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Utilization of Sawdust in Making Concrete Blocks: An Experimental Research on Hollow Concrete Block's Rigidity

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Abstract: The construction industry has been grappling with what waste material can substitute for sand in producing quality hollow concrete blocks. This gap motivated the researchers to conduct this study, which aimed to investigate the rigidity of concrete blocks using sawdust as a substitute for sand. The study was designed to test the compressive strength of developed hollow concrete blocks and compare it with the acceptable standard set by the Department of Public Works and Highways in the Philippines. The researchers obtained the results through a thorough observation from the 28-day curing process and compressive strength value using the Department of Public Works and Highways compressive strength machine. Mean and compressive strength formula (F=P/A) was used to analyze the result of the sampled hollow concrete blocks. Based on the forenamed findings, the researchers observed that the compressive strength and the mass of concrete samples decrease as sawdust increases. However, these data are insufficient to conclude that the concrete samples achieved the properties of a durable and robust concrete block. Thus, the researchers profoundly suggest increasing the number of samples to validate the findings. Moreover, other tools that can be used to analyze the rigidity of developed hollow concrete blocks using sawdust as a substitute for sand are also recommended.

Keywords: Concrete Blocks, Sawdust, Compressive Strength Machine, Aggregates

1. Introduction

Concrete blocks are regarded as a necessary material in all construction projects. Compared to clay bricks, concrete blocks are the most popular building material because they are inexpensive and available. Due to a lack of natural resources, the development movement raises demand for vital building materials such as sand. However, the availability of sand comes at a cost. With the increasing demand for rigid concrete and the scarcity of sand, the construction industry will face an economic dilemma in meeting consumer demand for rigid concrete. Furthermore, with increased environmental awareness, extensive study has been conducted globally on exploiting waste materials and by-products as construction materials [1]. One viable solution to this predicament is to utilize sawdust as a fine substitute for sand. Sawdust is a natural fiber that is used as a filler. Sawdust is a fine particle collection of intricate softwoods. This substance is a by-product made by chopping wood using a saw [18]. Because sawdust is relatively abundant and inexpensive, recycling such wastes into new construction materials could solve the emission problem and the difficulty of high building material costs that developed and developing countries are currently confronting.

Going through the operational progress is remarkable; the growth of a developing economy and working industrialization is highly significant to sustaining the needs and demands of a community. In South Asia, India is determined to achieve high growth in infrastructure [2]. The value of urbanization has been highly centralizing the urban population in a big city, insisting on affordable and proficient housing design with several developments in short-run production. But the immense utilization of sand in concrete structures likewise confronts a shortage of sand, raising environmental concerns. Removing sand from the river might create ecological problems in the future. Reducing the usage of sand in a concrete mix will eventually lessen the construction expenses [9]. In addition, when sand is decreased, the general cost of construction materials can be reduced as sawdust can be acquired economically at a sawmill and sometimes for free. Sawdust is a waste product of woodworking operations such as sawing, sanding, milling, and routing with fine wood particles. In addition, sawdust has unique characteristics and is competitive with other building materials [11].

Concrete blocks are one of the types of precast concrete items that are used in buildings. The term precast refers to the blocks being shaped and cured before being sent to the job site [13]. A concrete block is mainly used in the construction of walls as a building material. It is also known as a concrete masonry unit (CMU). The majority of concrete blocks have one or more hollow cavities, and their sides may be smooth or patterned. To shape the ideal length and height of the wall, concrete blocks are stacked one at a time and kept together with fresh concrete mortar. Hollow concrete blocks are more practical, and the most significant aspect is their ease of ventilation because of their lightweight [14]. It lowers the cost of building by reducing the amount of cement used in masonry work. Cement concrete hollow blocks (CHB) play a significant role in the current building industry in the Philippines; they are utilized as a building material in the construction of walls. Concrete blocks are a type of precast concrete product that is used in buildings. They are a more cost-effective and better alternative to bricks due to their high durability, fire resistance, partial sound resistance, thermal insulation, low dead load, and fast construction. The construction industry is a booming sector in today's world. The demand for this project is always high in cities and other urban regions and rural areas due to the development of residential flats, commercial buildings, industrial buildings, and minor constructions. This research aims to develop or construct a concept for dealing with the high demand for CHB. The study concentrated on developing a low-cost CHB molder capable of producing sufficient concrete blocks to begin a construction project. It is even possible to provide a bespoke hollow cement block in these cases.

The compressive strength of concrete blocks indicates the maximum load that the sample can bear until the crack or crush, divided by the sample press's cross-sectional area [12]. One of the most important properties for the design of masonry walls in various loading situations is compressive strength. After that, several research studies investigating the compressive behavior of concrete block masonry have been launched in the past [17]. The compressive strength of a concrete block differs significantly from that of solid brick masonry. Shapes and types of the blocks, mortar bedding types, curing, cement and sand type, and grout strength all play a role in the overall responses [5]. For industrial concrete, the average compressive strength of hollow concrete block units is approximately 7.8 MPa at dimensions 190 ×190 × 390 mm [16]. Moreover, the Department of Public Works and Highways indicated that an average of 3.45 MPa (Megapascals) is an individual block unit [4]. The test results of Ghosh show that it is possible to manufacture concrete containing sawdust with properties similar to those of natural concrete if the percentage of sawdust replaced by sand is between 10% and 20% [7]. Beyond that, it violates the IS code requirement because the strength of concrete decreases as the percentage of sand replaced by sawdust increases. Further, construction industries have a continuing predicament about what waste material could be used as a fine substitute to sand in manufacturing hollow concrete blocks. This gap, therefore, motivated the researchers to conduct this study which aimed to study the rigidity of concrete blocks with the waste product sawdust as a fine replacement to sand.

2. Methods

2.1. Research Design

The experimental design was used in this study which aimed to develop an acceptable concrete mixture with sawdust particles as a substitute to fine aggregate that can be used for building construction, particularly in a residential-class concrete slab, and analyze the effect of sawdust concrete mixture. This study design was made to provide accurate experimental procedures in pretreating the procured sawdust and using it as an acceptable aggregate substitute in hollow concrete block production, developing a good concrete mix, observing the blocks during the curing process, and examining the physical properties and strength of the sawdust-concrete. Observations from the tests and examinations performed were conducted in the laboratory where precise data can be gathered and wholly attained. Moreover, instruments used in this study include a shovel, sand sieve, concrete molder, compressive strength machine, digital weighing scale, floor weighing scale, and measuring cup.

2.2. Data Gathering Procedure

To facilitate the gathering of the data needed, the following steps were followed:

Procurement of Materials Needed in Making Concrete Blocks. Sawdust fibers are obtained from lumber stores. A 9-kg of sawdust is shredded to get an acceptable aggregate standard. Moreover, one bag of cement and fine aggregate is being used in the estimation of materials.

Pretreatment of Sawdust. The substances inside the timber fiber are being removed; otherwise, the binding process of the block will be affected. The pretreatment process consists of soaking the acquired sawdust with a limewater mixture. The percentage of lime concentration to that of the overall mix of the concrete is 0 L, 0. 25 L, 0. 50 L, 0. 75 L, 1.0 L, and 1.5 L. The process lasted for 60 minutes before mixing.

The Production of Concrete Block with Sawdust as Fine Aggregate. In the construction of concrete blocks, the following steps are carefully performed. Four samples of concrete block mix proportions with a mortared 1:2 ratio is cast – 5% (0.50 kg) sawdust replacement to sand, 10% (1.0 kg) sawdust replacement to sand, 15% (1.50 kg) sawdust replacement to sand are investigated, and 0% (0 kg) sawdust replacement to sand. Firstly, the researchers mixed the cement, 95% sand, and 5% sawdust along with the water, 10% sand, 90% sawdust and water, and 15% sand, 85% sawdust and water. Afterward, the researchers placed the combinations in the molder and removed them subsequently, and set it aside in preparation for curing after the mixture was complex.

Table 1. *Detailed Information of Each Block Sample.*

Sample	Sawdust Concentration (%)	Sawdust (Kg)	Cement (Kg)	Aggregate (Kg)	Lime Concentration to Sawdust (L)
1	0%	0 Kg	5 Kg	10 Kg	0 L
2	5%	0.50 Kg	5 Kg	9.50 Kg	0 L
3	5%	0.50 Kg	5 Kg	9.50 Kg	0.25 L
4	5%	0.50 Kg	5 Kg	9.50 Kg	0.50 L
5	10%	1 Kg	5 Kg	9 Kg	0 L
6	10%	1 Kg	5 Kg	9 Kg	0.50 L
7	10%	1 Kg	5 Kg	9 Kg	1 L
8	15%	1.5 Kg	5 Kg	8.50 Kg	0 L
9	15%	1.5 Kg	5 Kg	8.50 Kg	0.75 L
10	15%	1.5 Kg	5 Kg	8.50 Kg	1.5 L

Curing of Concrete Blocks. In curing concrete blocks, the researchers have sprinkled sufficient amounts of water to avoid cracking blocks. In this research, the curing has run for 28 days only.

Weighing. The cured blocks have been placed on a floor weighing scale to measure the average mass of each sample. The unit of measurement that is used to express the mass of the block samples in kilograms (kg).

Compressive Testing. The cured samples are transported to DPWH for compressive strength testing. Since, after the compressive test, the blocks will be futile, the researchers have produced two blocks from each type of concrete block for the first test and another for the second test.

2.3. Statistical Tool

The statistical tool used in this study are the following:

Mean. It was used to indicate the average load or compressive strength of the block samples.

Cross-sectional Area Formula. Measurement of cross-sectional was based on the dimension of the concrete molds using the formula:

$$A \text{ (cross-sectional area)} = b \times h$$

Where A is the cross-sectional area of the specimen (mm^2), b is the length of the block sample (mm), and "h" is the height (mm).

Compressive Strength Formula. Measurement of compressive strength using the formula:

$$F \text{ (compressive strength)} = P / A$$

Where F = compressive strength of the specimen (MPa), P = maximum load applied to the specimen (N), and A = cross-sectional area of the sample. The unit "mm^2" was used to evaluate the block's rigidity.

3. Results and Discussion

3.1. Mass of Concrete Blocks with and Without Sawdust as Fine Aggregate Substrate

Table 2 presents the mass of all block samples after 28 days of curing. Using a floor weighing scale, the researchers can investigate the effects of sawdust on the hollow concrete blocks according to their mass. The weight of concrete is a great factor in whether a concrete block is durable or not. Based on the table provided, block samples with the least sawdust replacement percentage are heavier than those with a substantial portion of sawdust replacement. Among those block samples that achieved a high mass are Sample 1 (0% Sawdust), Sample 2 (5% Sawdust), Sample 3 (5% Sawdust), and Sample 4 (5% Sawdust). Block samples with 10% and 15% - Sample 5 (10% Sawdust), Sample 6 (10% Sawdust), Sample 7 (10% Sawdust), Sample 8 (15% Sawdust), Sample 9 (15% Sawdust), and Sample 10 (15% Sawdust) – sawdust replacement achieved a lower mass than the mass achieved by the block samples with 5% sawdust replacement.

Table 2. *Mass of Each Concrete Block.*

Sample	Block Number	Mass (Kg)	Mean (Per sample)
1	#1	7.73	
	#2	7.76	7.75
2	#1	7.33	
	#2	7.35	7.34
3	#1	7.38	
	#2	7.18	7.28
4	#1	7.10	
	#2	7.26	7.18
5	#1	6.60	
	#2	6.76	6.68
6	#1	5.57	
	#2	5.75	5.66
7	#1	6.19	
	#2	6.31	6.25
8	#1	5.83	
	#2	5.92	5.88
9	#1	6.47	
	#2	6.42	6.45
10	#1	5.57	
	#2	5.49	5.53

A standard lightweight concrete block can achieve a mass ranging between 5 and 14 kg, depending on the mineralogical composition, particle shape, and aggregate grading [8]. One objective of this research is to produce a lightweight concrete hollow block with sawdust as a substitute to sand, the fine and generally recognized aggregate agent of any concrete. The dropping mass of each concrete sample as the amount of sawdust replacement progresses indicates that sawdust is a viable agent in the production of lightweight concrete blocks. Thus, all block samples acquired the mass a lightweight concrete block should possess [9]. Moreover, when lightweight aggregates or coarse aggregate are used in concrete production, the resulting block is lightweight concrete masonry. However, fine aggregates are utilized to produce lightweight hollow concrete blocks in this research. Aside from sawdust, which is the observed factor why the mass of concrete blocks drops as the percentage of sawdust replacement increases since coarse aggregates are not utilized, fine aggregates can also be considered a lightweight agent in the production of lightweight concrete if the coarse aggregate is omitted in the concrete ratio. Furthermore, sand is denser than water. Hence it settles to the bottom; wood (sawdust) has a lower density than water. Thus, sawdust will float on top of the water. Therefore, lowering the density leads to a reduction in weight, which leads to a reduction in total load [15].

***Table 3.** Average Load of Block in kN.*

Sample	Block Number	Load (kN)	Mean (Per sample)
1	#1	140.65kN	
	#2	119.35 kN	130.00 kN
2	#1	98.05 kN	
	#2	91.45 kN	94.75 kN
3	#1	70.75 kN	
	#2	65.50 kN	68.13 kN
4	#1	51.25 kN	
	#2	62.05 kN	51.65 kN
5	#1	70.30 kN	
	#2	88.75 kN	79.53 kN
6	#1	41.65 kN	
	#2	32.50 kN	37.08 kN
7	#1	56.65 kN	
	#2	49.00 kN	52.83 kN
8	#1	71.50 kN	
	#2	62.05 kN	66.78 kN
9	#1	51.25 kN	
	#2	51.40 kN	51.33 kN
10	#1	24.10 kN	
	#2	29.50 kN	26.80 kN

3.2. Average Load of Concrete Blocks with and Without Sawdust as Fine Aggregate Substitute

Table 3 presents the average load (kN) of all block samples that can withstand the compressive strength test. Table 3 shows that, unlike the mass, the average load that the block samples can withstand drops significantly as the percentage of sawdust replacement increases. Using the compressive strength machine, the researchers gathered the needed data to calculate the compressive strength of a block sample and unit. Data shows that Sample one (1) (Block Number 1 and 2) has a greater comprehensive strength result (x=130.00 kN) than other samples with sawdust and fine aggregates. The result shows that as the amount of sawdust added increases, the block's average load decreases.

3.3. Compressive Strength of Concrete Blocks with and Without Sawdust of Fine Aggregate Substitute

Table 4 shows the compressive strength of all block samples as measured in megapascals (MPa). The MPa of concrete determines how strong the material is and how probable it fail. Using the compressive strength formula, the average load of all block samples, and the cross-sectional area of the concrete mold, the researchers obtained the final compressive strength of all block samples. The same scenario is obtained in the final conversion of the compressive strength unit. Like the mass and average load, the final compressive strength measure decreases as the percentage of sawdust replacement increases. Another observation was that for 5% and 15% sawdust replacement, the block's compressive strength decreases as the number of lime concentrations increases.

***Table 4.** Comprehensive Strength of Block in MPa.*

Sample	Block Number	Compressive Strength (MPa)	Rating based on DPWH Standard (3.45 MPa and above)	Mean (per sample) (MPa)
1	#1	3.52	Passed	
	#2	4.98	Passed	4.25
2	#1	2.45	Failed	
	#2	2.29	Failed	2.68
3	#1	1.77	Failed	
	#2	1.64	Failed	1.71
4	#1	1.28	Failed	
	#2	1.55	Failed	1.42
5	#1	1.76	Failed	
	#2	2.22	Failed	1.99
6	#1	1.04	Failed	
	#2	0.81	Failed	0.93
7	#1	1.42	Failed	
	#2	1.23	Failed	1.33
8	#1	1.79	Failed	
	#2	1.55	Failed	1.67
9	#1	1.29	Failed	
	#2	1.29	Failed	1.29
10	#1	0.60	Failed	
	#2	0.74	Failed	0.67

As noted by the Department of Public Works and Highways, the mean compressive strength of a block unit should be 3.45 MPa and above [3]. Only the blocks of Sample one (1) have reached the average mean compressive strength of 4.25 MPa and have exceeded the standard concrete strength set by DPWH. However, 3.45 MPa can only be used as a standard for individual block units with a 1,680 kg/m³ to 2,000 kg/m³ of density or a 1:3 ratio for concrete hollow blocks which is one (1) part of cement and 3 parts of fine aggregate.

4. Conclusion

This study aimed to test the feasibility of utilizing sawdust as a partial substitute for sand in concrete. The researchers obtained these findings based on the present experimental results: the heavier the block is, the higher its compressive strength. The highest compressive strength achieved among all blocks is 4.98 MPa; 2.45 MPa for blocks incorporated with sawdust. Based on the forenamed findings, the researchers concluded that the compressive strength, average load, and mass of concrete block decreases as the percentage of sawdust replacement increases. There is a difference in the compressive strength, the total mass of concrete blocks, and concrete with sawdust at 5%, 10%, and 15% sawdust. In addition, all block samples were assessed and tested in a compressive strength machine. However, Sample 1, with a mean compressive strength of 4.25 MPa, reached the compressive strength criterion of the Department of Public Works and Highways (DPWH). The findings of this study agree that the compressive strength and weight of concrete decrease as the percentage of sawdust increases [7, 10].

5. Recommendation

After thorough analysis, the researchers came out with the following recommendations:

The number of specimens should be increased. There should be sufficient test materials for flexural and tensile strength tests to determine if sawdust, as partial replacement in fine aggregate in concrete, is efficient for construction industries. Density and water absorption of concrete block samples must also be assessed to gain more data on the drying phase and curing of the concrete blocks. Biowastes such as animal manure and food scraps can also be added to sawdust to create an alternative to fine and coarse aggregates in manufacturing eco-friendly concrete blocks.

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