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Manufacturing Environmentally Friendly Hollow Blocks using Different Aggregates: Effect on Mechanical Properties

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ABSTRACT: Hollow concrete block (HCB) is one of the most fundamental materials in building and construction worldwide. Therefore, HCB has emerged as a viable alternative to traditional building materials likebrick. It is an excellent choice for constructing walls, pavements, and other masonry work construct a long-lasting structure. Today's new world requires a green, eco-friendly, and sustainable world, and HCB can play a significant role in achieving that goal. HCB has superior thermal and fire resistance properties, greater strength, cost-effectiveness, and eco-friendliness. Only a small amount of construction in Bangladesh is done using HCBs. However, as sustainable structural technology advances, more frequent use of HCBs will be required. As a result, this article will provide a brief overview of the various applications of HCBs in Bangladesh, including the manufacturing process and its benefits and drawbacks. Specifically, this work investigates and compares the effect of different natural fine aggregates collected from different areas of Bangladesh on the mechanical properties of HCB. The fine aggregates used in this study came from the Dharala, Patgram, Lalmonirhat, and Someshwari rivers in Durgapur, Netrokona, Bangladesh. HCBs were manufactured using a hydraulic press machine and were constructed using mix design ratios of 1: 5: 1: 3 (Cement: Gravel Sand: Sylhet Sand: Crushed Stone), 1: 4.17: 1.67: 1.5 (Cement: Gravel Sand: Sylhet Sand: Crushed Stone), 1: 2.33: 2: 1.33 (Cement: Gravel Sand: Stone Dust: Crushed Stone), 1: 3.33: 2.33 (Cement: Gravel Sand: Stone Dust) and 1: 2.5: 1: 0.50 (Cement: Gravel Sand: Stone Dust: Crushed Stone) with water cement (W/C) ratio of 0.37. The specimens' dimensions were chosen to be 390 mm x 190 mm x 100 mm. The specimens were tested for unit weight, water absorption, compressive strength, and tensile strength after 28 days of water curing. The results showed that HCBs made with different fine aggregates from the Dharala, Patgram, Lalmonirhat, and Someshwari rivers in Durgapur, Netrokona, Bangladesh, have different compressive strengths at 28 days, namely 978 PSI, 1604 PSI, 1267 PSI, 1162 PSI, and 2128 PSI.

Keywords: Hollow Concrete Block (HCB); Compressive Strength; Tensile Strength; Water Absorption; Unit Weight

INTRODUCTION

The hollow concrete block is a cost-effective and environmentally friendly option for constructing masonry walls in tropical regions because it has low thermal conductivity and requires less material than traditional bricks. Furthermore, the construction of brick walls serves multiple functions, such as providing structural support and fire resistance (Al-Tarbi et al., 2022). Extensive research has been undertaken on creating environmentally friendly high-performance hollow concrete blocks (HCBs) to decrease manufacturing expenses and minimize environmental impact. HCBs possess a practical level of compressive strength, allowing for the use of waste materials in their mixture. Developers and environmentally conscious enterprises have transitioned from red bricks to high-performance hollow concrete blocks (HCBs) due to their significantly higher sustainability (Ayagi et al., 2022). Concrete masonry units, such as hollow concrete blocks (HCBs), are widely found and can be easily used with building waste. The blocks, made of cement, aggregate, and water, have openings. Hollow blocks offer numerous advantages when compared to solid blocks. Due to their hollow structure, the blocks are lighter and more portable. The mechanical properties of compressive strength and deformations play a crucial role in constructing masonry buildings. The hollowness, composition, and bonding of the joints between the walls along with the construction of the masonry units, all significantly influence the mechanical characteristics of masonry (Khalaf et al., 1992), (Khalaf, 1996), (Köksal et al., 2005), (Mohamad et al., 2007), and (Steadman et al., 1995). The HCB manufacturing sector has had a remarkable surge in value, reaching an impressive 90 billion taka. In response to the surging demand, numerous brick manufacturers have

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transitioned from producing red bricks to manufacturing high-compressive strength bricks (HCBs). One major challenge is to educate rural communities, who lack awareness of the negative impact of traditional red bricks, about the advantages of using hollow blocks. Hence, the primary objective of this study is to present the essential characteristics of HCB and underscore its construction techniques' potential in Bangladesh, while also acknowledging the associated challenges.

MATERIALS AND METHODS

Cement

This study used Portland composite cement (PCC) as a binding material CEM-II 52.5 N confirming to BDS EN 197-1:2003, and purchased commercially from the locally available market.

Fine Aggregate

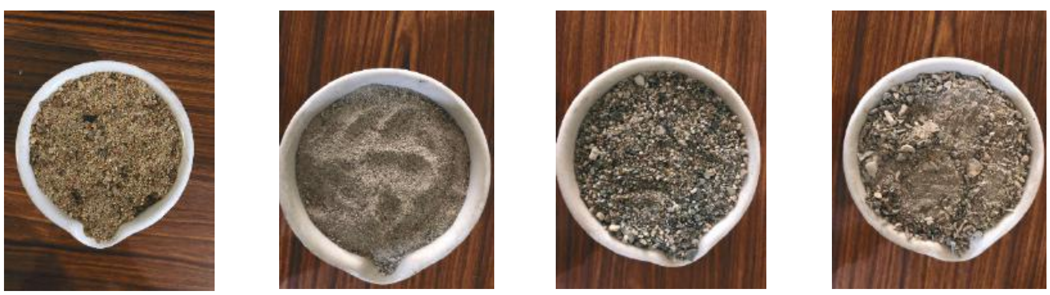
Fine aggregates are those whose size is less than 4.75mm. As shown in Figure 1, we used gravel sand, stone dust, and natural sand (Sylhet) as fine aggregates. ASTM C136 describes the testing procedures for sieve analysis of fine aggregate.

Coarse Aggregate

Generally, coarse aggregate is considered to be bigger than 4.75mm. This study uses the 5-6 mm aggregate size, as shown in Figure 1.

Water

In concrete, water is the most essential ingredient, and it is the least expensive. Hydration of cement uses a portion of the mixing water to create the binding matrix, which holds the inert aggregate suspended until the matrix has hardened. The remaining water provides permanent workability as a lubricant between the fine and coarse aggregate. Impurities in the mixing water cause concrete to lose some strength and durability. Concrete is mixed with clean water that contains no harmful levels of oils, alkalis, salts, organic compounds, or other contaminants that could harm the concrete. Concrete mixing employed water sourced from a deep tube well at the Housing & Building Research Institute (HBRI) in this research. This water is acknowledged for its absence of unusual impurities.



(a) Sylhet Sand (b) Stone Dust (c) Gravel Sand (d) Crushed Stone

Figure 1: Different Aggregate

Table 1: Physical Properties of Different Aggregate

Test Conducted	Sylhet sand	Gravel sand	Crushed stone	Stone dust
Fineness Modulus (FM)	3.12	3.78	2.78	1.46
Specific Gravity	2.40	2.32	2.63	2.72
Bulk Density	1585 kg/m^3	1625 kg/m^3	1480 kg/m^3	1365 kg/m^3

Preparation of Hollow Blocks

Hollow concrete blocks (HCBs) were made using a hydraulic press machine. The compaction pressure of the hydraulic machine (imported from China) is about 40 MPa. The usual size of blocks was cast in size (390 × 190 × 100) mm for hollow blocks. Composition of a block consists of four different materials, i. e., sand, cement (PCC) ratio of 1: 5: 1: 3 (Cement: Gravel Sand: Sylhet Sand: Crushed Stone), 1: 4.17: 1.67: 1.5 (Cement:

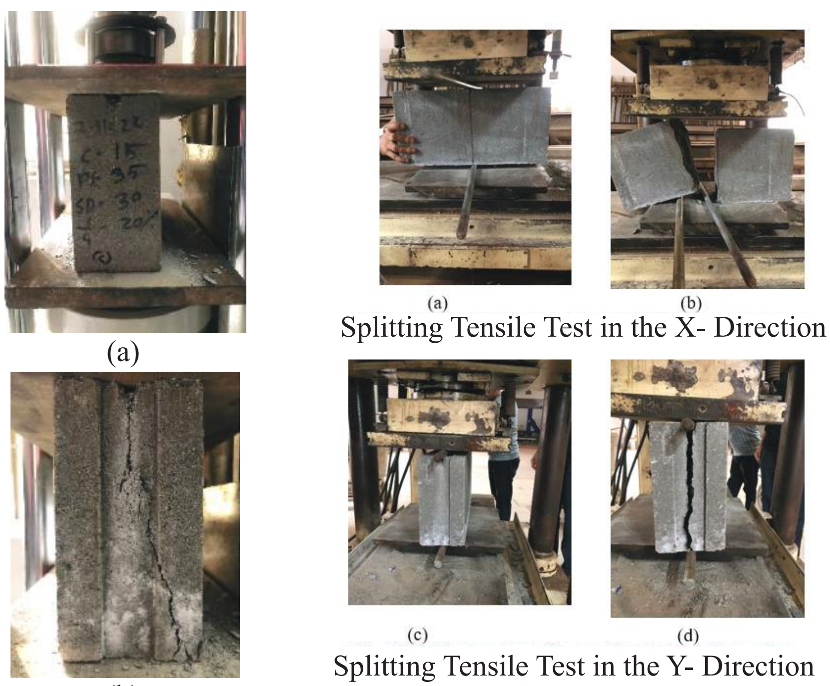
Gravel Sand: Sylhet Sand: Crushed Stone), 1: 2.33: 2: 1.33(Cement: Gravel Sand: Stone Dust: Crushed Stone), 1: 3.33: 2.33 (Cement: Gravel Sand: Stone Dust) and 1: 2.5: 1: 0.50 (Cement: Gravel Sand: Stone Dust: Crushed Stone) by weight. Preparation of hollow blocks consists of the following steps: i) Mixing of the ingredients (four different aggregates as sand, cement, and water) in a pan and then placement of materials in the molds, ii) Hydraulic compaction of the mixture in molds, and iii) Finally, demolding the specimen and drying for internal curing. A large number of hollow block specimens were prepared for compressive strength (ASTM C-140), water absorption (ASTM C-140), and density (ASTM C-140) tests collected from the Dharala River, Patgram, Lalmonirhat, and Someshwari Rivers, Durgapur, and Netrokona as fine aggregate (Fig. 1). The compressive strength of each test specimen was determined by dividing the crushing load by the average cross-sectional area of the corresponding hollow block specimen. This process also involved recording additional parameters, such as water absorption and density of the concrete.

Mix Design

For hollow blocks, the mix design ratio for 1: 5: 1: 3 (Cement: Gravel Sand: Sylhet Sand: Crushed Stone), 1: 4.17: 1.67: 1.5 (Cement: Gravel Sand: Sylhet Sand: Crushed Stone), 1: 2.33: 2: 1.33 (Cement: Gravel Sand: Stone Dust: Crushed Stone), 1: 3.33: 2.33 (Cement: Gravel Sand: Stone Dust) and 1: 2.5: 1: 0.50 (Cement: Gravel Sand: Stone Dust: Crushed Stone), respectively with water cement (W/C) ratio of 0.37. The mixture proportions of the mortar mixes for (390 x 190 x 100) mm cubes are summarized in Table 2.

Table 2: Mix Design for (390 x 190 x 100) mm Hollow Block

Mix Design	Mix -1	Mix -2	Mix -3	Mix -4	Mix -5
Cement	10%	12%	15%	15%	20%
Gravel sand	50%	50%	35%	50%	50%
Stone dust	-	-	30%	35%	20%
Sylhet Sand	10%	20%	-	-	-
Crushed stone	30%	18%	20%	-	10%


(a) (b) Splitting Tensile Test in the X- Direction

(a)

(c) (d) Splitting Tensile Test in the Y- Direction

(b)

Figure 2: Compressive Strength and Tensile Strength Test

RESULTS AND DISCUSSION

Compressive Strength

Figure 3 displays the average compressive strength outcomes for hollow blocks produced with four fine aggregates observed at various curing periods (7 and 28 days). The testing adhered to ASTM C 140 standards, employing a hollow block of dimensions 390 mm x 190 mm x 100 mm (Fig. 2). Notably, Mix 5, comprising 20% cement, 50% gravel sand, 20% stone dust, and 10% crushed stone, exhibited the highest compressive strength at 2128 PSI. A comparative analysis reveals a gradual strength increase attributed to the additional cement content.

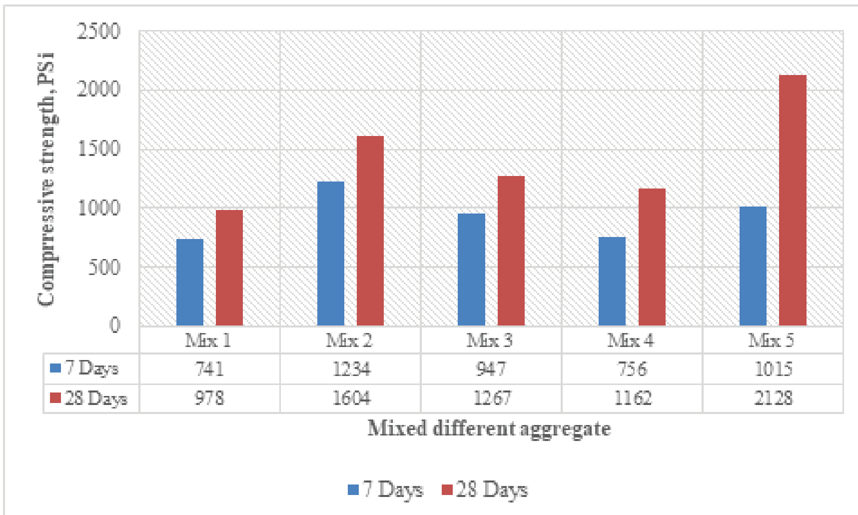


Figure 3: After 7 and 28 Days Compressive Strength

Splitting Tensile Strength X-X and Y-Y Direction

The hollow concrete blocks (HCBs) tensile strength evaluation follows the guidelines outlined in ASTM C 1006-13, employing hollow concrete block specimens sized at 390 mm x 190 mm x 100 mm. This test is executed using a compression testing machine. Figure 4 illustrates the outcomes of the split tensile strength test, revealing that the inclusion of cement hinders the rate of strength development. Notably, Mix 5 demonstrates commendable performance in this regard.

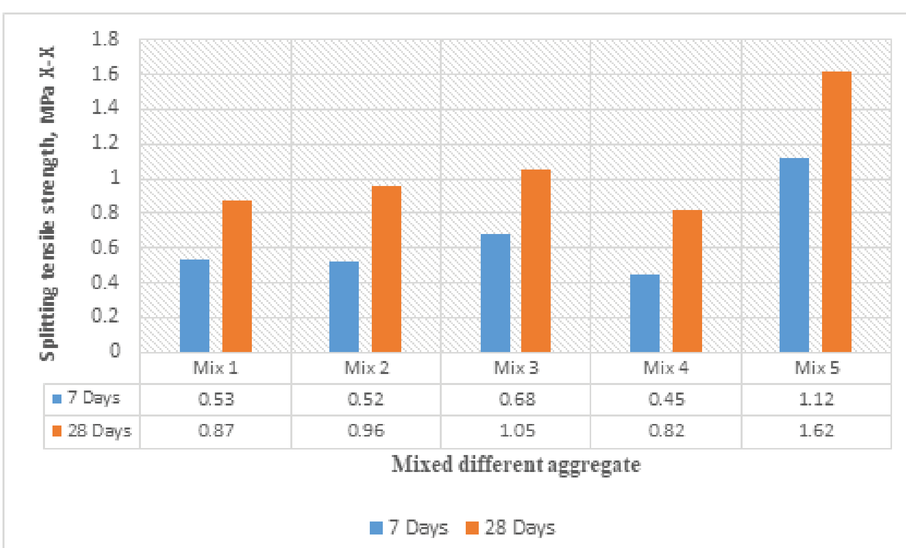


Figure 4: After 7 and 28 Days, Splitting Tensile Strength X-X Direction

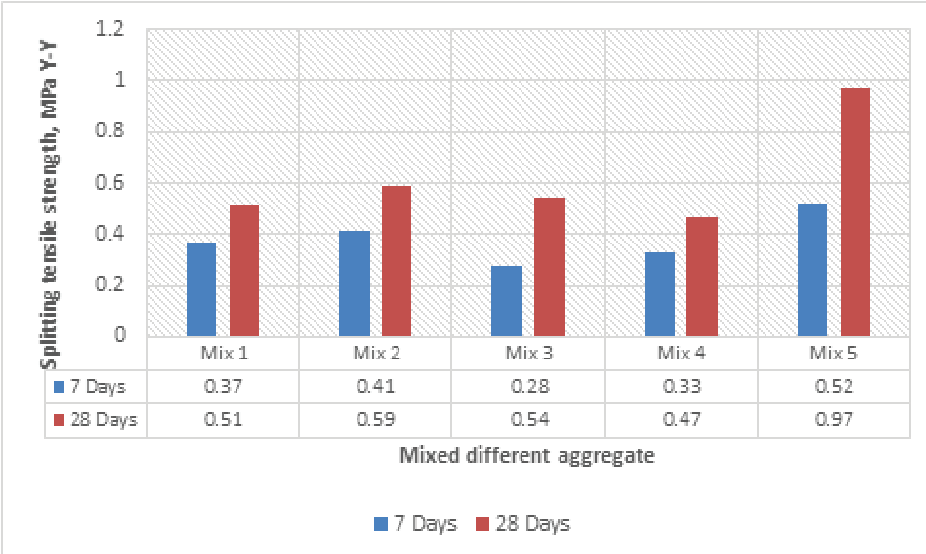


Figure 5: After 7 and 28 Days, Splitting Tensile Strength Y-Y Direction

Unit Weight

Figure 3 shows the density of hollow blocks produced using varying percentages of mixed fine aggregates. It was observed that the densities of Mix 1 and 4 are lower than that of Mix 5. It signifies that the Sylhet sand and crushed stone aggregate are lighter than gravel sand and stone dust. It is explained by the lower bulk densities of the Sylhet sand and crushed stone aggregates, which are less than gravel sand and stone dust, as shown in Table 1.

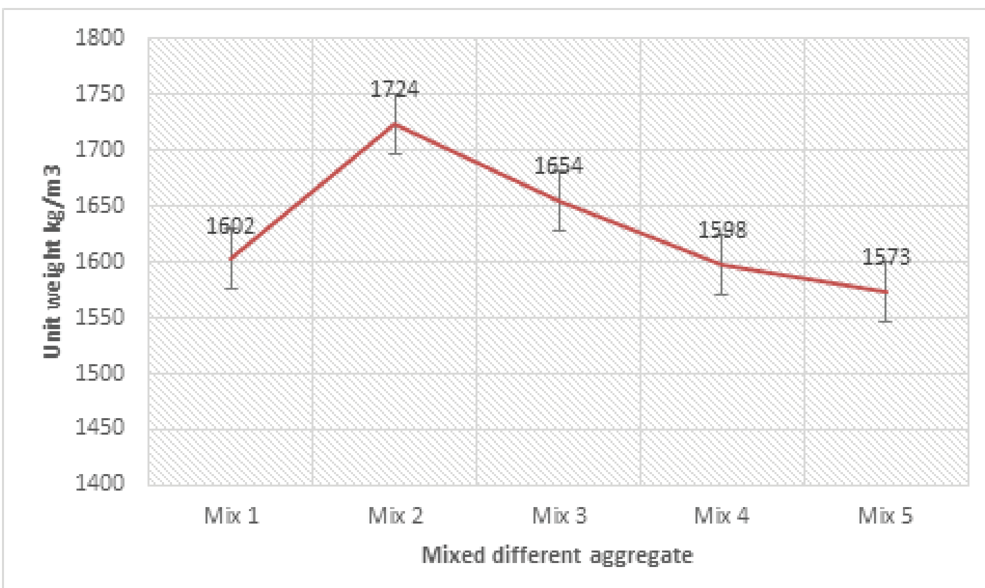


Figure 6: After 28 Days, Unit Weight

Water Absorption

The original total weight of the ingredients required to produce one hollow block is noted. After 28 days of underwater curing, the samples were oven-dried and weighed. Figure 10 shows the water absorption rate (%). The lowest result was obtained by Mix 3 of the four mixes (1, 2, 4, and 5 combined).

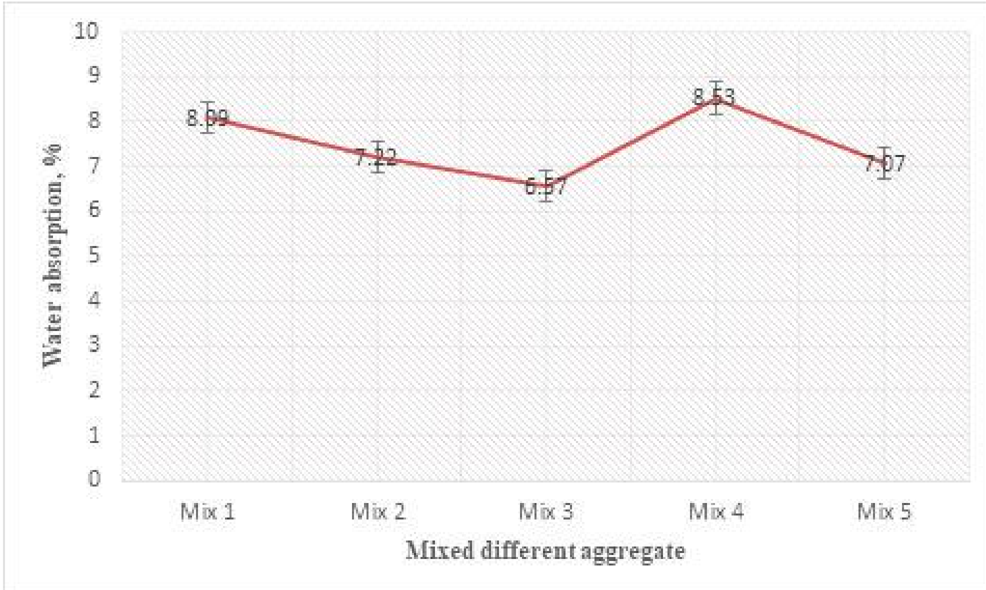


Figure 7: After 28 Days**,** Water Absorption

CONCLUSION

The research aimed to assess the feasibility of hollow block production using different aggregates as fine aggregates.

According to ASTM C 90 and ASTM C 129, the minimum compressive strength is 600 PSI for non-load-bearing walls. The minimum compressive strength is 1900 PSI for load-bearing walls; accordingly, the mix design ratio is 1: 2.5: 1: 0.50 (Cement: Gravel Sand: Stone Dust: Crushed Stone). Mix 5 is used for load-bearing walls, and Mix1, Mix2, and Mix3 are used for non-loadbearing walls, as shown in Figure 3. Cost of raw materials is the primary concern in making the hollow block cheap and affordable. Common practice is to use Sylhet sand as aggregate, which is costly. This research used different percentages of fine aggregates to reduce cement in the hollow concrete block (HCB), and it is unnecessary to use Sylhet sand as an expensive aggregate. We can get the desired compressive strength only by using different aggregates.On the other hand, this research has resulted in less use of cement.

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