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Compressive Strength of Hollow Blocks Made From Concrete Mixed With Bamboo Strips

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ABSTRACT

This study was conducted to determine the compressive strength of hollow blocks made from concrete mixed with bamboo strips.

A 2 x 2 factorial experiment in a completely randomized design with three (3) replications was employed to investigate the compressive strength of hollow blocks made from concrete mixed with bamboo strips of different lengths and at different amounts. The bamboo strips had cross-sectional area of 0.25 cm^2. The bamboo strips were 2 cm (LBS2) and 4 cm (LBS4)long while the amount of bamboo strips mixed with concrete were 5% (ABS5) and 10% (ABS10) of the total volume of the mixture of cement, sand, and water. A control treatment (no bamboo strips, NBS) was included.

The results showed that the amount and length of bamboo strips for hollow blocks greatly affected the compressive strength of concrete hollow blocks. After 7 days curing period, the LBS2 x ABS10 hollow blocks had the highest average compressive strength of 2.90MPa. After 14 days curing, the NBS hollow blocks had the highest average compressive strength of 3.78 MPa. After 21 days curing, the LBS2 x ABS5 hollow blocks had the highest average compressive strength of 4.11 MPa. After 28 days curing, the LBS4 x ABS10 hollow blocks had the highest average compressive strength of 3.78 MPa.

The researchers concluded that generally the amount of bamboo strips mixed with cement, sand, and water had significantly increased the average compressive strength of the hollow blocks.

Keywords *: Mixing Proportion, Compressive Strength, Bamboo Strips*

INTRODUCTION

Bamboo is a giant woody grass that grows chiefly in the tropics where it is widely cultivated. It is easy to grow and easy to cut, split and make into innumerable products; from chopsticks to houses, from food to fish traps and hunting spears, from the cradle to a coffin. Bamboo is suited to low technology processing as well as industrial manufacturing techniques. It is an ideal building material for low-cost, low-impact, earthquake-resistant housing projects.

Within its walls short, tough fibers sit in a resilient softer matrix providing nature's version of fiber glass. It has high tensile strength, splits straight, and is very hard.

Bamboo also has an important role in protecting the earth, binding topsoil in areas of instability where land is eroding and in preventing floods. It has a lot of uses in construction, in the paper and furniture industry, medical science, and erosion control and deforestation activities.

Hollow block is a compressed mixture of screened sand and cement which is a primary material for concrete walling structures. This is principally used for the construction of light weight partition walls and for filling in the intervals between the girder and the floor. It is also a cheap construction material and considered as the most economical with regards to durability.The Merit Student Encyclopedia, Vol. 17 (1971) states that concrete blocks, aside from cement and sand, may contain lightweight materials such as burned clay, log furnace, plant fibers, seaweeds, sawdust, rice hull and other materials.

According to Amada et al. (1997) the tensile strength of bamboo can reach up to 370 N/m^2 and this makes bamboo an alternative to steel in tensile applications. However, according to Steinfield (2001), bamboo has strong water absorption, low resistance to fire than steel, and show weak bond with concrete. But then in another study, Lo et al. (2004) concluded that both physical and mechanical characteristics of bamboo vary with respect to diameter, length, age, type, position along culminating, and moisture content of the bamboo.

Instead of the traditional hollow blocks which are usually made of cement and sand, this research study is aimed to add bamboo as additional component to hollow blocks making. The success of this research will help solve certain socio-economics problems in the region where bamboo is abundant. As a new source of raw materials for hollow blocks, bamboo could lessen the cost of hollow blocks.

Should this technology be developed, budget-constraint planners, designers, project implementers, and contractors may be encouraged to adopt the mixing of bamboo strips, among others, in concrete made into concrete beams, canals, tiles, and other agricultural structures. Hence, this practice of mixing bamboo in concrete mixing could solve the high cost of construction now.

OBJECTIVES

Generally, this study was conducted to look into the possibility of mixing bamboo strips in the production of concrete hollow blocks. Specifically, this study was aimed to:

1. measure the average compressive strengths of concrete hollow blocks made from concrete mixed with different amounts of bamboo strips at different curing periods;
2. determine the treatment combination/s (length of bamboo strips and amount of bamboo strips) of concrete hollow blocks whose average compressive strength is comparable to those of the concrete hollow blocks of the control treatment; and
3. find out whether the mixing of bamboo strips in concrete hollow blocks is economical and/or beneficial.

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METHODOLOGY

Materials

In the conduct of this research activity, the researchers used the following materials :washed sand, water, Portland cement, bamboo, steel hollow block maker, measuring can and plastic jar.

Research design

In this study, the 2 x 2 factorial experiment in a completely randomized design (CRD) with three (3) replications was used to quantify the effect of mixing bamboo strips in the making of concrete hollow blocks (CHB). For the determination of compressive strengths of CHB, the experiments involved two (2) amounts of bamboo strips(ABS5 – 5%, ABS10 – 10%) and two (2) lengths of bamboo strips (LBS2 – 2 cm, LBS4 – 4 cm) in three (3) replications. A control treatment (NBS) without any bamboo chips was included for comparison purposes. Hence, there were five (5) treatment combinations in this study, as shown next page :

	ABS5		ABS10		NBS
	LBS2	LBS4	LBS2	LBS4	
R_1	T_1	T_1	T_1	T_1	T_1
	T_2	T_2	T_2	T_2	T_2
	T_3	T_3	T_3	T_3	T_3
R_2	T_1	T_1	T_1	T_1	T_1
	T_2	T_2	T_2	T_2	T_2
	T_3	T_3	T_3	T_3	T_3
R_3	T_1	T_1	T_1	T_1	T_1
	T_2	T_2	T_2	T_2	T_2
	T_3	T_3	T_3	T_3	T_3

Figure 1. Experimental Layout

LEGEND :

T1, T2, T3 – Trial 1, Trial 2, Trial 3
R_1, R_2, R_3 – Replication 1, Replication 2, Replication 3
ABS5– Amount of bamboo strips added is 5% of the total volume of cement, sand and water.
ABS10 – 10% bamboo
LBS2 – 2 cm bamboo strips
LBS4 – 4 cm bamboo strips
NBS – no bamboo strips added (control / pure concrete)

The mixing composition of the concrete aggregates and bamboo strips usedin the production of concrete hollow blocks are given in the table below :

Bamboo Strips		Concrete Aggregates (lbs)			Weight of Bamboo (lbs)
Proportion	Size	Cement	Sand	Water	
5 %	2 cm	42.7	9	18.9	7.1
	4 cm	42.7	9	18.9	7.1
10 %	2 cm	42.7	9	18.9	14.2
	4 cm	42.7	9	18.9	14.2

Experimental procedures

1. **The Production of Bamboo Strips.** Matured bamboo poles (*patong*) were bought from a lumber dealer in Catarman, Northern Samar. The poles were split lengthwise into four (4) long strips. The long strips were then cut into shorter bamboo strips measuring 2 cm and 4 cm with a cross-sectional area of 1 cm x 1 cm. Fifty (50) kg of these short bamboo strips were produced and were submerged in salt water for 15 days. After submergence, the same strips were sundried for 60 hours.
2. **The Production of Hollow Blocks.** When the bamboo strips have been dried, the production of hollow blocks was undertaken following these procedures :
   a. All components of the concrete hollow blocks were assembled in an appropriate place ready for mixing.
   b. The cement, sand, and water were mixed until the desired consistency of the cement has been obtained. The short bamboo strips were mixed thoroughly to the concrete mix.
   c. The concrete and bamboo strips mixture was filled into a concrete hollow block molder in three (3) layers by compacting them layer after layer. Each layer was tamped 35 times with a wooden stamping rod.
   d. The hollow block maker made 12 concrete hollow blocks for the control treatment (NBS). In the same manner, he also made 12 concrete hollow blocks for the different treatment combinations : ABS5 x LBS 2, ABS10 x LBS2, ABS5 x LBS4, and ABS10 x LBS4.
   e. The moldedCHB were placed on a rigid horizontal surface free from vibrations.
   f. The concrete tiles were cured for 7, 14, 21, and 28 days in a room under normal room temperature.
   g. After 7, 14, 21, and 28 days of curing, the CHB were transported to the Engineering Laboratory Building, College of Engineering, UEP, for compressive strength testing.
3. **The Compressive Strength Testing of Concrete Hollow Blocks.** After the 7, 14, 21, and28-day curing periods, the sample CHBs were brought to the Engineering Laboratory Building, College of Engineering, UEP, where the compressive strength testing was conducted using a Universal Testing Machine (UTM).The compressive strength testing was done following the procedures enumerated below :
   a. The plain (lower) bearing block, with its hardened face up on the table or platen of the testing machine, is placed directly under the spherically seated (upper) being block. The bearing faces of the upper and lower bearing blocks and of the test specimen are

wiped clean and the test specimen is placed on the lower bearing block. The axis of the specimen was carefully aligned with the center of thrust of the spherically seated block and was gently rotated prior to testing to assure uniform setting.

b. The load is applied continuously and without shock at a constant rate within the range of 0.14 to 0.034 MPa per second (20 to 50 psi / sec). During the application of the first half of the anticipated load, a higher rate of loading was permitted. The load was applied to the specimen until it breaks. The type of failure and the appearance of the concrete tiles were noted and recorded.

4. **The Statistical Analyses.** This study employed both the numerical comparison technique and the standard statistical procedures.

   a. The numerical comparison technique was employed to compare the average compressive strengths of CHBs made from concrete with bamboo strips compared to the control treatment.
   b. The F-Test (ANOVA) was employed to test whether the numerical differences in the average compressive strengths as well as the average material cost of CHBs of the different treatment combinations are significant from those of the control treatment.
   c. The Benefit Cost Analysis. Using the prevailing prices of the concrete aggregates and some important assumptions, the average material costs of CHBs for the different treatment combinations were estimated.

RESULTS AND DISCUSSION

Compressive strength after different curing periods

1. **The compressive strength of concrete hollow blocks after 7-days curing period.** The average compressive strength of CHBsmade from concrete with different amounts of bamboo strips of different lengths after 7-days curing are shown in Table 1.It can be gleaned from Table 1 that the CHBs made from concrete mixed with 10% bamboo strips of 2 cm long (LBS4 x ABS10) had the highest average compressive strength of 2.90 MPafollowed by the average compressive strengths of CHBs made from concrete mixed with 10% bamboo strips of 4 cm (2.07 MPa). The CHBs made from concrete without bamboo strips (NBS) had the lowest average compressive strength of 1.37MPa.

Table 1. The average compressive strengths of concrete hollow blocks with different amounts of bamboo strips of different lengths after 7-days curing period.

Amount of Bamboo Strips Added, %	Length of Bamboo Strips Added, cm	Average Compressive Strength (MPa)*
0 (NBS)	-	1.37^{c}
5 (ABS5)	2 (LBS2)	1.82^{b}
10 (ABS10)	2 (LBS2)	2.90^{a}
5 (ABS5)	4 (LBS4)	1.52^{b}
10 (ABS10)	4 (LBS4)	2.07^{b}

*Averages followed by a common letter are not significantly different at 5% level of significance.

The DMRT results indicated that at 7 days curing period, the average compressive strengths of the CHBs made from concrete mixed with different amounts and different lengths of bamboo strips were all significantly higher than those of the control (NBS) hollow blocks.

The results also showed that the average compressive strengths of CHBs generally increased with the amount of bamboo strips added to the concrete mix. On the contrary, the average compressive strengths of CHBs generally decreased with the length of bamboo strips added to the concrete mix.

2. **The compressive strength of concrete hollow blocks after 14-days curing period.** The average compressive strength after 14-days curing of CHBs made from concrete with different amounts of bamboo strips of different lengths are shown in Table 2. It can be gleaned from this table that the CHBs made from pure concrete (NBS) had the highest average compressive strength of 3.78MPafollowed by the average compressive strength of CHBs made from concrete mixed with 5% of bamboo strips of 4 cm long. The CHBs made from concrete with 10% bamboo strips 2 cm long (LBS2 x ABS2) had the lowest average compressive strength of 1.81MPa.

   The DMRT results indicated that at 14 days curing period, the average compressive strengths of the CHBs made from concrete mixed with different amounts and different lengths of bamboo strips were all numerically lower than those of the control (NBS) hollow blocks. However, results further revealed that the average compressive strength of CHBs made from concrete mixed with 4-cm long bamboo strips were all significantly higher than the average compressive strength of the CHBs made from concrete mixed with 2-cm long bamboo strips. The results also showed that the average compressive strengths of CHBs generally decreased with the amount of bamboo strips added to the concrete mix. On the contrary, the average compressive strengths of CHBs generally increased with the length of bamboo strips added to the concrete mix.

Table 2. The average compressive strengths of concrete hollow blocks with different amounts of bamboo strips after 14-days curing period.

Amount of Bamboo Strips Added, %	Length of Bamboo Strips Added, cm	Average Compressive Strength (MPa)*
0 (NBS)	-	3.78[a]
5 (ABS5)	2 (LBS2)	2.11[b]
10 (ABS10)	2 (LBS2)	1.81[c]
5 (ABS5)	4 (LBS4)	3.26[a]
10 (ABS10)	4 (LBS4)	3.23[a]

*Averages followed by a common letter are not significantly different at 5% level of significance.

3. **The compressive strength of concrete hollow blocks after 21-days curing period.** The average compressive strength after 21-days curing of CHBs made from concrete with different amounts of bamboo strips are shown in Table 3. The table shows that the CHBs made from pure concrete (NBS) had the highest average compressive strength of 4.11MPa, followed by the average compressive strength of CHBs made from concrete mixed with 10% bamboo strips of 4 cm long. The CHBs made from concrete with 10% bamboo strips 2 cm long (LBS2 x ABS2) had the lowest average compressive strength of 1.76MPa.

Table 3. The average compressive strengths of concrete hollow blocks with different amounts of bamboo strips after 21-days curing period.

Amount of Bamboo Strips Added, %	Length of Bamboo Strips Added, cm	Average Compressive Strength (MPa)*
0 (NBS)	-	4.11[a]
5 (ABS5)	2 (LBS2)	3.23[b]
10 (ABS10)	2 (LBS2)	1.76[c]
5 (ABS5)	4 (LBS4)	1.83[c]
10 (ABS10)	4 (LBS4)	3.73[a]

*Averages followed by a common letter are not significantly different at 5% level of significance.

The DMRT results indicated that at 21 days curing period, the average compressive strengths of the CHBs made from concrete mixed with different amounts and different lengths of bamboo strips were all numerically lower than those of the control (NBS) hollow blocks. However, the results further revealed that the average compressive strength of CHBs made from concrete mixed with 2-cm long bamboo strips at 10 % and with 4-cm long bamboo strips at 5% have significantly lower average compressive strength than those of the NBS concrete hollow blocks. The results also showed that the average compressive strengths of CHBs decreased with the amount of 2-cm long bamboo strips added to the concrete mix whereas the average compressive strengths of CHBs increased with the amount of 4-cm long bamboo strips added to the concrete mix. On the contrary, the average compressive strengths of CHBsdecreased with the length of bamboo strips added to the concrete mix at 5% while the average compressive strengths of CHBs increased with the length of bamboo strips added to the concrete mix at 10%.

4. **The compressive strength of concrete hollow blocks after 28-days curing period.** The average compressive strength after 28-days curing of CHBs made from concrete with different amounts of bamboo strips are shown in Table 4. The table reveals that the CHBs made from concrete mixed with 10% bamboo strips4-cm long (LBS4 x ABS2) had the highest average compressive strength of 3.78MPa while the CHBs made from concrete with 5% bamboo strips 2 cm long (LBS2 x ABS1) had the lowest average compressive strength of 2.12MPa.

Table 4. The average compressive strengths of concrete hollow blocks with different amounts of bamboo strips after 28-days curing period.

Amount of Bamboo Strips Added, %	Length of Bamboo Strips Added, cm	Average Compressive Strength (MPa)*
0 (NBS)	-	3.36[a]
5 (ABS5)	2 (LBS2)	2.12[b]
10 (ABS10)	2 (LBS2)	3.66[a]
5 (ABS5)	4 (LBS4)	2.96[b]
10 (ABS10)	4 (LBS4)	3.78[a]

*Averages followed by a common letter are not significantly different at 5% level of significance.

The DMRT results indicated that at 28 days curing period, the average compressive strengths of the CHBs made from concrete mixed with 2-cm and 4-cm bamboo strips at 10% were all numerically greater than those of the control (NBS) hollow blocks. On the other hand, the average compressive strengths of the CHBs made from concrete mixed with 2-cm and 4-cm

long bamboo strips at 5% were both significantly lower than the average compressive strength of the NBS hollow blocks. The results further showed that, after 28 days of curing, the higher the amount of bamboo strips added to the concrete mix, the higher was the average compressive strengths of CHBs. In the same manner, the longer the bamboo strips added to the concrete mix, the higher was the average compressive strengths of CHBs.

The best treatment combination

Table 5 presents the average compressive strengths of the concrete hollow blocks of the different treatment combinations. The table shows that the concrete hollow blocks of treatment LBS4 x ABS2 had the highest average compressive strength followed by the average compressive strengths of concrete hollow blocks of treatments LBS2 x ABS2, NBS, LBS4 x ABS1. The lowest average compressive strength was obtained from the CHBs of treatment LBS2 x ABS1.

Table 5. The average compressive strength of concrete hollow blocks of the different treatment combinations after the 28 days curing period.

Treatment Combinations	Average Flexural Strength (MPa)*
LBS4 x ABS2	3.78[a]
LBS2 x ABS2	3.66[a]
NBS (Control)	3.36[a]
LBS4 x ABS1	2.96[b]
LBS2 x ABS1	2.12[b]

*Average followed by a common letter are not significantly different at 5% level of significance.

The results revealed that the best treatment combination is treatment LBS4 x ABS2, the average compressive strength of its CHBs has been measured to be 3.78 MPa which is numerically higher than the control CHBs.

Benefit / cost analysis

1. **The prices of the experimental materials.** The prices of the concrete aggregates and bamboo strips used in the conduct of a simple economic analysis to find out whether the mixing of bamboo strips in concrete is economical are given below :
   a. Cost of cement was P 240.00 per bag
   b. Cost of sand was P 350.00 per cubic meter
   c. Cost of bamboo strips was P 200.00 per cubic meter
   d. Water was P 10.00 per cubic meter
2. **The material cost of concrete hollow blocks of the different treatment combinations.** Thematerial costs of hollow blocks produced from concrete mixed with different amounts of bamboo strips of different lengths are presented in Table 6. The CHBs of treatment LBS2 x ABS10 had the highest average material cost of P 11.20 per piece while the CHBs of treatment LBS4 x ABS10 had the lowest average material cost of P 10.40 per piece. The CHBs of the control (NBS) treatment had an average material cost of P 10.80 per piece.

Table 6. The average material cost per piece of hollow block of the different treatment combinations.

Treatment Combinations	Average Material Cost of CHBs (PhP/pc)*
LBS2 x ABS10	11.20[a]
LBS2 x ABS5	11.15[ab]
NBS (Control)	10.80[bc]
LBS4 x ABS5	10.70[c]
LBS4 x ABS10	10.40[c]

*Average followed by a common letter are not significantly different at 5% level of significance.

The analysis of variance revealed that the length of bamboo strips added to the concrete mixture significantly affected the average material cost of CHBs. On the other hand, the amount of bamboo strips added to the concrete mix did not significantly affect the average material cost. The DMRT at 5% level of significance revealed that the average material cost of CHBs of treatment LBS2 x ABS10 was significantly higher than the average material cost of the CHBs of the control treatment and those treatment combinations containing 4 cm long bamboo strips.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

A 2 x 2 factorial experiment in a completely randomized design with three (3) replications was employed in this study to investigate the compressive strength of hollow blocks made from concrete mixed with bamboo strips of different lengths and at different amounts. The bamboo strips have cross-sectional area of 0.5 cm x 0.5 cm or 0.25 cm^2. The different lengths of the bamboo strips were 2 cm (LBS2) and 4 cm (LBS4) while the amount of bamboo strips mixed with concrete were 5% (ABS5) and 10% (ABS10) of the total volume of the mixture of cement, sand, and water. This study had a total of five (5) experimental treatment combinations to include a control treatment (no bamboo strips) for purposes of comparison : LBS2 x ABS5, LBS2 x ABS10, LBS4 x ABS5, LBS4 x ABS10, and NBS (no bamboo strip) as control treatment.

After 7 days of curing, the CHBs made from concrete mixed with 10% bamboo strips of 2 cm long (LBS4 x ABS10) had the highest average compressive strength of 2.90 MPa followed by the average compressive strengths of CHBs made from concrete mixed with 10% bamboo strips of 4 cm (2.07 MPa). The CHBs made from concrete without bamboo strips (NBS) had the lowest average compressive strength of 1.37 MPa.

After 14 days of curing, the CHBs made from pure concrete (NBS) had the highest average compressive strength of 3.78 MPa followed by the average compressive strength of CHBs made from concrete mixed with 5% of bamboo strips of 4 cm long. The CHBs made from concrete with 10% bamboo strips 2 cm long (LBS2 x ABS2) had the lowest average compressive strength of 1.81 MPa.

After 21 days of curing, the CHBs made from pure concrete (NBS) had the highest average compressive strength of 4.11 MPa, followed by the average compressive strength of CHBs made from concrete mixed with 10% bamboo strips of 4 cm long. The CHBs made from concrete with 10% bamboo strips 2 cm long (LBS2 x ABS2) had the lowest average compressive strength of 1.76 MPa.

After 28 days of curing, the CHBs made from concrete mixed with 10% bamboo strips 4-cm long (LBS4 x ABS2) had the highest average compressive strength of 3.78 MPa while the CHBs made from concrete with 5% bamboo strips 2 cm long (LBS2 x ABS1) had the lowest average compressive strength of 2.12 MPa.

The simple benefit cost analysis showed that the CHBs of treatment LBS2 x ABS10 had the highest average material cost of P 11.20 per piece while the CHBs of treatment LBS4 x ABS10 had the lowest average material cost of P 10.40 per piece. The CHBs of the control (NBS) treatment had an average material cost of P 10.80 per piece.

CONCLUSIONS

Based on the results of the study, the following conclusions were drawn:

1. After 7 days curing period, the average compressive strengths of the NBS, ABS5 x LBS2, ABS5 x LBS4, ABS10 x LBS2 and ABS10 x LBS4 concrete hollow blocks were 1.37, 1.82, 1.52, 2.90 and 2.07 MPa, respectively.
2. After 14 days curing period, the average compressive strengths of the NBS, ABS5 x LBS2, ABS5 x LBS4, ABS10 x LBS2 and ABS10 x LBS4 concrete hollow blocks were 3.78, 2.11, 3.26, 1.81 and 3.23 MPa, respectively.
3. After 21 days of curing, the average compressive strengths of the NBS, ABS5 x LBS2, ABS5 x LBS4, ABS10 x LBS2 and ABS10 x LBS4 concrete hollow blocks were 4.11, 3.23, 1.83, 1.76 and 3.73 MPa, respectively.
4. After 28 days of curing, the average compressive strengths of the NBS, ABS5 x LBS2, ABS5 x LBS 4, ABS10 x LBS2 and ABS10 x LBS4 concrete hollow blocks are 3.36, 2.12, 2.96, 3.66 and 3.78MPa, respectively.
5. After 28 days of curing, the concrete hollow blocks made from concrete mixed with 10% bamboo strips of 4 cm long has comparable and even higher average compressive strength than the NBS (control) hollow blocks.
6. The mixing of bamboo strips 4 cm long has been beneficial since the average material cost of the CHB has been reduced numerically though not statistically significant. However, the mixing of bamboo strips 2 cm long has increased the material cost of CHB.

RECOMMENDATIONS

Based on the conduct of this study and conclusions drawn, the following recommendations were drawn :

1. The mixing of 4 cm long bamboo strips at 10% of the concrete mix is recommended for adoption especially for agricultural structures.
2. Further research on the mixing of bamboo strips considering higher amounts of mixing and longer strips should be pursued.

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