figure 2. Project Development

3. RESULTS AND DISCUSSION

3. 1. Physical Properties of Concrete Hollow Blocks (CHB)

Table 1 shows the physical properties of commercial CHB and CHB with coconut shell and fiber. The color is simply observed through visual inspection. CHB with coconut and fiber is much darker than the commercial CHB. The texture of both specimens are absolutely rough, they are the same with this property. Both CHB has a dimension of 100 mm × 400 mm × 800 mm. It is commonly used a material for construction purposes such as wall panels and partitions. Moreover, CHB with coconut shell and fiber has a density of 1213.59 kg/m³ while commercial CHB has a density of 1529 kg/m³.

Table 1. Physical properties of CHB

Property	Commercial CHB	CHB with coconut shell and fiber
Color	Gray	Dark Gray
Texture	Rough	Rough
Size	100 × 400 × 800 mm	100 × 400 × 800 mm

3. 2. Mechanical Properties of Concrete Hollow Blocks (CHB)

Table 2. Compressive strength test of commercial CHB and C HB with coconut shell & fiber

Time (days)	Commercial CHB			CHB with coconut shell and fiber		
	Specimen	Load (KN)	Stress (MPa)	Specimen	Load (KN)	Stress (MPa)
7	1	17.58	0.80	1	43.50	2.11
	2	11.65	0.57	2	34.42	1.67
	3	15.07	0.73	3	37.56	1.82
14	1	20.24	0.98	1	48.02	2.33
	2	14.71	0.71	2	60.25	2.92
	3	14.9	0.72	3	50.74	2.46
28	1	27.07	1.31	1	65.00	3.16
	2	25.09	1.22	2	75.63	3.67
	3	26.09	1.27	3	84.99	4.13

As shown in Table 2, the compressive strength of CHB w/ coconut shell and fiber in 7 days of age reached a load capacity of 34.42 KN to 43.5 KN, and stress capacity of 1.67 MPa to 2.11 MPa.

For 14 days of age reached a load capacity of 48.02 KN to 60.25 KN and a stress capacity of 2.33 MPa to 2.92 MPa. For 28 days of age reached a load capacity 65 KN to 84.99 KN and a stress capacity 3.16 MPa to 4.13 MPa. This signifies that the number of aging requirements was achieved.

As shown in Figure 3, the commercial CHB, in 7 days of age reached a load capacity of 11.65 KN to 17.58 KN, and stress capacity of 0.57MPa to 0.8MPa. For 14 days of age reached a load capacity of 14.71 KN to 20.24 KN and a stress capacity of 0.71 MPa to 0.98 MPa. For 28 days of age reached a load capacity 25.09 KN to 27.07 KN and a stress capacity 1.22 MPa to 1.31 MPa. This signifies that the number of aging requirements was achieved

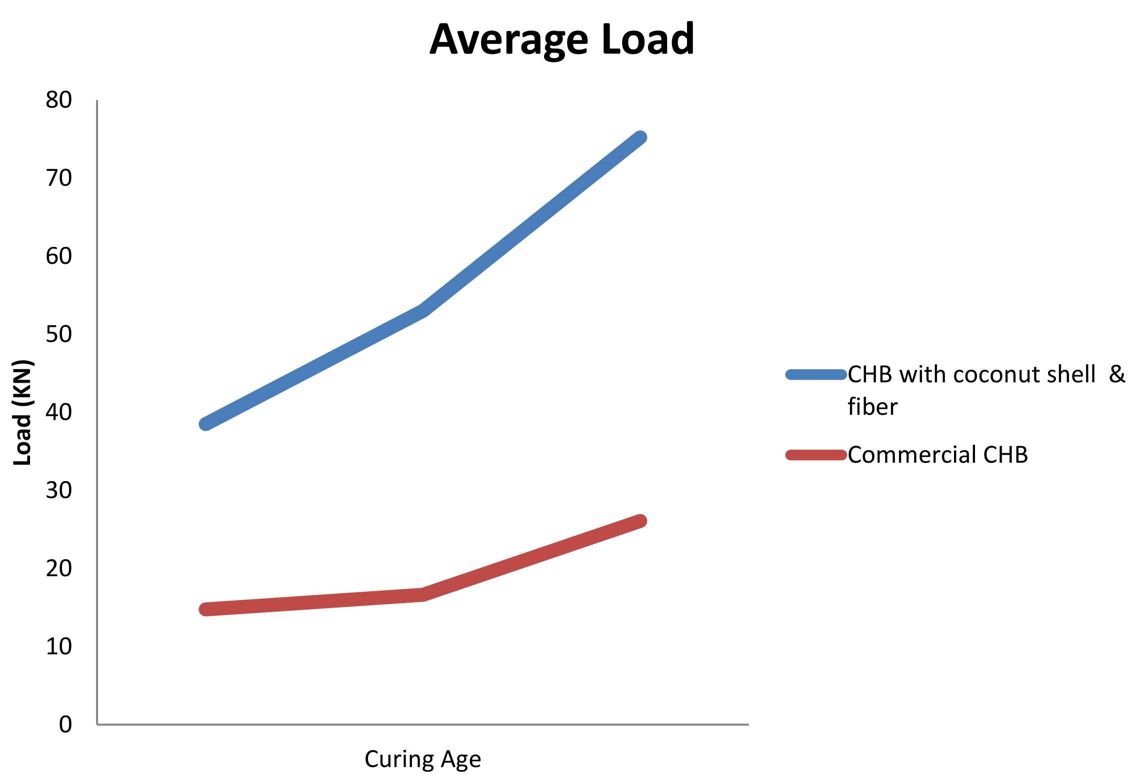

Figure 3. Average Loads of CHB w/ coconut & fiber and commercial CHB after 7th, 14th and 28th days of curing

Table 3 and figure 4 show that the average modulus of elasticity of CHB w/ coconut shells and fiber for 7th, 14th and 28th are 1400 MPa, 1927.5 MPa and 2740 MPa while commercial CHB for 7th, 14th and 28th days has an average modulus of elasticity of 525 MPa, 602.5 MPa, and 950 MPa. Using modulus of elasticity for concrete unit masonry, Êm = 750 ƒ ‘m and must not be greater than 20.5 GPa. Based on the results CHB w/ coconut shell sand fiber has the greater modulus of elasticity rather than commercial CHB.

Table 3. Modulus of elasticity of commercial CHB and CHB with coconut shell and fiber

Time (days)	Modulus of Elasticity (MPa)		
	Specimen	Commercial CHB	CHB with coconut
7	1	600.00	1582.50
	2	427.50	1252.50
	3	547.50	1365.50
14	1	735.00	1747.50
	2	532.50	2190.00
	3	540.00	1845.00
28	1	982.50	2370.00
	2	915.00	2752.50
	3	952.50	3097.50

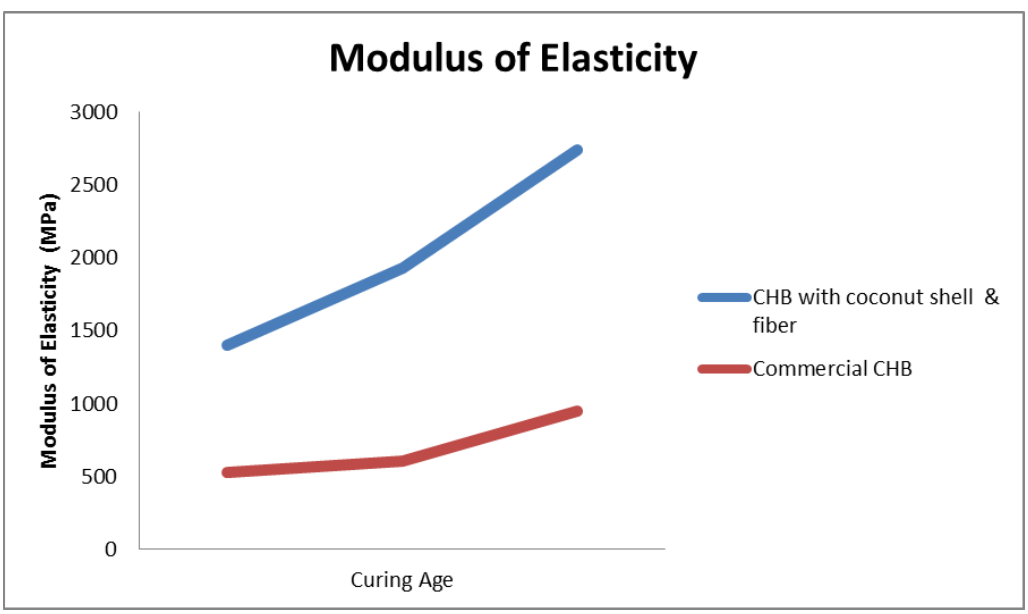

Figure 4. Average modulus of elasticity after 7th, 14th and 28th days of curing

Table 4 and Figure 5 shows that the average modulus of rupture of CHB with coconut shell and fiber for 7th, 4th and 28th days are 0.392 MPa, 0.54 MPa, and 0.40 MPa.

Table 4. Modulus of rupture of CHB with coconut shell and fiber

Time (days)	Specimen	CHB with coconut shell and fiber
7	1	0.4431
	2	0.3507
	3	0.3822
14	1	0.4893
	2	0.6132
	3	0.5166
28	1	0.3733
	2	0.4020
	3	0.4270

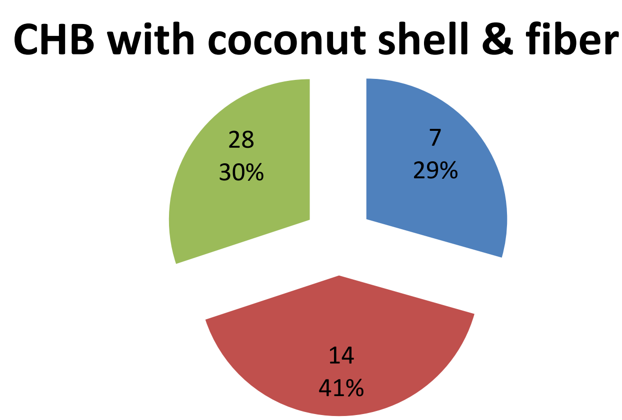

Figure 5. Average modulus of rupture after 7th, 14th and 28th days of curing

Table 5 shows that CHB with coconut shell and fiber have lesser moisture content and water absorption than the commercial CHB.

Table 6 shows that CHB with coconut shell and fiber can resist freezing gained a large value of the load. In cold temperature, CHB with coconut shell and fiber has a load capacity of 96.69 KN and stress capacity of 4.69 MPa

Table 7 shows that even in high-temperature condition, CHB with coconut shell and fiber can resist. It was subjected to the compressive test to determine if the strength will change. In warm temperature, CHB with coconut shell and fiber has a load capacity of 50.47 KN and stress capacity of 2.97MPa

Table 5. Moisture content of concrete hollow blocks

Specimen	Commercial of CHB	CHB with coconut shell & fiber
Weight (Kg)	5.2	7.8
Oven dry weight (Kg)	5.0	7.6
Saturated weight (Kg)	5.4	7.8
% Moisture content	8.0	5.41
% Water absorption	4.0	2.63

Table 6. Thermal conductivity at cold temperature

Specimen	Commercial CHB	CHB with coconut shell & fiber
Weight (Kg)	12.4	10.6
Load (KN)	12.87	96.69
Stress (MPa)	0.62	4.69

Table 7. Thermal conductivity at warm temperature

Specimen	Weight (Kg)	Load (KN)	Stress (MPa)
1	6.8	50.47	2.97
2	9.4	59.98	2.97

Table 8. Fire resistances of CHB with coconut shell and fiber.

Specimen	Weight (Kg)	Load (KN)	Stress (MPa)
1	9.8	68.32	3.38
2	9.4	59.98	2.97

Table 8 shows that the specimens are subjected to a high degree of temperature for a certain period of time. It was subjected to the compressive test to determine if the strength will change. Data's gathered shows that CHB with coconut shell and fiber can resist in a fire. This means that CHB with coconut shells and fiber can resist in the high degree of temperature. The results at 28th days attained an average load capacity of 64.15 KN and 3.175 MPa for average stress.

Table 9. Good indicators of coconut shell and fiber as aggregate

Good indicators	Significance
1. Particle shape and texture	Affects workability of fresh concrete.
2. Resistance to crushing	In high strength concrete, an aggregate is low in crushing value. This will not give high strength even though cement strength is higher
3. Absorption and surface moisture	Affects the mix proportions and control water content to maintain the water-cement ratio
4. Grading	Economizes cement content and Improves workability.
5. Resistance to freezing and heating	Significant to cold countries where frost action deteriorates concrete due to alternate freezing and heating.
6. Lightweight	Reduce weight of structure

4. DESIGNED TECHNICAL SPECIFICATION OF CHB WITH COCONUT SHELL AND FIBER

4. 1. General Objectives

a) To show the improvement of the composite material in term of weight (density) so the material provides faster and easy erection process.
b) To increase the amount of information on physical and mechanical properties of the composite material.

4. 2. Specific Objectives

a) To determine the basic physical and mechanical properties of concrete hollow blocks with coconut shell and fiber as aggregate with regards to strength, workability, and durability.
b) To find the optimum mix design with regards to the amount of water, coconut shell and fibers, cement, and sand required.

c) To investigate the mechanical properties of the concrete hollow block with coconut shell and fiber density (lightweight), strength (compression), fire resistance and thermal conductivity

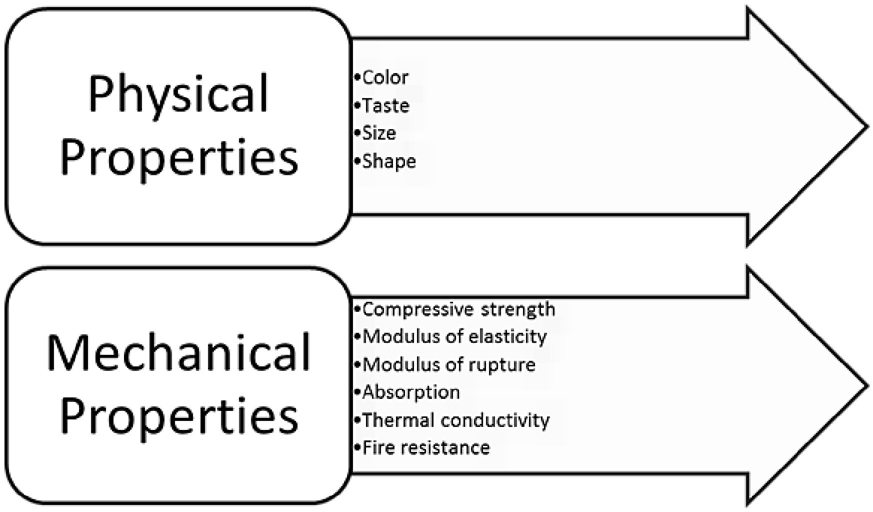

Figure 5. Technical Specifications of CHB with coconut shell and fiber

Table 10. Fire resistances of CHB with coconut shell and fiber.

Properties	CHB with coconut shell and fiber
Texture	Rough
Size	100 × 400 × 800 mm
Color	Dark Gray
Density	1213.56 kg/m^3
Weight	10.6 kg
Mix proportion	1:3:3
Compressive strength (28 days)	75.21 KN
Modulus of elasticity (28 days)	2740 MPa
Modulus of rupture (28 days)	0.401 MPa
Moisture content	5.41%
Water absorption	2.63%

5. CONCLUSIONS

Figure 6. Preparation and Molding of CHB with coconut shell and fiber

Figure 7. Commercial CHB and CHB with coconut shell and fiber

After evaluating the results of the above-mentioned findings, the following conclusions were drawn:

a) The physical properties of CHB with coconut shell and fiber affect the quantity and quality in terms of production.
b) The compressive strength of CHB with coconut shell and fiber attained the highest average loads and stress compared to commercial CHB
c) The thermal conductivity of CHB with coconut shell and fiber for cold and warm temperature resist freezing and heating gained a large value of the load.
d) The fire resistance of CHB with coconut shell and fiber affects its mechanical properties in terms of compressive strength.
e) The CHB with coconut shell and fiber exceeds the minimum strength of commercial CHB at 28 days.

f) The good indicators of CHB with coconut shell and fibers are particles shape and texture, resistance to crushing, absorption and surface moisture, grading, resistance to freezing and heating and lightweight.
g) The CHB with coconut shell and fiber is used as an alternative coarse aggregate for CHB

Biographies

Dr. Tomas U. Ganiron Jr received the doctorate degree in Construction Management in Adamson University (Philippines), and subsequently received his Master of Civil Engineering major in Highway and Transportation Engineering at Dela Salle University (Philippines). He is a registered Civil Engineer in the Philippines and Professional Engineer in New Zealand. Aside from having more than two decades of experience as a professor, department head and researcher in the Philippines and New Zealand, Dr. Ganiron Jr is a practicing Civil and Construction Engineer for 20 years, having designed and supervised projects such as sewerage and waterworks structures, ports and marine structures, water treatment plant, and structural buildings and bridges. He is also very active in other professional groups like Railway Technical Society of Australasia and Australian Institute of Geoscientists where he became the Committee of Scientific Research. He has received the Outstanding Civil Engineer in the field of Education given by the Philippine Media Association Inc. (1996), ASTM Award CA Hogentogler (2008) awarded by International Professional Engineers New Zealand and Plaque of Recognition as Outstanding Researcher (2013) given by Qassim University-College of Engineering.

Nieves Ucol-Ganiron holds a Bachelor of Business Administration from the University of the East in 1966. Her major field of study is Banking and Finance. She did her summer internship at May Bank and the final internship at Banco de Oro Uni Bank Inc. She had an experience working as an economist analyst in Board of Fisheries in Manila and claims processor in Philippines Post Office. Her research interest includes financial management, risk management, financial statement analyst and career planning.

Tommy U. Ganiron III received the Bachelor of Science in Medical Technology degree from the University of Perpetual Help System DALTA in Las Piñas City in 1999. Currently, he is an aviation/security officer at the Ninoy Aquino International Airport. He had been involved in quality control at the United Laboratory and Associate Production.at the AstraZeneca Pharmaceuticals. His research interests are aviation operations, security systems and risk management

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