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Plastic waste bottles and bamboo powder sawdust as a partial replacement to fine aggregates in production of concrete hollow blocks

Prince Joshua H. Quiambao
pjquiambao12@gmail.com
Don Honorio Venura State University, Bacolor, Philippines

Paul Jermel G. Razon
pauljermelrazon@gmail.com
Don Honorio Venura State University, Bacolor, Philippines

Mark B. Dayrit
markbondocdayrit1@gmail.com
Don Honorio Venura State University, Bacolor, Philippines

John Kerwin L. Pedroche
pedrochejohnkerwin@gmail.com
Don Honorio Venura State University, Bacolor, Philippines

Kyle JC P. Guintu
kyle.jc.p.guintu@gmail.com
Don Honorio Venura State University, Bacolor, Philippines

Raymond Carlo Cordero
raymondcarlocordero@gmail.com
Don Honorio Venura State University, Bacolor, Philippines

Aaron S. Malonzo
eybisimalonzo4@gmail.com
Don Honorio Venura State University, Bacolor, Philippines

Mildred M. Fabian
mildrednmejia@gmail.com
Don Honorio Venura State University, Bacolor, Philippines

ABSTRACT

Polyethylene Terephthalate (PET) and Bamboo Sawdust take an exceptionally long time to decompose. These wastes can cause detrimental pollutants that can have an impact on the environment in the remote future. To help decrease pollution, these substances can be used as an alternative material in producing concrete hollow blocks which are a key item used in construction. The purpose of this study was to test the performance of PET particles and bamboo sawdust as an example partial replacement for the use of fine aggregates in the manufacture of concrete hollow blocks. PET plastics were cut into small pieces at least 1 mm in diameter and bamboo powder

sawdust were collected. Both the compressive strength and weight classification percentage were determined by testing the hollow blocks. Four set-ups with differing percentages of PET particles (0, 5%, 10%, 15%) with BSD (1%) were prepared to partially replace the volume of sand. The block dimension was 4in x 20cm x 40cm and 1:4 cement to sand ratio having 0.5 to 0.55 water-cement ratio was used. Forty-eight (48) hollow blocks were produced and underwent curing times of 7, 14, and 28 days and were examined afterward. According to the findings of the study, it was seen that as the alternative materials in the blocks decrease, their respective compressive strength increases. There were no consistent results observed with the density. The CHB with 5% PET and 1% bamboo sawdust cured for 7 days was discovered to be the desirable proportion in producing CHB as it obtained the highest average compressive strength and greatly reached the required average tensile strength of the Department of Public Works and Highways (DPWH) and ASTM C129

Keywords: *Polyethylene Terephtalate (PET), Bamboo Sawdust (BSD)*

1. INTRODUCTION

Concrete hollow blocks made by concrete making machine have large output, high efficiency, save manpower and save raw materials. Moreover, the produced hollow block has high strength and accurate size. Concrete hollow block has become an important part of contemporary new wall materials and has broad development space and development prospects.

Hollow blocks are often used in non-load-bearing parts. Blocks with large empty spaces and a small number are called hollow blocks. Hollow blocks are the main wall material commonly used in the construction industry. Due to its advantages of light weight and low consumption of raw materials, it has become the first recommended product by the national construction department.

Concrete Hollow Blocks are more commonly used in masonry construction. It accelerates the construction process, saves cement and steel, and reduces the work expenses at the construction site. These blocks lower the natural weight of masonry constructions and improve the physical properties of walls, such as noise and thermal insulation. They also provide facilities for concealing electrical conduit, water and soil pipes. This project report deals with the design and development of an improved hollow concrete block making machine. The machine lays a particular number of blocks over the platform and moves further to lay another set of blocks, to cover the casting platform, in a continuous casting process. This study attempts to solve the problems encountered on the existing hollow concrete block making machine by improving the design of basic components, increasing production rate and minimizing damages of uncured blocks during transfer. The design was based on data from literature review about concrete in building construction, concrete block machine developmental stage, how concrete block making machine works and manual calculation.

In this study, the researchers tend to use plastic waste bottles and sawdust specifically bamboo sawdust due to the pollution that gives it to our society. Plastic waste bottles are the most common solid waste. Sawdust is a by-product generated during the process of manufacturing. The recycling of such waste provides the benefits of reducing the need to extract new raw materials and limiting the air pollution due to incineration. The potential of bamboo sawdust as a replacement of fine aggregates in concrete hollow blocks.

2. BACKGROUND OF THE STUDY

Due to significant economic and demographic growth, waste generation in the Philippines has increased dramatically, contributing to environment deterioration. According to study by the Senate Economic Planning Office (SEPO, 2017), the amount of garbage produced in the country has gradually increased from 37,427.46 tons per day in 2012 to 40,087.45 tons per day in 2016. Meanwhile, the amount of solid trash manufactured by Philippine cities is expected to rise by 165 percent by 2025, to 77,776 tons (SEPO, 2017). According to a report by the Provincial Government Environment and Natural Recourses Office (PGENRO), the province of Pampanga produces 1, 043.15 tons of garbage waste every day, which is equivalent to 76 truckloads, assuming each truckload weighs more or less 13.5 metric tons, for a total waste volume of 28,956.4 metric tons per year, or 25,759 truckloads (Mapiles, 2019). While the normal solid waste output in Central Luzon is predicted to be 5,598 tons every year, according to DENR's Environmental Management Bureau-Region 3 information, (Philippine News Agency, 2021). The primary causes of the country's solid waste problem are inappropriate trash disposal, poor waste collection, and a lack of disposal sites. Unless these issues are addressed, waste collected from various sources will pose great health risks and have significant environmental consequences, such as contamination of ground and surface water, flooding, pollution, and disease spread. Given the present situation of solid waste, it is about time to find ways to reduce it and use it as an alternative in the development of innovative construction materials.

The conversion of industrial wastes into useful materials for construction is a challenge for civil engineers, especially in the last decade, due to increased demand for building materials caused by population growth, which has resulted in a chronic shortage of building materials (Turgut & Halil, 2007). The concrete hollow blocks (CHB), which are noted for their lightweight nature and easy-to-use features, are not extremely affordable but also provide design flexibility, durability, energy efficiency, and resistance to extreme weather conditions. The hollow concrete block is gaining popularity in a variety of construction applications, from residential to industrial.

Depending on the species, bamboo typically consists of 50% parenchyma, 40% fiber, and 10% conducting tissues. The outer layer of bamboo is known as the parenchyma. The majority of parenchyma consists of lesions, not fibers. Its function in bamboo remains unknown. Conversely, fiber constitutes sclerenchyma tissue. 60-70 percent of a culm's weight is composed of fibers. A significant portion of the fiber's ultrastructure consists of polymer-like secondary walls. The innermost stratum of certain bamboo species, including Bambusa blumeana, Ochlandra, and Oxytenanthera, is covered with tumors. The polylamellate wall structure of the fibers at the culm's periphery confers high tensile strength. (W.Liese, 2005).

One of the important mechanical properties of a bamboo is its tensile strength especially when it is used as reinforcement. According to CBRC (2008), the tensile strength per unit weight of bamboo is 3 or 4 times as high as steel which makes it a very good material for all construction works. Also, comparing its shear strength with other structural woods, bamboo has greater shear strength and longer time before reaching its ultimate strength. Bamboo has a high flexural strength because it has the ability to bend without breaking. Lastly, it is said that the compressive strength of bamboo is twice that of other structural woods.

3. REVIEW OF RELATED LITERATURES

3.1 For Plastic waste Bottles

Plastics are non-biodegradable, and their increasing production poses a disposal problem. One promising strategy for addressing this issue is to discover alternative applications for used plastics. While there are numerous studies on the assimilation of waste materials into concrete, the incorporation of plastic residues into concrete has received little attention. Also, these few studies have focused on cylindrical concrete specimens; to the authors' knowledge, no online-published articles have focused on concrete hollow blocks. The present study narrowed that gap by shifting the focus of research from the conventional cylindrical specimen to concrete hollow block. Thus, the main objective of the study was to assess the potential of concrete hollow blocks with PP pellets as partial replacement for sand. Polypropylene (PP), which is a subset of these plastics, were pelletized and incorporated in concrete hollow blocks as partial replacement for sand. Five batches of specimens, each with 0%, 10%, 20%, 30%, 40% PP replacement (by volume) were molded and cured for 28 days. The compressive strength and bulk density of the specimens from these batches were determined and compared. Results showed that, generally, compressive strength and bulk density decrease as percent replacement increases; however, it was observed that the compressive strength of the specimens from batch with 10% PP replacement were higher compared to batches with 0% PP replacement. Compressive Strength and Bulk Density of Concrete Hollow Blocks (CHB) with Polypropylene (PP) Pellets as Partial Replacement for Sand. (According to Jonathan David Lasco, Marish Madlangbayan, Marloe Baclayon Sundo).

3.2 For Bamboo sawdust

In many developing nations, the daily demand for steel as a reinforcing material is rising. However, when steel is in limited supply, bamboo can be considered as an alternative reinforcement material. Due to its resilience, it can be used as a reliable reinforcing material and is abundantly available. In addition, bamboo's porous tubular structure allows it to withstand atmospheric pressures as a natural product. This article assesses the properties of bamboo and the performance of bamboo fibers in concrete. (Dr. S. Kavitha, Professor, Jain University, Bangalore)

4. OBJECTIVES OF THE STUDY

4.1 General Objectives

The general purpose of this research is to investigate the performance of plastic bottles and bamboo powder as partial replacement of fine aggregates in producing non-load bearing concrete hollow blocks (CHB) in order to mitigate the increasing threat of waste to the environment.

4.2 Specific Objectives

1. To determine the cement, sand, plastic bottles and bamboo powder ratio that will successfully construct non-load bearing concrete hollow blocks using experimental observation.

2. To examine the substantial difference in compressive strength between standard hollow blocks and concrete hollow blocks with plastic bottles and bamboo powder.

3. To determine the difference of a Control block sample, 5%, 10%, and 15% block sample with 1% sawdust.

4. To determine the difference of production from the sample CHB when it comes to plastic waste.

5. To determine whether the making of modified CHB with regards to ease of production is better than the normal control block.

5. SIGNIFICANCE OF THE STUDY

This research aimed to partially substitute the fine aggregate in the production of eco-friendly concrete hollow blocks using plastic bottles and bamboo powder. The environmental cost posed by plastic garbage pollution is now generally understood since plastics take years to decompose and have few choices for disposal. On the other hand, bamboo powder was proven that it can strengthen a regular concrete hollow block. To mitigate the problem concerning these wastes, the researchers explored the use of plastics bottles and bamboo powder in creating one of the most versatile building products, hollow blocks. The following would also greatly benefit from the study:

- For the environment, it would benefit from this study by reducing solid waste particularly plastic wastes which can somehow help in solving environmental and societal issues concerning solid wastes. With the reduction of this solid waste, pollution of the environment, soil, air, and water will also decrease. Less garbage is being dumped in landfills, seas, and incinerators. It also minimizes landfill space while also reducing harmful gas emissions.
- For the community and its market, this study encourages innovation in terms of establishing new materials using recyclable resources. It also minimizes the effect of hazardous or nuisance wastes on the community. Furthermore, amid the extension of material development, a new window for commercial exchange with reusable wastes such as plastic bottles and bamboo powder.
- For researchers, this study will gain a comprehensive understanding of the obtained data, studies, and subjects as the research study develops.
- For future researchers will gain from this work since it will educate them on how to make a product out of waste plastic bottles and bamboo powder, which may pique their interest in developing a low-cost, environmentally friendly construction material.

6. SCOPE AND LIMITATIONS

This investigation was limited to the partial substitution of fine aggregates with bamboo powder (sawdust) and plastic refuse bottles in the production of concrete hollow blocks. It forms after evaluating the materials' effectiveness when combined with cement and fine aggregates. Through mechanical test (Compressive Strength Test). The collection of raw materials especially plastic bottles will be around Pampanga province only and the bamboo sawdust will be collected from nearby saw mill particularly in Guagua and Lubao. Other forms of tests such as Water Absorption, Weight and Sieve Test were not conducted as per advice. Non load bearing was used in this test.

7. METHODOLOGY

This chapter provides an overview of the numerous research approaches that will be used to the subsequent sections of the study. This technique covers a wide range of topics, including study design, research environment, tools utilized, and experimental methods.

7.1 Research Design

In this study, an experimental research design was used for the investigation. The research strategy that was used in this study consisted of assigning one or more people to a variety of treatments, and then observing the results to draw conclusions. Experimentation is an ideal method for this study since its objectives include determining the degree to which regular concrete hollow blocks vary from those made using recycled plastic bottles and bamboo sawdust, as well as determining the quantity of cement that should be used for each kind of block. A certain mix of sand, plastic bottles, and bamboo sawdust is required to produce a more durable concrete hollow block.

7.2 Research Setting

The resources for this study were gathered outside the university/campus area. The researchers gathered plastic bottles and bamboo sawdust in the barangay where they live in Pampanga. The researchers collected data on the appropriate mixture and preparation for concrete hollow block manufacture which took place within Pampanga. The development of the research took place within the area of the researchers living within Pampanga.

7.3 Preparation of Raw Materials

1. PET Bottles

a. Collection

The researchers collected not less than 30 kilograms of plastic bottles for the study.

b. Cutting

The researchers will prepare the plastic bottles by shredding or cutting them into ideal sizes.

2. Bamboo Sawdust

a. Collection

The researchers will gather bamboo sawdust from various woodwork and carpentry shops.

3. Advance Cement

4. Sand

5. Water

7.4 Proportioning of Materials

The objective of this project was to find an alternative material to utilize as fine aggregates in the manufacturing of concrete hollow blocks. Accordingly, partial fine aggregate replacement of cut plastic bottles was in four set-up hollow blocks varied between 0%, 5%, 10%, and 15%, while the bamboo sawdust replaced the deviating percentages of 0 and 1%. The cement-to-sand ratio was 1:4, meaning one component cement to four parts fine aggregate by volume.

MATERIALS (Design Mixture) 1:4	DESIGN PROPORTIONING BY VOLUME (1.5 cu.m of concrete)			
	CONTROL	CHB – 1	CHB – 2	CHB – 3
CEMENT	100%	100%	100%	100%
FINE AGGREGATES	100%	94%	89%	84%
PLASTIC BOTTLES	0%	5%	10%	15%
BAMBOO SAWDUST	0%	1%	1%	1%

Table 1: Design Mixture of Cement Hollow Blocks (By Volume).

8. OBSERVATION

8.1 Compressive Strength Test

Compressive strength test was carried out to find out how a material or concrete's ability could support a load before failure. It is necessary to apply this test to find out the durability of the manufactured concrete hollow block. With this method, the appropriate design composition, the aggregates to be used, and the ideal curing period can be determined.

Table 2: Compressive Strength Test Results for 7 days cured Concrete Hollow Blocks

The results for the seven-day curing of the control, and plastic bottles and bamboo sawdust mixed concrete hollow blocks were presented in Table 2. After 7 days of curing, CHB-1 with5% Plastic bottles and 1% bamboo sawdust content recorded an average compressive strength of 864 PSI equivalent to 6 MPa. This block was observed to be 85.41% higher than the control blocks which only recorded an average compressive strength of 466 PSI or 3 MPa. The CHB - 2 with 10% Plastic bottles and 1% bamboo sawdust content obtained an average compressive strength of 733 PSI or 5 MPa and was 57.30% greater than the compressive strength of the control hollow blocks. Lastly, CHB-3 containing 15% Plastic bottles particles and 1% human bamboo sawdust which got an average compressive strength of 716 PSI or 5 MPa was seen to be 53.65% higher than the control blocks' average compressive strength.

SAMPLE IDENTIFICATION (PET – BSW)	NET AREA	MACHINE READING	COMPRESSIVE STRENTH			
	mm²	KN	PSI	AVE	MPA	AVE
CONTROL (0% - 0%)	28634	102	517	466.333	3.562	3.213
		70	355		2.446	
		104	527		3.631	
CHB – 1 (5% - 1%)	28634	165	836	864.333	5.760	5.955
		191	967		6.662	
		156	790		5.443	
CHB – 2 (10% - 1%)	28634	124	628	732.666	4.326	5.047
		153	775		5.339	
		157	795		5.477	
CHB – 3 (15% - 1%)	28634	143	724	715.666	4.988	4.930
		137	694		4.781	
		144	729		5.022	

SAMPLE IDENTIFICATION (PET – BSW)	NET AREA	MACHINE READING	COMPRESSIVE STRENTH			
	mm²	KN	PSI	AVE	MPA	AVE
CONTROL (0% - 0%)	28634	134	679	614.666	4.678	4.188
		110	557		3.837	
		116	588		4.051	
CHB – 1 (5% - 1%)	28634	150	760	753.333	5.236	5.19
		150	760		5.236	
		146	740		5.098	
CHB – 2 (10% - 1%)	28634	104	527	594.333	3.631	4.094
		127	643		4.430	

		121	613		4.223	
CHB – 3 (15% - 1%)	28634	125	633	685.333	4.361	4.721
		137	694		4.781	
		144	729		5.022	

Table 3: Compressive Strength Test Results for 14 days cured Concrete Hollow Blocks

The results of the control blocks' and modified blocks' fourteen-day curing are shown in Table 3. The CHB containing 10% plastic bottles and 1% bamboo sawdust, which recorded an average of 594 PSI and 4 MPa, did not meet the required minimum compressive strength of 600 PSI and 4.14 MPa, following the Department of Public Works and Highways. DPWH) Table 1046.4(Strength Requirements) and ASTM C129. On the other hand, the control hollow blocks and the CHB that contained 5% and 15% Plastic bottles with 1% bamboo sawdust, exceeded the minimum compressive strength.

SAMPLE IDENTIFICATION (PET – BSW)	NET AREA	MACHINE READING	COMPRESSIVE STRENTH			
	mm²	KN	PSI	AVE	MPA	AVE
CONTROL (0% - 0%)	28634	80	405	458	2.790	3.153
		91	461		3.176	
		100	507		3.493	
CHB – 1 (5% - 1%)	28634	140	709	822	4.885	5.665
		155	785		5.408	
		192	973		6.703	
CHB – 2 (10% - 1%)	28634	130	658	657	4.533	4.524
		139	704		4.850	
		120	608		4.189	
CHB – 3 (15% - 1%)	28634	125	633	633	4.361	4.714
		137	694		4.781	
		144	729		5.022	

Table 4: Compressive Strength Test Results for 28 days cured Concrete Hollow Blocks

The results for the twenty-eight-day curing of the control and experimental blocks were presented in Table 4. During the 28th day of curing, just like the first two tests, CHB -1 with 5% plastic bottles and 1% bamboo sawdust content recorded the highest average compressive strength among the other blocks having 822 PSI or 6 MPa. In comparison, the average compressive strength of the control blocks was 458 PSI, or 3 MPa, which was 79.48% less. In contrast, the CHB-2 was found to have a 43.45% higher compressive strength than the control hollow blocks, achieving an average of 657 PSI or 5 MPa. Lastly, the CHB-3 that got an average compressive strength of 633 PSI or 4 MPa was seen to be 38.20% greater than the average compressive strength of the control blocks. It was found that the control block, which measured an average compressive strength of 466 PSI, failed to pass the required minimum compressive strength of 600 PSI or 4.14 MPa based on Table 1046.4 of the DPWH and ASTM C129. However, CHB - 1 got the highest average compressive strength among all the specimens.

To summarize, the CHB - 1 with 5% Plastic bottles particles and 1% human bamboo sawdust cured for 7 days obtained the highest average compressive strength of 864 MPa in contrast with the other samples. It could also be seen that the concrete hollow blocks containing 5% Plastic bottles particles and 1% bamboo sawdust regardless of how long they had been cured, they still passed the compressive strength test.

The control blocks cured for 7 and 28 days, as well as the CHB-2 with 10% Plastic bottles with 1% bamboo sawdust which was cured for 14 days, did not attain the minimum average compressive strength. The remaining CHB was seen to pass the recommended average compressive strength of the DPWH and ASTM C129.

9. CONCLUSION

The researchers came to the following results after studying plastic bottles with bamboo sawdust as a partial substitute for fine aggregates in producing masonry blocks. Since the sample blocks had proven to have significantly higher compressive strength compared with control blocks, plastic bottles and bamboo sawdust could be used as alternative materials for fine aggregates. By performing different kinds of tests, it was found that the most suitable proportion of plastic bottles to bamboo sawdust to sand is 5%:1%:94% respectively by volume. This was the design proportion used for the CHB - 1. When compared to the other results in the compressive strength test, CHB - 1 with 5% Plastic bottles and 1% bamboo sawdust that was cured for 7 days had the highest compressive strength of 864 PSI. CHB - 1 also appeared to have the maximum compressive strength after 14 and 28 days of curing, with 753 and 822 PSI, respectively. All the above values with greater than 600 PSI, indicating that the blocks meet the DPWH Standard Specification Item 1046.4 – Strength Requirement minimum requirement and are categorized as non-load bearing CHBs. The CHB with the lowest plastic bottles content recorded the highest compressive strength among the other CHB types regardless of its curing days. This confirmed that as the plastic bottles content decreases, the compressive strength increases.

10. RECOMMENDATION

This study had been pursued to identify the effectiveness of Plastic bottles and bamboo sawdust as partial substitutes for fine aggregates in concrete hollow blocks. In terms of results, the concrete hollow block samples passed the standard specification for non-load bearing blocks, led by CHB samples containing 5% plastic bottles and 1% bamboo sawdust. The researchers of this study were confident enough to recommend utilizing plastic bottles and bamboo sawdust as partial substitutes for fine aggregates in producing concrete hollow blocks. Recycling plastic bottles and bamboo sawdust into construction materials can be one solution to the increasing solid waste problem and an answer to the resource shortage crisis. After thorough research and testing for this study, the researchers recommend the following to improve and expand the scope of the study:

- Further study and research about the physical and chemical properties of plastic bottles and bamboo sawdust.
- Use another kind of plastic such as Low-density Polyethylene or LDPE and examine the performance in the mixture of concrete hollow blocks.
- Perform the process of installation of the concrete hollow blocks manufactured with the Plastic bottles and bamboo sawdust in the building infrastructure.
- Use another type of concrete block such as AAC block.
- Vary the size of plastic and make it finely pulverized plastic particles.
- Use bamboo sawdust in form of powder as an additional reinforcement fiber.
- Vary the percentage of bamboo sawdust in CHB.
- Use a lower proportion of plastic bottles.
- A better method of shredding plastic bottles for improved plastic bottles sizing.
- Additional use of other testing procedures such as water absorption, weight and sieving test.

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