Design Of Reinforced Light Weight Concrete Hollow Blocks Using Shredded Card Board As Fine Aggregate with Steel Fiber

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Abstract: - With approximately 24 million tons of cardboard thrown away annually, the need for cardboard as a packing material has made it the single largest waste product (by weight) in the trash. The researchers are worried about cardboard recycling to lessen the impact of trash for both environmental and financial reasons. The capacity of waste cardboard to be utilized as a construction material as a partial replacement of aggregates up to a certain level and check its capability to hold certain required compressive strength of a Concrete Sample has thus been the subject of specific research. This study includes the Trial mix of 3 different mixture percentages of Shredded cardboard (1:2:5,1:3:4 and 1:4:3) as partial replacement to fine aggregates with 50 grams steel fiber reinforcement for every 1 cement ratio and to conduct compressive strength test, water absorption, and moisture content on concrete cured for 7,14-, and 28-Days hollow blocks to know the performance of the concrete. Overall, the 1:2:5 cement, cardboard pulps, and sand mixture—which is the ideal ratio for producing hollow blocks—was found to have the highest compressive strength and lowest absorption percentage. The 1:2:5 mix of cement, cardboard pulps, and sand results in high compressive strength because it combines the strength of cement, the fibrous reinforcement provided by the pulps, and the filler and binding capabilities of the sand. The lowest absorption rate is also present in this mix ratio. This means that the finished concrete block will be the least likely to collect moisture or water, which is essential for the block's durability. When freezing and thawing cycles are occurring, concrete blocks that have absorbed water may be more susceptible to cracking, weakening, and even disintegration. Finally, it has been found that using a 1:2:5 ratio of cement, cardboard pulps, and sand for making hollow blocks is the ideal option because it produces the necessary strength, durability, and low water absorption attributes while still being economical and practical.

Key Words: — *Cardboard, Steel Fiber, Compressive Strength, Absorption, Mixture, Ratio, Hollow Blocks.*

I. INTRODUCTION

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Solid Waste Management (SWM) is a significant issue in the Philippines, particularly in urban regions like Metro Manila. The primary challenges in the country's waste management are the improper disposal of waste, inefficient collection methods, and inadequate disposal facilities. If these issues are not resolved, the waste generated from different sources will continue to pose risks to public health and cause severe environmental problems, including contamination of water sources, flooding, air pollution, and the spread of diseases (Philippine Solid Wastes, 2017).

Table.1. Waste Generation of the Philippines, 2012-2016 (Tons per day)

Region	2012	2013	2014	2015	2016
1	1,709.17	1,739.54	1,769.90	1,800.27	1,830.64
2	1,100.64	1,120.19	1,139.75	1,159.31	1,178.86
3	3,631.99	3,696.52	3,761.05	3,825.58	3,890.12
4a	4,145.52	4,219.18	4,292.83	4,366.49	4,440.15
4b	909.43	925.59	941.74	957.90	974.06
5	1,878.74	1,912.12	1,945.50	1,978.88	2,012.26
6	2,700.14	2,748.11	2,796.09	2,844.06	2,892.04
7	2,605.68	2,651.97	2,698.27	2,744.57	2,790.86
8	1,497.47	1,505.75	1,532.04	1,558.33	1,584.61
9	1,391.95	1,416.68	1,441.41	1,466.15	1,490.88
10	1,693.94	1,724.03	1,754.13	1,784.23	1,814.32
11	1,818.05	1,850.35	1,882.65	1,914.95	1,947.26
12	1,348.20	1,372.15	1,396.10	1,420.06	1,444.01
13	884.69	900.41	916.13	931.85	947.57
CAR	620.64	631.67	642.70	653.72	664.75
NCR	8,601.60	8,754.43	8,807.26	9,060.09	9,212.92
ARMM	907.64	923.76	939.89	956.02	972.14
TOTAL	37,427.46	38,092.46	38,757.46	39,422.46	40,087.45

The Philippines is experiencing a continuous increase in waste generation due to population growth, improved living standards, rapid economic development, and industrialization, particularly in urban areas. According to the National Solid Waste Management Commission (NSWMC), the country's daily waste generation rose from 37,427.46 tons in 2012 to 40,087.45 tons in 2016. The estimated average per capita waste generation for urban and rural areas is 0.40 kilograms daily. The National Capital Region (NCR), with its large population, numerous establishments, and modern lifestyle, has consistently produced the highest volume of waste over the past five years. In 2016, Metropolitan Manila generated 9,212.92 tons of waste per day. Region 4A followed with a waste generation of 4,440.15 tons per day (11.08%), and Region 3 with 3,890.12 tons per day (9.70%) (NSWC).

In terms of the weight of municipal solid waste fractions, around 52.31 percent consists of biodegradable waste, approximately 27.78 percent is recyclable waste, and about 17.98 percent is residual waste, which includes materials such as plastics, paper and cardboard, metals, glass, textiles, leather, and rubber. The remaining 1.93 percent is classified as special waste (LBP Published, 2021).

According to Rinkesh (2022), the demand for cardboard as a packaging material has made it the single greatest waste product (by weight) in the trash, with over 24 million tons of cardboard thrown away each year, causing major environmental difficulties. For environmental and economic reasons, the researchers are concerned about recycling cardboard to reduce the impact of waste.

On September 01, 2020, Win Gatchalian, Senator of the Republic, held a privileged speech at the Senate of the Philippines. In his words, “the Philippines is facing a garbage crisis” that requires immediate concerted action from the government and civil society. “And we need to act now before it is too late.” Will the country overcome the crisis?

In a time when sustainability and innovation are paramount, there is a greater push for ground-breaking building materials that balance ecological concerns with structural requirements. Amid this intense search, an unexpected pair appears as a sign of progress: Cardboard and Concrete Hollow Blocks (CHB). This thesis went on an investigation, probing these two materials' unexplored territory and revealing their unrealized potential. This study sought to transform modern construction by examining their distinctive qualities and compatibility and exposing transformative possibilities.

Cardboard, which is frequently associated with packing and disposability, has a stunning range of qualities that elevate it to a formidable competitor in construction. Its inherent strength, lightweight, recyclable nature, and remarkably low carbon footprint put the fundamental foundations of conventional building materials to the test. However, CHB has a track record of stability and structural integrity, allowing buildings to stand firmly for many years.

A remarkable synergy was promised by combining cardboard's adaptability and environmental friendliness with CHB's durability and dependability. This seamless partnership opens the door to countless possibilities, from temporary buildings and disaster relief strategies to futuristic eco-conscious housing developments and beyond.

This thesis aims to shed light on the viability, structural integrity, and environmental effect of integrating shredded cardboard as fine aggregates with steel fiber in CHB in a unified building method through thorough investigation, testing, and careful analysis. Uncovering these materials' special qualities and interoperability ushers in a new age of inventive construction methods, challenging preexisting paradigms and opening the door for environmentally friendly, economically practical, and aesthetically pleasing constructions.

The challenges and limitations of this study are addressed in the study. The foundation is set for overcoming challenges and improving the practical implementation of shredded cardboard as fine aggregates with steel fiber in CHB in real-world applications by resolving issues regarding moisture resistance, fire safety, long-term durability, and cost efficiency.

A picture of a future in which superior architectural design coexists compatibly with sustainable construction methods crystallizes as the researchers set out on their radical adventure.

The researchers are building a way towards a greener, more resilient built environment by exploring the hitherto uncharted territories of cardboard with steel fiber in CHB.

The weight of concrete is a crucial factor in achieving cost-effective structures. Light Weight Concrete (LWC) offers improved economic benefits compared to traditional concrete due to its lower self-weight and increased efficiency. The use of lightweight concrete dates to ancient times and is an area of significant research interest due to its numerous advantages. These advantages include reduced transportation, reinforcement, and foundation costs, cost-effective scaffolding and formwork, enhanced constructability, absence of surface bleed water, sound absorption properties, improved hydration through internal curing, decreased susceptibility to buckling caused by temperature gradients, reduced seismic forces, and improved insulation against heat, fire, and frost. (Aslam et al., 2017).

Given the escalating environmental problems faced today and considering the rapid depletion of conventional aggregates, the use of aggregates from by-products and/or solid waste materials from different industries is highly desirable. One such alternative is waste cardboard which is a form of solid waste (Teo et al, 2007).

Determining the structural bond characteristics of lightweight concrete using shredded cardboard and pulping it as fine aggregate was the first step in this study (Teo et al, 2007).

According to Anupoju (2021), American Concrete Institute (ACI) committee 318 "Building Code Requirements for Reinforced Concrete" does not yet recognize the enhancements that fiber reinforcement can provide for the structural behavior of concrete elements (even the most common and well-researched type of fiber-steel). However, according to the State-of-the-Art report written by ACI Committee 544, the use of Fiber-Reinforced Cement (FRC) is increasing worldwide for various applications. Some of the common applications of FRC include precast architectural cladding panels, slabs on grade, mining, tunneling, excavation support applications, and shotcrete, among others. Most of these applications utilize fibers in place of welded wire fabric reinforcement, providing a potentially cost-effective solution to the need for reinforcement in orthogonal directions (Erdogmus, 2015).

This study included the Trial mix of three (3) different mixture percentages of shredded cardboard (1:2:5,1:3:4 and 1:4:3) as partial replacement to fine aggregates with 50 grams steel fiber reinforcement for every one cement ratio and to conduct compressive strength and water absorption test on concrete cured in 7,14 28 days hollow blocks to know the performance of the concrete (Aslam et al., 2017).

II. METHODOLOGY

The researchers chose to conduct the study in Pampanga, where the researchers reside, for much convenient monitoring of the study and where one can work without distraction. The availability of abundant raw materials was ensured before proposing this study. The researchers intended to add a small minimal amount of steel fiber to the mix. The actual test was performed in the Department of Public Works and Highways (DPWH) testing Laboratory located in Sindalan, San Fernando, Pampanga, for data gathering to ensure precision and bias of result. All resources of the proposed research are gathered from the internet and some ideas from previous projects.

The researchers used a research and development design. The study performed raw materials evaluation needed to use in casting the proposed design. Quality test of materials is needed to conduct as reference for the design mix process. Experimentation on different percent mixture of card board pulp to designed concrete hollow blocks in accordance to the requirements DPWH standard specification for item 1046 – Masonry Works.

The physical tests carried out from raw material up to prototype include: Sieve analysis, unit weight, and moisture density test of material that was used as a reference on the blending ratio for the trial mix. Prototype samples are subject to determination of unit weight and compressive testing to determine if they can pass the specification for non-load bearing CHB.

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All raw materials for casting concrete hollow blocks must conform to DPWH Standard specifications. The cement fall under Item 700 hydraulic cement and Sand shall conform to item 405 of DPWH standard specification - structural concrete. Water shall be clear and apparently clean and conform to Item 714 – Water of DPWH Standard Specification.

The dry rodded unit weight of aggregate is determined by compacting dry aggregate into a container of a known specific volume as per ASTM test method C 29. The weight of the aggregate is measured and divided by the volume of the container to yield the dry rodded unit weight in terms of weight per volume such as pounds per cubic foot. By knowing the dry rodded unit weight of a nominal maximum size coarse aggregate and the fineness modulus of the fine aggregate, the weight of the coarse aggregate needed per unit volume of concrete mix can be estimated.
Fine aggregate performance was checked according to DPWH standard specification Item 405 – Structural Concrete.

Table.2. DPWH standard specification Item 405 –

Sieve Designation	Mass Percent Passing
9.5 mm (3/8 in)	100
4.75 mm (No. 4)	95 – 100
2.36 mm (No. 8)	-
1.18 mm (No. 16)	45 – 80
0.600 mm (No.30)	-
0.300 mm (No.50)	5 – 30
0.150 mm (No. 100)	0 – 10

Structural Concrete Steel fibers are available in lengths from 38 mm to 50 mm and aspect ratios between 40 and 60. The fibers are manufactured either deformed or hook end, and conform to ASTM A-820. Steel fiber reinforced concrete has stronger post-crack flexural strength, better fracture resistance, increased fatigue strength, higher resistance to spalling, and higher first-crack strength, while recorded rates of improvement varies. When steel fibers are added to mortar, Portland cement concrete or dry concrete composite's flexural strength rises from 25% to 100%, depending on the proportion of fibers added and the mix design. Steel fiber technology turns a brittle material into one more ductile. Because the fibers continue to maintain the weight after cracking, catastrophic failure of concrete is almost eliminated.

Fig.1. Steel

As blending material to the study, the Shredded Cardboards was soaked to water for at least 48 hours, with the use of Electric Drill attached with paint mixer paddle pulping process will be faster to converted the shredded cardboard into pulp state. The paper pulp is subject to drying until it reaches it saturated surface dry condition (SSD) to use in different blending proportion with fine sand.

Fig.2. Cardboard

To ensure a level of consistency between cement-producing plants, certain chemical and physical limits are placed on cements. These chemical limits are defined by a variety of standards and specifications. For instance, Portland cements and blended hydraulic cements for concrete in the U.S. conform to the American Society for Testing and Materials (ASTM) C150 C595 (Standard Specification for Blended Hydraulic Cement) or C1157 (Performance Specification for Hydraulic Cements).

Fig.3. Cement

The test can be run on either dry or washed aggregate. The washed sieve analysis takes longer but produces a more accurate gradation, particularly the percent passing the No. 200 (0.075 mm) sieve since the washing helps remove these small particles from the larger particles. The dry sieve analysis procedure is often used where rapid results are required. The basic sieve analysis consists of weighing an aggregate sample and then passing it through a nest of sieves. The nest of sieves is made up of a stack of wire-cloth screens with progressively smaller openings from top to bottom. After testing the raw materials and ensuring that they passed, the next step is casting the CHB with the proposed blending ratio.

The material retained on each sieve is weighed and compared to the total sample mass. Particle size distribution is expressed as a percent retained or percent passing by weight on each sieve size. While manual test sieving method continues to be used today, but automated shakers have become more prevalent, and modern shakers are even relatively silent. Other methods of particle size analysis have been developed and are frequently used for submicron analysis in situations where sieves are impractical. The sieve process as follows:

- Weigh a sample and record the original weight.
- Place the sample on the top sieve of a stack of sieves and cover the top sieve with a flat cover.
- Shake the stack (keeping it vertical) for a specified length of time at a predetermined speed.
- When the shaking is complete, reweigh and record the weight of each sieve and the bottom pan.
- Weigh and record the weight per retain on sieve.
- Calculate the weight of sample on each sieve and the pan.
- Calculate the percent of sample on each sieve and the pan.

The researchers utilized an experimental research type of research in designing reinforced light weight concrete hollow blocks using shredded card board as fine aggregates with steel fiber. Experimental research design is a process of conducting research in an objective and controlled manner in order to maximize precision and reach specific conclusions regarding a hypothesis statement (Pubrica-academy, 2022). By employing an experimental research design, the researchers were able to gather, analyze and interpret the data collected.

The design of reinforced light weight CHB is compose of card board paper pulp as a replacement of fine aggregates dried to saturated surface dry condition blended in different proportion with sand 1:2:5,1:3:4 and 1:4:3 with 50 grams steel fiber per cement ratio respectively using 1:7 cement-sand ratio as the base of design. Clean water should be use and shall not exceed 28 liters per 40 kilograms of cement and slump test shall not exceed 10 cm as per ASTM c-143.

Concrete blocks are often made of 1:3:6 concrete with a maximum size aggregate of 10mm or a cement-sand mixture with a ratio of 1:7, 1:8, or 1:9. These mixtures, if properly cured, give concrete blocks a compression strength well above what is required in a one-story building. The blocks may be solid, cellular, or hollow. Cellular blocks have cavities with one end closed, while in hollow blocks, the cavities pass through. Lightweight aggregate, such as cracked pumice stone, is sometimes used.

After testing the raw materials and ensuring that they passed, the next step is casting the CHB with the proposed blending ratio.

Concrete masonry units are manufactured in three classes, based on their density: lightweight units, medium-weight units, and normal-weight units, with dry unit weights as shown in Table 5. Well-graded sand, gravel, and crushed stone are used to manufacture normal- weight units. Lightweight aggregates such as pumice, scoria, cinders, expanded clay, and shale manufacture lightweight units.

Table.4. Strength and Absorption Requirements for Concrete Masonry Units.

DESIGN MIXTURE	CEMENT	CARD BOARD PULP	SAND	STEEL FIBER
1:2:5	1	2	5	50 grams
1:3:4	1	3	4	50 grams
1:4:3	1	4	3	50 grams

Weight Classification	Oven-dry density of concrete, lb/ft^3 (kg/m^3) Average of 3 untis	Maximum water absorption, lb/ft^3 (kg/m^3)		Minimum net area compressive strength, psi (MPa)	
		Average of 3 Individual Units	Units	Average of 3 Individual Units	Units
Lightweight	Less than 105 (1,680)	18 (288)	20 (320)	1,900 (13.1)	,700(11.7)
Medium weight	105<125 (1,680 – 2,000)	15 (240)	17(272)	1,900 (13.1)	1,700(11.7)
Normal weight	125 (2,000) or more	13 (208)	15(240)	1,900 (13.1)	1,700(11.7)

ASTM C90In producing CHBs, a suitable place and shaded area is needed to work without distraction. Before mixing, the cardboards will shred in small strips, soak to water for about 48 hours, and pulverize to pulp using paint mixer paddle loaded in Electric drill. The cardboard pulp is subject for drying to attain its saturated surface dry condition (SSD). (See fig. 2) for the proportioning mix.

In producing CHBs, a suitable place and shaded area is needed to work without distraction. Before mixing, the cardboards will shred in small strips, soak to water for about 48 hours, and pulverize to pulp using paint mixer paddle loaded in Electric drill. The cardboard pulp is subject for drying tThe cement and sand will be mixed manually until the mixture appears homogenous. 50 grams steel fiber for every 40 kilos of cement will be added until mixture was even and uniform. Then the cardboard pulp fiber was mixed at the exact ratio (1:2:5, 1:3:4, and 1:4:3) until uniformity of the mixture was apparent. The pre-determined amount of clean water will be poured into the mixture of the component materials. Mixing of the water with the component materials was done using hand trowels. When the mix attains the workable consistency, the concrete mix will be poured into molds.

An amount of the mix about one-third of the height if the mold was poured and then slightly compacted using a 1” x 1” tamping rod. This was then followed by the filling the mold with an additional concrete until two-third and full volume and slightly compacting it with 1” x 1” tamping rod to reduce and remove the air voids. Last, the CHB samples will be unmolded in a plain surface and stored in a room under normal condition where they were cured for 28 days by sprinkling with water thrice a day.

The purpose of curing is to protect the concrete hollow block from the loss of moisture. Curing helps the material to grow in strength and diminish cracking. CHBs were shaded from sunlight in order to process started after unmolding the CHB sample with a curing period of 28 days. The CHB samples were then watered three times a day.

All blocks should be checked; the length, width, and height are measured with steel scale. Then the web thickness and face shell are measured with caliper ruler. The nominal dimensions of concrete masonry block vary as follows: Length: 400 or 500 or 600 mm, Width: 200 or 100 mm, and Width: 50, 75, 100, 150, 200, 250, or 300 mm.

To determine the density of block, first ensure the samples in Saturated Surface Dry condition. Dimensions of block and from that find out the volume and weigh the block. The density of block is determined from the below relation and the average density of 3 blocks will be the final block density. Density of block = mass/volume (kg/m3) density values.

To determine the water absorption, each sample will be weighed before to being placed in a preheated oven at 105 degrees Celsius for 24 hours. The initial weight will be determined once the prototype has cooled to room temperature. The samples are then immersed in tap water. After 24 hours, remove it from water and wiped the prototype’s surface with an absorbent cloth before taking the final weight. The test will be conducted on seventh, fourteenth, and twenty- eight days of the healing period.

Blocks are taken to determine the average compressive strength of concrete masonry blocks. The blocks should be tested within three days after being collected in the lab. The age of each block shall be 7, 14, and 28 days. The compressive strength testing machine consists of two steel bearing blocks, one in a rigid position on which masonry unit is placed, and another is movable, which transmits the load to the masonry unit when applied. The plates are arranged on steel blocks in such a way that the centroid of the masonry unit coincides with the center of thrust of blocks. Bearing area of concrete masonry units are capped with the sulphur and granular materials coating or gypsum plaster capping. After placing the unit in testing machine, one- half of the expected maximum load is applied at a constant rate, and the remaining load is applied in not less than 2 minutes. Note down the load at which masonry unit fails and the maximum load divided by gross sectional area of unit will give the compressive strength of block.

Results of the compressive strength testing will be graphed for 7, 14, and 28-day age of curing. The increase or decrease of compressive strengths of the CHB will be presented in percentages and compared to the control mix. Variations of compressive strengths at different fiber lengths will also compare in terms of percentages. To identify the significance in the variation in compressive strengths, the analysis of variance was conducted.

III. Results And Discussion

The conclusions of the study are thoroughly explained in this section, which typically follows the methodology and data analysis sections of a thesis. Interpret the data considering the hypotheses, drawing conclusions about the importance of the findings and their implications for the research topic. By using this interpretation, unsupported assertions or hypotheses are avoided.

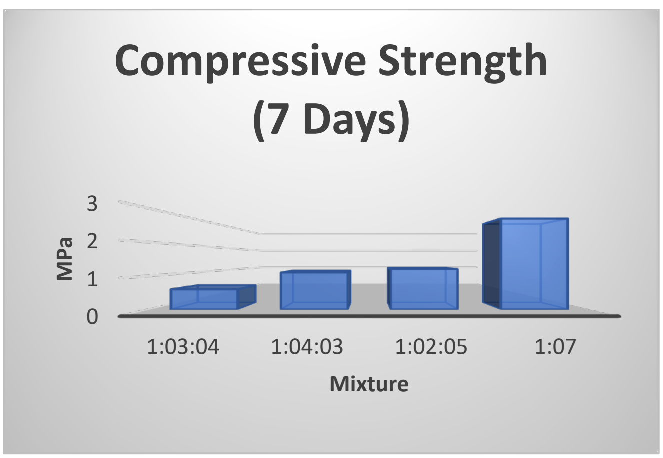

Fig.4. Compressive Strength (7 Days)

The information displays the compressive strength values for three combinations following a 7-day curing time (MPa). The proportions of cement, sand, and cardboard in the combinations are what distinguishes them. After seven days, Mixture 1:7 (2.7 MPa) exhibits the highest compressive strength among the tested mixtures. This mixture is made up of 1 part cement and seven parts sand. After seven days, Mixture 1:2:5 (1.2 MPa) displays a higher compressive strength than Mixture 1:3:4 (0.6 MPa). This shows that the 1:2:5 mixture's higher compressive strength is a result of the larger amount of cardboard in it. Following a week, Mixture 1:4:3 (1.1 MPa) exhibits the maximum compressive strength among the mixtures with the predetermined ratio of cement, sand, and cardboard. This mixture's improved compressive strength results from how the materials are arranged in it.

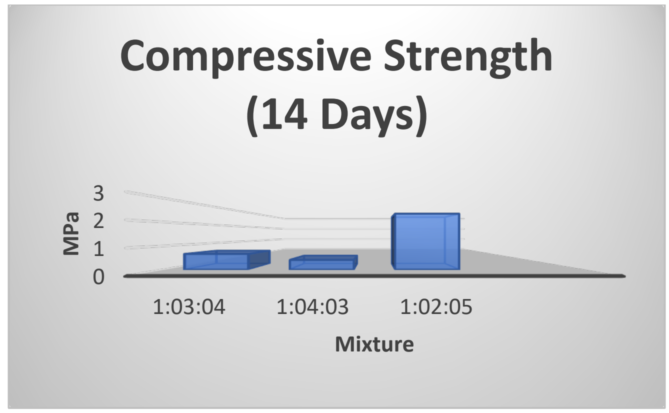

Fig.5. Compressive Strength (14 Days)

Figure 5 shows the mixture's compressive strength following a 14-day curing period. The combination is stronger if the value is higher since it signifies a larger capacity to endure compressive forces. After 14 days, mixture 1:2:5 (2.35 MPa) has the maximum compressive strength, proving it is the strongest of the three mixtures. Although mixture 1:3:4 (0.66 MPa) has a lesser compressive strength than mixture 1:2:5, it is still more potent than mixture 1:4:3 (0.41 MPa), which had the lowest compressive strength of the three mixtures. The compressive strength of the mixture increases with the quantity of cement-sand cardboard ratio, and also varies depending on mixes and curing durations.

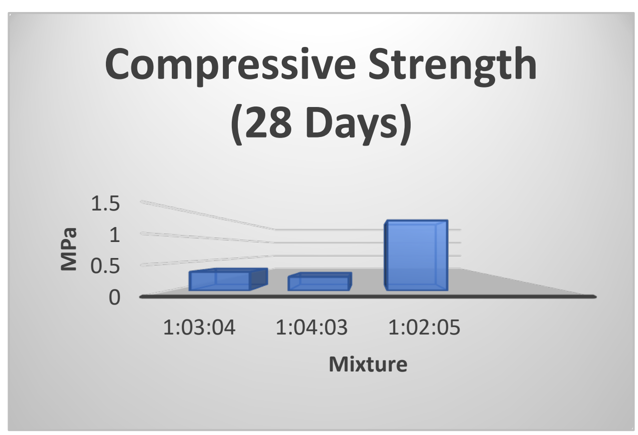

Fig.6. Compressive Strength (28 Days)

Figure 6 shows the mixture's compressive strength following a 28-day curing period. The combination is stronger if the value is higher since it signifies a larger capacity to endure compressive forces. After 28 days, mixture 1:2:5 (1.27 MPa) has the maximum compressive strength, proving it is the strongest of the three mixtures. Although it has a lesser compressive strength than mixture 1:2:5, mixture 1:3:4 (0.34 MPa) is still more potent than mixture 1:4:3. After 28 days, Mixture 1:4:3 (0.25 MPa) had the lowest compressive strength of the three mixtures. The compressive strength of the mixture increases with the quantity of cement to sand and cardboard. Results for compressive strength may vary depending on mixes and curing durations.

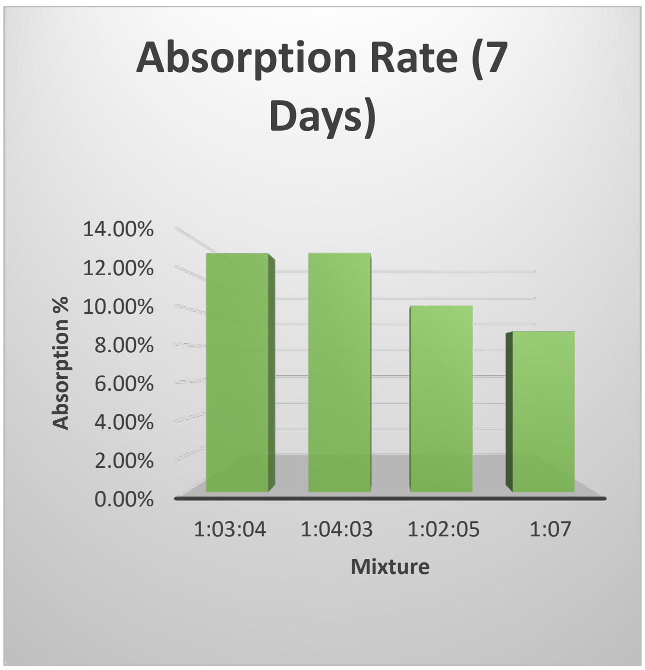

Fig.7. Absorption Rate (7 Days)

The ability of a substance to absorb moisture or water is indicated by its absorption rate, which is expressed as a percentage. Materials with high absorption rates may be more susceptible to damage or deterioration when exposed to moisture, so it is an important attribute to consider in construction. After seven days, the mixture's absorption rate is 12.96% with a ratio of 1:3:4 cement, cardboard, and sand. After the same seven days, the mixture with the ratio of 1:4:3 cement, cardboard, and sand has a marginally better absorption rate of 12.98%. The mixture indicated by the number 1:7 has the lowest absorption rate, measuring 8.73% after seven days.

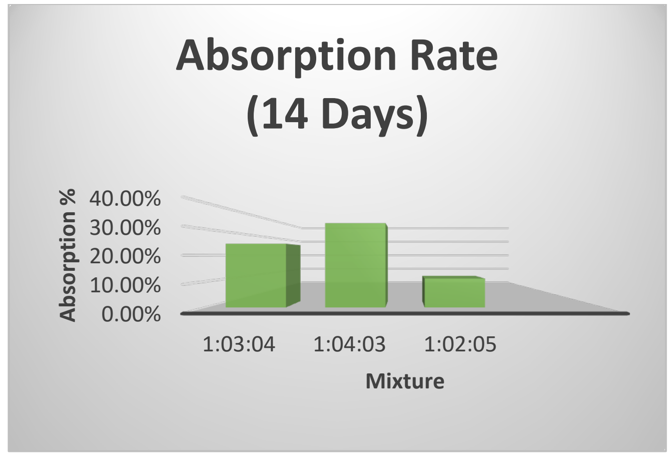

Fig.8. Absorption Rate (14 Days)

After 14 days of curing, each mixture absorbs moisture at the rate indicated by the absorption values, which are expressed as percentages. After 14 days, the combination with the following proportions has an absorption rate of 24.39%: 1:3:4 cement, cardboard, and sand. After the same 14 days, the mixture with the ratio of 1:4:3 cement, cardboard, and sand have a greater absorption rate of 32.29%. The mixture with the ratio 1:2:5 cement, cardboard, and sand had a lower absorption rate of 11.04%. The absorption rates indicate the ability of each mixture to absorb moisture.

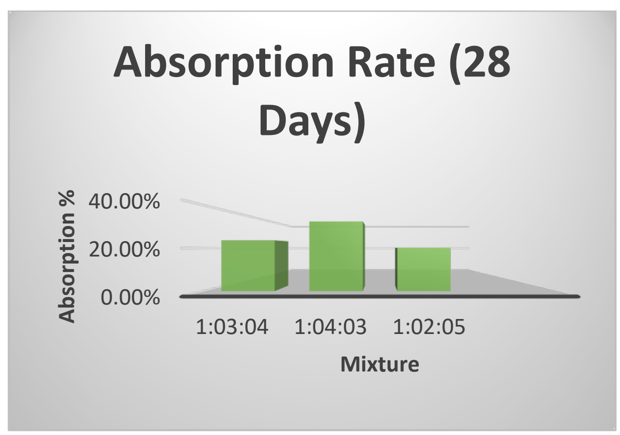

Fig.9. Absorption Rate (28 Days)

After 28 days of curing, each mixture absorbs moisture at the rate indicated by the absorption values, which are expressed as percentages. After 28 days, the combination with the following proportions has an absorption rate of 23.66%: one part cement, three parts sand, and four parts gravel. After the same 28 days, the mixture with the ratio of 1 part cement, 4 parts sand, and three parts gravel has a greater absorption rate of 32.48%. After 28 days, the mixture's absorption rate is 20.20 percent (one part cement, two parts sand, and five parts gravel). Lower absorption rates, on the other hand, imply that the material is less likely to absorb water, which may be favorable in terms of longevity and resistance to moisture damage. It is crucial to remember that many variables, such as the precise components utilized, the curing circumstances, and the makeup of the mixtures, can affect absorption rates.

Table.5. Price and Strength of CHB in the Philippines (Construct PH, 2023)

Strength	Material	Size	Cost
450 PSI	Ordinary CHB	4”	₱12.50
	Ordinary CHB	5”	₱13.50
	Ordinary CHB	6”	₱16.50

Based on their strength, composition, size, and cost, various varieties of CHB are summarized in the data that is provided. The CHB varieties listed are made of an unidentified substance and have a 450 PSI strength rating. Three different sizes—4 inches, 5 inches, and 6 inches—are offered. For these CHB types, the comparable prices are 12.50, 13.50, and 16.50.

Table.6. Cost of Raw Materials

Quantity	Material	Unit	Unit Cost (Php)	Total Cost (Php)
3	Cement	Bag	212/bag	₱636
0.34	Sand	Cubic Meter	521/cu. m	₱186.07
150	Cardboard	Kilogram	1/kg	₱180
1.50	Steel Fiber	Kilogram	55/kg	₱82.5
				₱1,084.57

Quantities, materials, unit costs, and total costs are shown in the data for a variety of commodities. The relevant ingredients are cement, sand, cardboard, and steel fiber, and the quantities range from bags to cubic meters and kilos. The unit costs and total costs are given in Philippine Pesos (Php) for each item.

Table.7. Price of CHB based on Cost of Raw Materials

Mixtures	CHB(pcs.)	Size	Cost/pc.(Php)
1:3:4	21 pcs.	5”	₱17.21
1:4:3	21 pcs.	5”	₱17.21
1:2:5	21 pcs.	5”	₱17.21
TOTAL	63		₱1,084.23

Based on the given data, the cost of the mixtures (Php 17.21 per piece) 5” is higher than the cost of a 5” size of Ordinary CHB in the Philippines (Php 13.50). Therefore, if cost is the only factor to consider, choosing the 5” of Ordinary CHB that meets the project's requirements would be more economical than using the mixtures. However, researcher’s archetype can also compete with the country’s existing hollow blocks through its innovation.

IV. Summary Of Findings

In studying the lightweight CHB using cardboard shreds, the researchers saw that they could use different aggregate parts rather than gravel. They have gathered data using different kinds of methods, such as the Bulk Water Absorption test, to get the absorption rate of the hollow blocks and the Compressive Strength test, to test the load that the concrete block can carry before failing. The researchers focused on getting data on the following cement, cardboard pulps, and sand mixtures: 1:2:5, 1:3:4, and 1:4:3.

- The information is given within seven days of curing; the compressive strength of different concrete block samples made with varied mix ratios. The sample with a 1:7 mix ratio exhibits the highest compressive strength, measuring 96.65 psi or 2.70 MPa. On the other hand, the sample with a 1:3:4 mix ratio has the lowest compressive strength, coming in at 21.37 psi or 0.60 MPa. The sample with a 1:2:5 mix ratio exhibits the second highest compressive strength, at 1.20 MPa. This mixture's precise composition—the way the elements are arranged—is what gives it its increased strength.
- According to the data, three concrete mixtures' compressive strength, expressed in MPa, following a 14-day curing time. The 1:2:5 mixture is the strongest of the three, as evidenced by its high compressive strength of 2.35 MPa. Despite having a lesser compressive strength of 0.66 MPa than the mixture with a ratio of 1:4:3, which has the lowest compressive strength at 0.41 MPa, the mixture with a ratio of 1:3:4 is still stronger than that. It is vital to remember that these outcomes may change based on the precise mix ratios and curing times.

- The concrete mixture with a ratio of 1:2:5 (1.27 MPa) exhibits the maximum compressive strength among the samples after 28 days of curing. This mixture's greater cardboard content probably gives it its additional strength. Contrarily, the 1:2:5 mixture has higher compressive strength than the 1:3:4 mixture (0.34 MPa), perhaps due to the mixture's higher sand-to-cardboard ratio. The ratio of 1:4:3 (0.25 MPa) mixture has the lowest compressive strength of all the mixtures, which can be related to how its elements are arranged.
- In order to produce high-strength hollow blocks, it has been found that a mixture of one part cement, two parts cardboard pulps, and five parts sand works well. This mixture is best for building sturdy concrete blocks since it has the maximum compressive strength and the lowest absorption percentage. The concrete blocks will also resist moisture penetration due to the low absorption rate, which lowers the chance of cracking, weakening, and disintegration, especially during freezing and thawing circumstances. The optimum combination for building hollow blocks is the 1:2:5 cement, cardboard pulps, and sand ratio since it balances affordability, strength, durability, and minimal water absorption.
- Among the combinations shown in Figure 11–16, the 1:2:5 mixture is the heaviest, while the 1:3:4 mixture is the lightest. As a measure of the blocks' strength and durability as building materials, their "Bulk Specific Gravity" relates to their physical density. In general, blocks with a higher density are stronger and more long-lasting. The 1:2:5 blend of cement, cardboard pulps, and sand is the densest of the three compositions, making it the strongest and most resilient. Blocks with a high-water absorption rate might not be appropriate in humid or heavily rained-on environments. The 1:2:5 mixture is the best option for areas with a lot of rainfall because it has the lowest absorption percentage.

V. Conclusion

The major goal of this project was to create reinforced lightweight concrete hollow blocks utilizing finely ground cardboard shreds and steel fiber reinforcement. Also, to determine the effectiveness of the newly made prototype compared to the traditional hollow blocks of the Philippines. The experiment proved that the efficient and ideal ratio for making hollow blocks is a 1:2:5 mixture of cement, cardboard pulps, and sand while the least sample is 1:4:3. The ratio 1:2:5 is high in compressive strength, low absorption rate, and durability are all produced by this ratio, which is also economical and practical.

Because cement is strong, cardboard pulps provide fibrous reinforcement, and sand has filling and binding capabilities and is a suitable binder. When freezing and thawing cycles are present, this mixture will produce completed concrete blocks less prone to cracking, weakening, and disintegration. Also, this study shows that the traditional blocks were more effective than the best prototype the researchers had created in terms of compressive strength. Still, the archetype of the researchers can compete with hollow blocks present in the country.

VI. Recommendations

The researchers gathered information using a variety of techniques, such as the Compressive Strength test and the Bulk Water Absorption test, to assess how well various combinations of cement, cardboard pulps, and sand performed. As indicated by their "Bulk Specific Gravity," the blocks' density also significantly contributed to their toughness and longevity. The 1:2:5 mixture was the densest of the compositions that were evaluated, making it the most durable and robust choice. On the other hand, blocks with a high-water absorption rate were unsuitable for areas with high humidity or frequent rain.

Consequently, due to its lowest absorption percentage and its recommendation for places with substantial rainfall, the 1:2:5 mixture was used. With this ratio, the strength, durability, moisture resistance, and water absorption are all improved. It is encouraged to conduct more research to examine longer curing times and evaluate the suggested blend's long-term strength and structural performance. The practical use of the 1:2:5 ratio in construction projects can result in environmental advantages, and improved building performance.

The efficacy and longevity of the suggested ratios for making hollow blocks require additional study utilizing controlled trials. This will make it easier to determine and guarantee the consistency and dependability of the ideal mixture ratio for concrete hollow blocks. Investigating how well this mixture performs over the long term in various environmental circumstances, such as high or low humidity levels, is also crucial. Additionally, investigating the possibility of adding additional waste materials to the mixture, like recycled plastics or glass, may further enhance the hollow blocks' properties. Such studies can offer insightful information for the construction industry's affordable and sustainable building materials development. A major limitation of this study is that the researchers provide few ratios to try, hence, getting little data about the experiment.

Based on the results and experience of the researchers, the following are also recommended for future researchers:

- Improve the methods and tools in casting CHB
- Collaborate with hardware's or skilled, semi-skilled laborers who knows more about making and casting CHB

Many things still need to be done to guarantee that the block production sector implements environmentally friendly and sustainable methods. To lessen the industry's influence on the environment, waste reduction and efficient disposal techniques should also be used. The adoption of sustainable techniques will foster the growth of a more moral and ethical building industry.

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