ANALYSIS OF THE STRENGTH OF BAMBOO REINFORCED PLASTIC BOTTLE CONCRETE BEAMS FOR LOW-COST HOUSING

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ABSTRACT

The world consumes about a million plastic bottles a minute, with the Philippines as one of the top plastic polluters. It is currently one of the many crises that the Philippines is experiencing. Using plastic bottles in designing a reinforced concrete beam is one of the many examples in the modernization of sustainable structures. An alternative for traditional construction materials is the key point, thus, this study incorporated the use of bamboo fibers as reinforcement in replacement of steel which is known for its high cost. Bamboo is known for its low-cost, wide availability and it is well known for its diverse properties. This research intends to investigate the flexural capacity of bamboo reinforced plastic bottle concrete beams for low-cost housing, determine the potential of this model in the field of construction, and analyze its effect on cost.

Keywords: bamboo reinforcement, steel reinforcement, concrete blocks, plastic bottles, low-cost housing

INTRODUCTION

The Accreditation Board for Engineering and Technology (ABET) circumscribed engineering as a profession that develops ways to engage economical materials and forces of nature (Wright, 2002). Engineering is a compendious field that is divided into various disciplines and sub-disciplines. These disciplines are categorized into four main categories, namely: mechanical, chemical, electrical and civil. Civil engineering, specifically, deals with the design and construction of different infrastructures like bridges, roads, high-rise buildings, and houses. It is said to be dated back to ancient Egypt when construction of shelter, infrastructure, and transportation was considered essential. The field of civil engineering is considered as the refinement of civil society by the application of scientific knowledge. Fulfilling basic human needs and helping others in their daily lives is a civil requirement (What is Engineering, n.d.). In the construction industry, construction materials have their own significance and engineers need to consider its quality. Also, one of the things to consider is the cost of the project which is the problem when it comes to low-cost housing.

Theoretical Background

Synthesis

The aim of this study is to provide alternative materials for the construction of low-cost housing, specifically plastic bottles incorporated into concrete beams and bamboo as reinforcement. Aside from this, another aim is to help the environment by utilizing disposable plastic bottles. Thus, it dwells on the economic and environmental impact of using these materials without the sacrifice of strength.

Past studies have shown that plastic bottles incorporated into concrete beams have provided an increase in compression strength. Some have shown that the use of plastic bottles filled with sand has resulted in only 35% of the usual costs of construction.

Further, bamboo is known as being high in tensile strength which could reach up to 370 MPa, thus making it a suitable alternative to steel. Aside from its high tensile strength, a study has stated that the required energy for the production of bamboo is 50 times lower than that of steel. Though proper treatment is required, it can be cost-effective most especially in places in which they grow in abundance.

In light of the characteristics stated above, this study will provide insight as to the combined strengths of these two materials and its impact on cost as an alternative to low-cost housing.

Theoretical Framework

Unlike other studies which use bamboo as reinforcing bars as their main focus, this study uses two materials in obtaining the flexural capacity of the specimen through application in low-cost housing without sacrificing the strength of the structure. Many materials were already steeped in the studies about increasing the flexure capacity and reduce the cost of the materials without using the substandard materials. The four samples and the curing days were used as parameters. The ratio of cement and sand was also used. However, the fixed parameter was used in this study was the curing which is the 7th and 28th days.

METHOD

In this study, the researchers decided to use a mix ratio of 1:2:4. The bamboo and steel reinforcements were tested for its tensile strength according to ASTM E8. A total of 12 cylinder specimens (6 cylinders w/ bottle and 6 cylinders w/o bottle) were produced and tested for compressive strength according to ASTM C192 on its 7th and 28th day of curing. A total of 24 concrete beam specimens (4 specimens each for PRC, PBRC, BRC, and PSRC) were produced according to ASTM C192 and tested for flexural strength according to ASTM C293 on its 3rd and 14th day of curing.

Tensile and Compressive Test

This phase focused on the testing of the tensile strength of three bamboo strips, three 12 mm steel rebars, and the compressive strength of the concrete cylinder reinforced with a 500 ml plastic bottle.

Sample Specimen

A total of 24 concrete beams with different reinforcements were in this study. For the specimens of Phase 2: A, B, C, and D, three specimens each were tested for the 3rd and 14th day.

Table 3.1: Description and Abbreviation of Specimens

PHASE 2	DESCRIPTION	ABBREVIATION
A	Plain Reinforced Concrete Beam	PRC
B	Bamboo Reinforced Concrete Beam	BRC
C	Plastic Steel Reinforced Concrete Beam	PSRC
D	Plastic Bamboo Reinforced Concrete Beam	PBRC

Cured Samples for Testing

The sample specimens were tested under a high rate of loading in UTM according to ASTM C293 standards. The flexural strength of the PRC, BRC, PSRC, and PBRC beams that have been cured for 3 and 14 days were tested.

Flexural Test Results

After conducting the tests, the researchers evaluated the result of the concrete beams that were tested. The ultimate load and flexural strength of each specimen were compared in order to determine if plastic bottles and bamboo fibers can be an effective alternative to steel reinforcement for low-cost housing. The researchers prepared the cost analysis and statistical analysis of each specimen to determine whether the capacity of a plastic bottle concrete reinforced with bamboo fiber will be suitable in building low-cost houses.

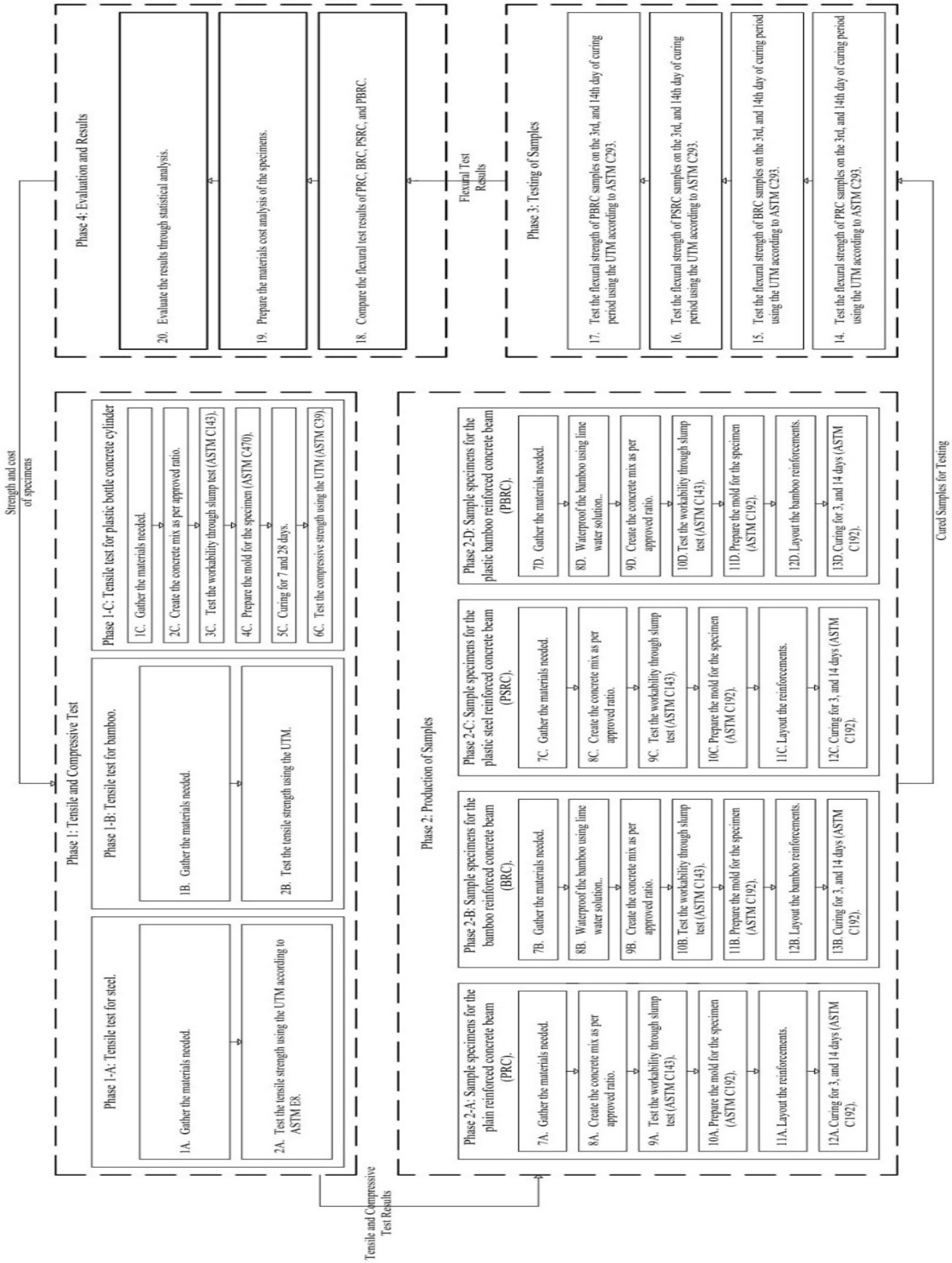

Figure 1: Conceptual Framework

Design

The research comprises a dependent and independent variable. The independent variable is considered the predictive variable and the dependent variable is the outcome being measured due to the effect brought by the independent variable. Thus, in this study, the researchers chose to use the role of the strength of concrete as the independent variable, and the use of the other materials (such as the plastic bottles, bamboo reinforcement, and steel reinforcement) as the dependent variable. Using the universal testing machine (UTM), the strengths of the multiple specimens were tested and compared.

RESULTS AND DISCUSSION

Flexural Test Results

The four types of beams were tested on its 3rd and 14th day of curing. Three specimens were tested each curing day.

Table 4.1 Summary of Results for PRC

PRC

Specimen	Curing Day	Flexural Strength		
		Load (kN)	Mpa	Average (Mpa)
A	3	30	4	
B	3	31	4	3.67
C	3	21	3	
D	14	43	6	
E	14	53	7	6.67
F	14	52	7	

The flexural strength of the PRC beam on its 3rd and 14th day of curing resulted in average strength of 3.67 MPa and 6.67 MPa, respectively.

Table 4.2 Summary of Results for BRC

BRC

Specimen	Curing Day	Flexural Strength		
		Load (kN)	Mpa	Average (Mpa)
A	3	21	3	
B	3	13	2	2
C	3	10	1	
D	14	21	3	
E	14	20	3	3
F	14	21	3	

The flexural strength of the BRC beam on its 3rd and 14th day of curing resulted in average strength of 2 MPa and 3 MPa, respectively.

Table 4.3 Summary of Results for PBRC

PBRC

Specimen	Curing Day	Flexural Strength		
		Load (kN)	Mpa	Average (Mpa)
A	3	10	1	
B	3	10	1	1.33
C	3	13	2	
D	14	18	2	
E	14	19	2	2.33
F	14	20	3	

The flexural strength of the PBRC beam on its 3rd and 14th day of curing resulted in average strength of 1.33 MPa and 2.33 MPa, respectively.

Table 4.4: Summary of Results for PSRC

PSRC

Specimen	Curing Day	Flexural Strength		
		Load (kN)	Mpa	Average (Mpa)
A	3	49	6	
B	3	43	6	6
C	3	46	6	
D	14	59	8	
E	14	54	7	7.33
F	14	57	7	

The flexural strength of the PSRC beam on its 3rd and 14th day of curing resulted in average strength of 6 MPa and 7.33 MPa, respectively.

Data shows that the PSRC beams attained the highest strength, while the PBRC beams attained the lowest strength.

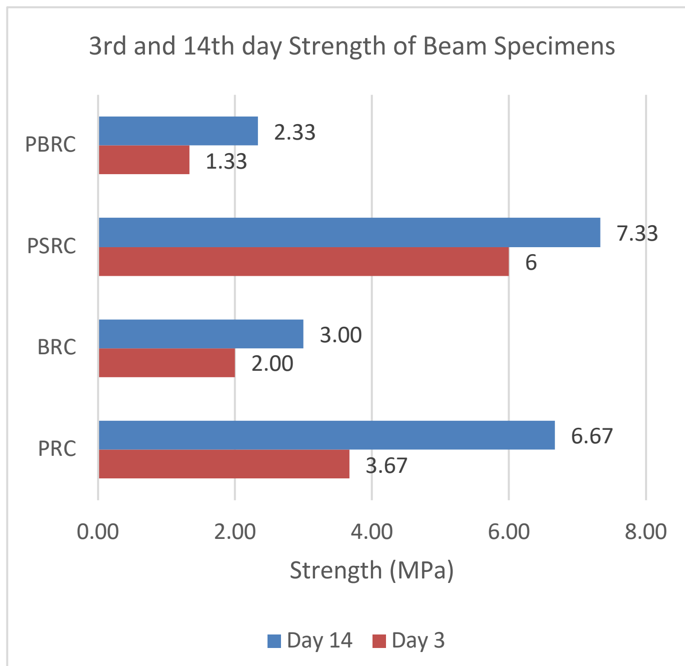

Figure 4.1: Flexural Strength of PRC, BRC, PSRC, and PBRC

Data Analysis

Table 4.5: Significant difference between BRC and PRC.

Curing day		Mean	SD	T-value	P-value	Interpretation
Day 3	PRC	3.67	0.58	2.50	0.08	Not Significant
	BRC	2.00	1.00			
Day 14	PRC	6.67	0.58	11.00	0.01	Significant
	BRC	3.00	0.00			

Df = 2, T-tabular value = 4.303

Table 4-13 presents a significant difference between BRC and PRC. No significant difference was observed between PRC and BRC on the 3rd day with a p-value of 0.08. However, significant differences were observed on the 14th day with a p-value of 0.01 thus, the null hypothesis was rejected. The mean value showed that differences occurred because PRC was statistically higher with a mean of 6.67 than BRC with a mean value of 3.00.

Table 4.6: Significant difference between PSRC and PRC

Curing day		Mean	SD	T-value	P-value	Interpretation
Day 3	PRC	3.67	0.58	-7.00	0.02	Significant
	PSRC	6.00	0.00			
Day 14	PRC	6.67	0.58	-1.41	0.23	Not Significant
	PSRC	7.33	0.58			

Df = 2, T-tabular value = 4.303

Table 4-14 presents a significant difference between PSRC and PRC. No significant difference was observed between PRC and PSRC on 14th day with a p-value of 0.23 but it was previously signed with a p-value of 0.02 thus, the null hypothesis was rejected on the 3rd day. The mean value showed that differences occurred because PSRC was statistically higher with a mean of 6.00 than PRC with a mean value of 3.67.

Table 4 - 7: Significant difference between PBRC and PRC

Curing day		Mean	SD	T-value	P-value	Interpretation
Day 3	PRC	3.67	0.58	4.95	0.01	Significant
	PBRC	1.33	0.58			
Day 14	PRC	6.67	0.58	9.19	0.00	Significant
	PBRC	2.33	0.58			

Df = 2, T-tabular value = 4.303

Table 4-15 presents a significant difference between PBRC and PRC. Comparison between PRC and PBRC was significant on the 3rd day with a p-value of 0.01 thus, the null hypothesis was rejected on the 3rd day. The mean value showed that differences occurred because PBRC was statistically higher with a mean of 3.67 than PRC with a mean value of 3.67. Differences remained significant on the 14th day with a p-value of 0.00 thus, the null hypothesis was rejected on the 14thday. The mean value showed that differences occurred because PBRC was statistically higher with a mean of 6.67 than PRC with a mean value of 2.33.

Cost Analysis

The cost computed here is on a per beam basis. The amount of cement, sand, and gravel was computed by multiplying the volume of the beam to the values tabulated in Table 4 – 16. The amount was then multiplied to the market price for each respective material.

Table 4 - 8: Concrete Proportion

FOR MATERIALS ESTIMATE

Mixture Class	Cement in 40kg Bag	Sand	Gravel
A	9.00	0.5	1

Table 4 - 9: Summary of Prices for PRC and BRC

PRC & BRC

Computations			Price
Volume	0.01	m^3	-
Cement	0.11	bags	PHP 24.45
Sand	0.01	m^3	PHP 8.27
Gravel	0.01	m^3	PHP 16.54
		TOTAL	**PHP 49.26**

The total cost for PRC and BRC is Php 49.26 per beam.

Table 4 - 10: Summary of Prices for PRC and BRC

PBRC & PSRC

Computations			Price
Volume	0.01	m^3	-
Cement	0.10	bags	PHP 22.38
Sand	0.01	m^3	PHP 7.57
Gravel	0.01	m^3	PHP 15.14
		TOTAL	**PHP 45.09**

The total cost for PSRC and PBRC is Php 45.09 per beam.

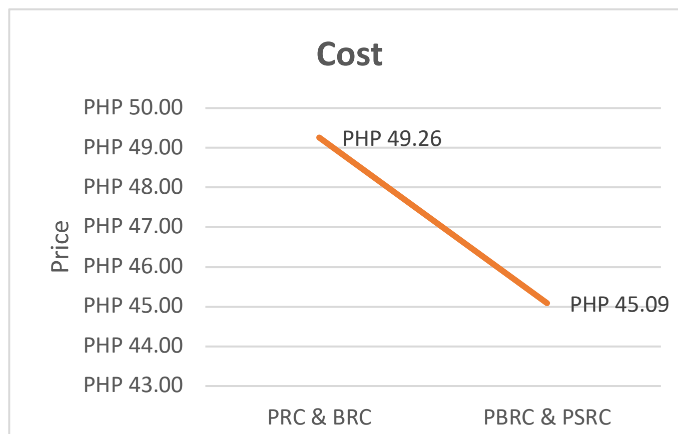

Figure 4 - 4: Cost Analysis of PRC, BRC, PSRC, and PBRC

The cost was computed through the concrete proportion (based on the class mixture) multiplied to its price. The cost obtained is only based on the volume of the beam specimens. Thus, the difference in cost between the beams with and without plastic bottles is Php 4.17.

Table 4.11: Difference between PRC & BRC and on PBRC & PSRC on Cost of Cement, Sand, Gravel

	PRC & BRC	PBRC & PSRC	Diffe-rence	T-value	P-value	Interpre-tation
Cement (bags)	PHP 24.45	PHP 22.38	-9.2%	0.220	0.837	Not Signi-ficant
Sand (m3)	PHP 8.27	PHP 7.57	-9.2%			
Gravel (m3)	PHP 16.54	PHP 15.14	-9.2%			

Df = 2, T-tabular value = 4.303

Table 4.19 *presents* the comparison between PRC & BRC and on PBRC & PSRC on Cost of Cement, Sand, Gravel. The table showed that PBRC & PSRC was cheaper by 9.2% than PRC & BRC however when compared, the p-value was 0.837 which means that there is no significant difference between PRC & BRC and on PBRC & PSRC on Cost of Cement, Sand, Gravel. This means that the cost of both groups is statistically similar.

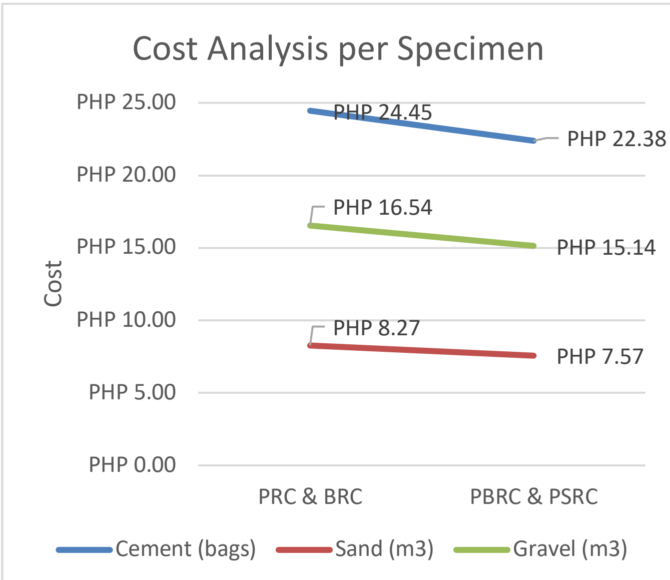

Figure 4 - 5: Graphical presentation of the difference between PRC & BRC and on PBRC & PSRC on Cost of Cement, Sand, Gravel

CONCLUSION

Statistical analysis was done based on the data results obtained and this will determine whether the data is significant or insignificant. If the p-value is less than or equal to 0.05 ($p \leq 0.05$) it is interpreted as significant; and if the p-value is greater than 0.05, it is interpreted as insignificant.

The 28th-day compressive test results of the cylinder with and without bottles showed significant difference with a p-value of 0.02. The tensile test for steel and bamboo resulted in a p-value of 0.01, thus significant. The 14th-day flexural test results of the PSRC, BRC, and PBRC was compared to the flexural test results of PRC which served as the control sample. The PRC and PSRC beams are both reinforced with steel, while the BRC and PBRC beams are reinforced with bamboo. The PSRC and PBRC beams contain plastic bottles within while the PRC and BRC beams do not. The statistical results of PRC compared to PSRC, BRC, and PBRC showed a p-value of 0.23 (insignificant), 0.01 (significant), and 0.00 (significant) respectively. For costs, the beams were separated into two groups: beams with no bottles (PRC and BRC) and beams with bottles (PBRC and PSRC). The beams with no bottles are more expensive than the beams with bottles by 9.2%.

For future researchers, test the raw materials to be used and then determine the mix ratio to be used based on the results. Look for alternative ways to incorporate the use of plastic into the beam, one example of this is the use of pulverized plastic. When computing for the cost analysis, instead of computing it per beam, provide a cost analysis for a whole low-cost house.

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