MANUFACTURING SANDCRETE BLOCKS USING DIFFERENT AGGREGATES: EFFECT ON MECHANICAL PROPERTIES

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ABSTRACT

Sandcrete blocks are generated from appropriately mixed ingredients of cement, fine aggregate, and water. Sandcrete blocks are used in the construction of both load-bearing and non-load-bearing walls all over the world. This research investigates and compares the mechanical properties of natural fine aggregate (Sylhet sand) sandcrete blocks made with different fine aggregate concrete blocks. The four different types of fine aggregates used for this study were sourced from the Dharala River, Patgram, Lalmonirhat, and Someshwari Rivers in Durgapur, Bangladesh. Sandcrete blocks were manufactured using a hydraulic press machine and were constructed using mix design ratios of 1: 1: 1.33: 3.33 (Cement: Crushed sand: Stone dust: Gravel sand), 1:1:1.33:3.33 (Cement: Sylhet sand: Stone dust: Gravel sand), 1: 2: 2: 5 (Cement: Crushed sand: Stone dust: Gravel sand), 1: 5.67 (Cement: Sylhet sand) and 1: 9 (Cement: Sylhet sand) respectively, using ingredients that were batched by weight for the sandcrete blocks.Water-cement ratio was 0.37 . Different percentage amounts of fine aggregate were used in all samples used in this study, except mix design ratios of 1: 5.67 and 1: 9. The study was mix designed to test the compressive strength, unit weight, and water absorption of developed sandcrete blocks and compare it with the acceptable standard set by the Department of Public Works in Bangladesh and ASTM standards. After 28 days of water curing, the specimens were tested for unit weight, water absorption, compressive strength, tensile strength. The dimension of the specimens was selected as 241 mm x 114 mm x 70 mm. After 28 days of water curing the specimens were tested for unit weight, water absorption, compressive strength, tensile strength and direct tensile strength. The results revealed that sandcrete blocks produced with different fine aggregates from the Dharala River, Patgram, Lalmonirhat, and Someshwari Rivers give compressive strengths of 28.67 MPa, 28.98 MPa, 21.50 MPa, 34.85 MPa, and 19.93 MPa at 28 days, respectively. Therefore the study concluded that different aggregates used in sandcrete blocks production are suitable and do not affect the quality or strength of the blocks.

Keywords: *Sandcrete blocks, compressive strength, tensile strength, water absorption and unit weight.*

INTRODUCTION

The Bangladeshi Public Works Department (PWD) Civil works-2022 described sandcrete block as constructional material comprising of cement, sand and water made into different sizes. A sandcrete block is a building unit made from Ordinary Portland Cement (OPC) and Portland Composite Cement (PCC), sharp sand from rivers and streams, and water from streams, rivers, or wells, mixed together in the appropriate proportions and molded into various shapes and sizes (Barry, 1958). According to Public Works Department (PWD) Schedule- 2022 sandcrete blocks can either be solid or hollow rectangular types with 241mm × 114mm × 70mm and 390mm × 190mm × 90mm being the most common sizes. ASTM C 90 and ASTM C 129 specified there are two types of blocks: type A blocks, which is load bearing, and type B blocks, which is non-load bearing. Sandcrete blocks are cost-effective construction materials that offer excellent resistance to damage without protection devices. They are environmentally friendly and do not decay, rust, or attract harmful insects like other materials. They do not contain harmful materials (Odeyemi, 2012). Large cities of Bangladesh, including Dhaka, are experiencing excessive air pollution during the dry season because of dust from unplanned and uncontrolled construction activities, pollution from brick kilns, black smoke from vehicles, and the burning of municipal waste. On November 24, 2019, the government issued a gazette notification to gradually use 100% eco-friendly blocks in all government construction works by 2025. As a result, people are gradually becoming interested in building eco-friendly houses due to the various advantages of eco-friendly eco-blocks and the responsibility of preventing environmental damage caused by conventional brick kilns. Due to increasing urbanization, a lot of concrete buildings are being constructed all over the country. Considering the overall convenience, people are now building brick-cement houses instead of wood and tin houses. As a result, the demand for bricks has increased. In Bangladesh, bricks are usually prepared by burning the top soil layer. Due to this, the environment is being damaged in many ways. Firstly, the amount of agricultural land in this country is already insufficient. This land is further shrinking for brick kilns. The land adjacent to the brick kiln is also losing its fertility. Secondly, forest resources are being destroyed due to brick burning. Trees are being cut for burning in brick kilns. Thirdly, toxic fumes emitted from brick kilns are polluting the air and threatening public health (source Prothom Alo news paper).

Recently, the construction industry in Bangladesh has witnessed a high level of criticism regarding the use of sandcrete blocks and debates on building issues. This issue is compounded by poor-quality building materials and construction methods (Olufisayo, 2013). Many contractors and engineers follow the permissible standards outlined in the American Code, the Department of Public Works (PWD) Schedule, and the Housing and Building Research Institute (HBRI) Code, but others violate it mainly to maximize their business profits by using inferior quality materials for such construction projects. As much as the use of economical materials is important in construction projects, it remains the most important structure for safety.

Sandcrete blocks have been manufactured for building construction in Bangladesh for many days. In Bangladesh, conventional bricks were the most common type of masonry building. As a result of the government's ban on burnt clay bricks, sandcrete blocks will be used instead for most common and partition wall applications.

In Bangladesh, many block factories use aggregates for making sandcrete blocks without considering the origin, features, and quality of the aggregates. In any process, the quality of inputs has a direct impact on product quality; therefore, this is the result of habit building and cracks are occurring in the walls of the structures which are threatening to our future. It will be discouraged that clients use the blocks if they are not made according to their guidelines.

It is a very simple manufacturing process that does not require highly skilled labor. The goal of this study was to develop sandcrete blocks from different aggregates using PCC cement. Research has been conducted on properties such as unit weight, water absorption, split tensile strength and compressive strength. The cost of sandcrete blocks made from Sylhet sand compared to sandcrete blocks made from mixed aggregate has also been examined.

MATERIALS AND METHODS

2.1 Cement

The sandcrete blocks were mixed and produced using 42.5 N-type Portland Composite Cement (PCC), a good-condition, ASTM C 150/ C150M CEM II/B-M-produced binding material. Physical properties were tested according to ASTM C187 (2011a) for normal consistency, ASTM C191 (2013a) for initial and final setting time, ASTM C188 for specific gravity and d ASTM C109 (2013b) for compressive strengths are given in Table 2 here.

2.2 Fine Aggregate

Local Sylhet sands and Gravel sand, Crushed stone, Stone dust were used as fine aggregates for the present study as shown figure 1. Sylhet sands was collected from Someshwari rivers, Durgapur, Netrokona and Gravel sand, Crushed stone, Stone dust from from the Dharala river, Patgram, Lalmonirhat, Bangladesh. Gravel sand, Crushed stone and Stone dust are mainly used in many constructions, as well as road carpeting and concrete products such as sandcrete block and pavers. These days the demand for sandcrete block factories which are made of concrete instead of bricks in building construction has increased more than ever. Because it is used as one of the main materials in concrete block factories to make sandcrete block products. As per ASTM standards, its gradation, specific gravity, and absorption capacity were determined by following ASTM C128 (2015) and ASTM C136 (2014). In Table 1, the physical properties of the sand are listed, while Figure 2 illustrates the gradation of the sand along with the ASTM upper and lower limits.

2.3 Water

In this study, drinking water has been used to mix concrete supplied from the Housing & Building Research Institute (HBRI) deep tube well and is known to have no unusual impurities conforming to BDS ISO 12439:2011.

Figure 1: Different types Aggregates: (a) Sylhet Sand, (b) Stone dust, (c) Gravel sand, (d) Crushed stone .

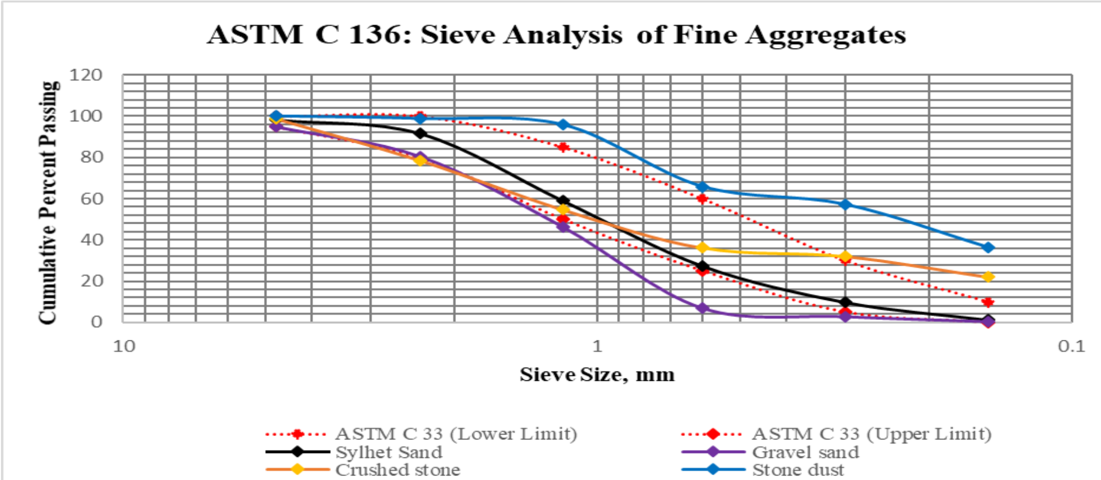

Figure 2: Particle size distributions of different aggregates

Table 1 Physical properties of fine 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/m3	1625 kg/m3	1480 kg/m3	1365 kg/m3

2.4 Preparation of Sandcrete Block

Sandcrete blocks were made in a Hydraulic press machine. The usual size of blocks was cast in size (241 x 114 x 70) mm for solid block. Composition of block is four different sand, Cement (PCC) ratios of 1: 1: 1.33: 3.33 (Cement: Crushed sand: Stone dust: Gravel sand), 1:1:1.33:3.33 (Cement: Sylhet sand: Stone dust: Gravel sand), 1: 2: 2: 5 (Cement: Crushed sand: Stone dust: Gravel sand), 1: 5.67 (Cement: Sylhet sand) and 1: 9 (Cement: Sylhet sand) by weight. The water cement ratio was 0.37. Preparation of Sandcrete blocks consists of the following steps: i) mixing of the ingredients (four different aggregate as sand, cement, water) in pan and then placement of materials in the molds, ii) hydraulic compaction of mixture in molds and iii) finally, demolding the specimen and drying for internal curing. A large number of sandcrete block specimens were prepared for compressive strength (ASTM C-140), water absorption (ASTM C-140) and density (ASTM C-140) and split tensile strength (ASTM C 1006-13).

Table 2: Physical properties of cement

Physical Properties	Test Results	Standard Method	Standard Requirements, ASTM 595-12
Normal Consistency, %	25.64	ASTM C 187	
Initial Setting Time, minutes	151	ASTM C 191	Not less than 45 minutes
Final Setting Time, minutes	229	ASTM C 191	Not more than 420 minutes
Specific Gravity, gm/cm3	3.13	ASTM C 188	
	Test Results (MPa)	Period (Days)	Standard Requirements, Minimum: ASTM 595-12
Compressive Strength	18.95	3	13.0 MPa
	23.25	7	20.0 MPa
	28.96	28	28.0 MPa

2.5 Mix Design

For sandcrete block, the mix design ratio for 1: 1: 1.33: 3.33 (Cement: Crushed sand: Stone dust: Gravel sand), 1:1:1.33:3.33 (Cement: Sylhet sand: Stone dust: Gravel sand), 1: 2: 2: 5 (Cement: Crushed sand: Stone dust: Gravel sand), 1: 5.67 (Cement: Sylhet sand) and 1: 9 (Cement: Sylhet sand) respectively with water cement (w/c) ratio of 0.37. The mixture proportions of the mortar mixes for (241mm by 114mm by 70mm) cube are summarized in Table 3.

Table 3: Different Mixes of Sandcrete Blocks

Mix No	Materials	Ratio	Percentages (%)	Quantity (kg)
Mix 0	Cement	1:1:1.33:3.33	15	37.50
	Crushed sand		15	37.50
	Stone dust		20	50
	Gravel sand		50	125
Mix 1	Cement	1:1:1.33:3.33	15	37.50
	Sylhet sand		15	37.50
	Stone dust		20	50
	Gravel sand		50	125
Mix 2	Cement	1: 2: 2: 5	10	25
	Crushed sand		20	25
	Stone dust		20	50
	Gravel sand		50	125
Mix 3	Cement	1: 5.67	15	15
	Sylhet sand		85	85
Mix 4	Cement	1: 9	10	10
	Sylhet sand		90	90

2.1 SANDCRETE BLOCKS TESTING

2.1.1 Compressive Strength of Sandcrete Blocks

Crushing tests were conducted on sandcrete solid blocks with a 2000KN capacity, compressive testing machine according to BS EN 12390-3 (2002) for the different curing periods of 7 and 28 days. Moreover, it is also the average compressive strength of 3 blocks, with each block's value not less than 10% of the average according to the Bangladesh National Building Code (BNBC-2020). It is expressed mathematically as

$$\text{Crushing Strength} = \frac{\text{Failure load (KN)}}{\text{Loaded area (mm2)}}$$

2.1.2 Unit Weight of Sandcrete Blocks

Density is defined as the number of particles packed in a given area of an element or material. Generally, the more tightly packed the particles, the higher the density of the material. The higher the level, the greater the degree of compaction. The mass of the masonry unit divided by the dimensional volume is expressed mathematically as

$$\text{Unit weight, (kg/m}^3\text{)} = \frac{\text{mass of block (kg)}}{\text{dimensional volume of block (m3)}}$$

2.1.3 Water Absorption of Sandcrete Blocks

A sample of each research block, whose weight was noted in the dry state, was then fully immersed in water. The time required for full immersion was noted, and 24-hour period was allowed to elapse. After the 24 hours, the wet block samples were the removed and weighed. The difference between the dry and wet weights of each block was the calculated by subtracting the dry weight from the wet weight. It is expressed mathematically as

$$\text{Water absorption, (kg/m}^3\text{)} = \frac{\text{mass of saturated block (kg)} - \text{mass of dry block (kg)}}{\text{volume of block (m3)}}$$

The ASTM C140 (Testing & Materials, 2005) recommended maximum water absorption capacity of 240 kg/m3.

2.1.4 Split Tensile Strength of Sandcrete Blocks

In this work, the splitting test was carried out applying the ASTM – C-1006-13 standard. The tests were performed in different directions:

For blocks with all mixes, sandcrete blocks in the X and Y direction were tested. It is expressed mathematically as

$$\text{Split tensile strength, T} = \frac{2P}{\pi HL}$$

Where,
T = splitting tensile strength, psi (MPa),
P = maximum applied load indicated by the testing machine, ton,
L = split length, in. (mm),
and
H = distance between rods, in. (mm).

RESULTS AND DISCUSSION

3.1 Specific Gravity and Particle Size Distribution Tests

The specific gravity of the fine aggregates (Sylhet Sand, Gravel sand, Crushed Stone and Stone Dust) used for the production of the sandcrete blocks are: 2.40, 2.32, 2.63 and 2.72 respectively. The results of the specific gravity for the four fine aggregates fall within the range; 2.30 –2.90 suitable for sandcrete block production as prescribed by the ACI Education Bulletin from 2007 and reported by (Odeyemi et al., 2019). The coefficient of uniformity and coefficient of curvature obtained from the particle size distribution for the four fine aggregates are shown in Table 4. The well graded soils as they met the conditions ($Cu \geq 6$ and $1 < Cc \geq 3$) for well graded soils reported by (Terzaghi et al., 1996); (Neville, 1995); (Shetty & Jain, 2019). On the other hand Sylhet Sand, Gravel sand, Crushed Stone and Stone Dust were not satisfying requirements hence, it is poorly graded sand**.**

Table 4: Coefficient of uniformity and Coefficient of curvature of the different aggregates

SL	Different Aggregates	Coefficient of Uniformity (Cu)	Coefficient of Curvature (Cc)
1	Sylhet Sand	3.96	1.15
2	Pea Gravel	5.99	31.30
3	Crushed Stone	-1.64	-77.88
4	Stone Dust	-9.59	-3.99

3.2 Compressive Strength of Sandcrete Blocks

Testing the compressive strength of sandcrete blocks is used to determine the quality of the material. The compressive strength of sandcrete blocks with all mixes was determined at 7 and 28 days. 7 and 28 each days, three samples per combination were tested and their average was calculated. Compressive strength results are presented in Figure 5 for all mixes of sandcrete blocks. As shown in the figure test result indicate that sandcrete blocks have a compressive strength that ranges between 19.78 and 34.85 MPa of Mix 4 and Mix 3. The statistical analysis shows that the significant decrease in the compressive strength results due to the mixed different aggregate of material, compared with the mix 3. ASTM C 90 sets a minimum criterion of 13.1 MPa, as an average of three specimens, or 11.7 MPa for individual specimen tests and Department of Public Works (PWD) schedule for 2022 a minimum strength 15 MPa for load bearing wall. But as shown in the figure all the specimens have compressive strength greater than 19.78 MPa at 28 days of age satisfied the ASTM C 90 and Department of Public Works (PWD) schedule Bangladesh for 2022.

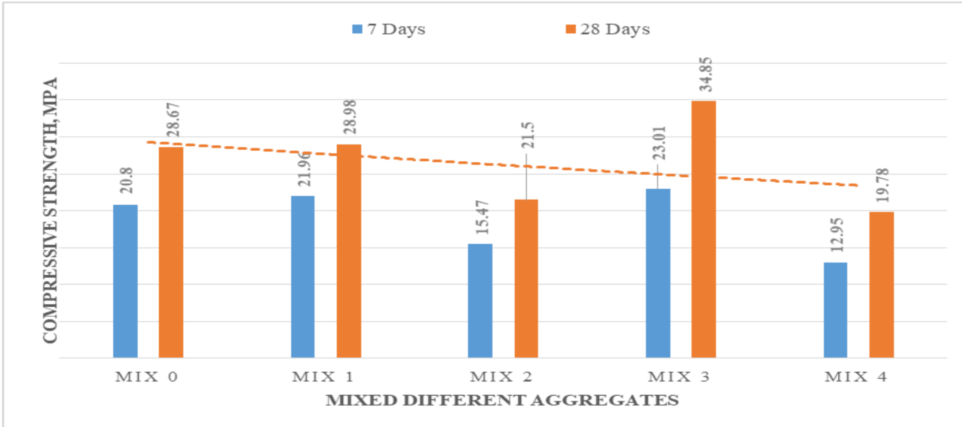

Figure 5: Variation of compressive strength with mixed different aggregates.

3.3 Split Tensile Strength of Sandcrete Blocks

Tensile strength of sandcrete blocks is determined according to (ASTM C 1006-13) for this sandcrete blocks specimen of size (241mm by 114mm by 70mm) are used. This test is conducted on Universal Testing Machine (UTM) testing machine. Figure 6 & Figure 7 gives split tensile strength, (X-X and Y-Y) direction test results respectively. It is noticed that the mixing of different aggregates slows down the process of strength gain. Mix 3 gives good performance than the mix for spilt tensile strength of both directions.

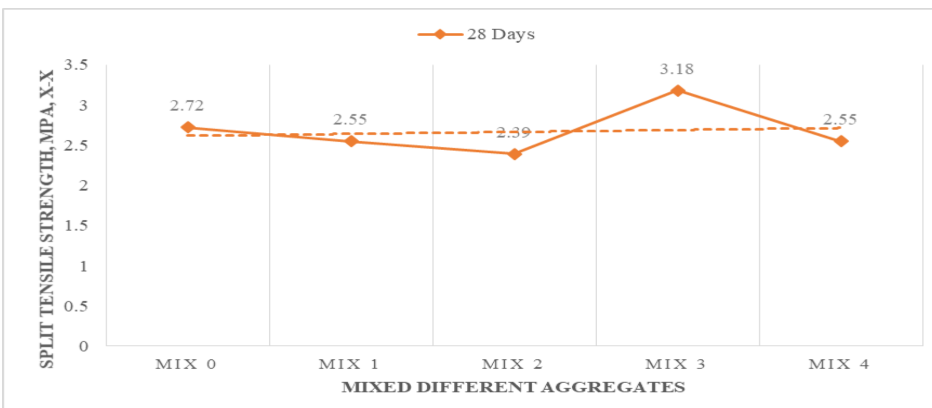

Figure 6: Variation of split tensile strength, X-X direction with mixed different aggregates

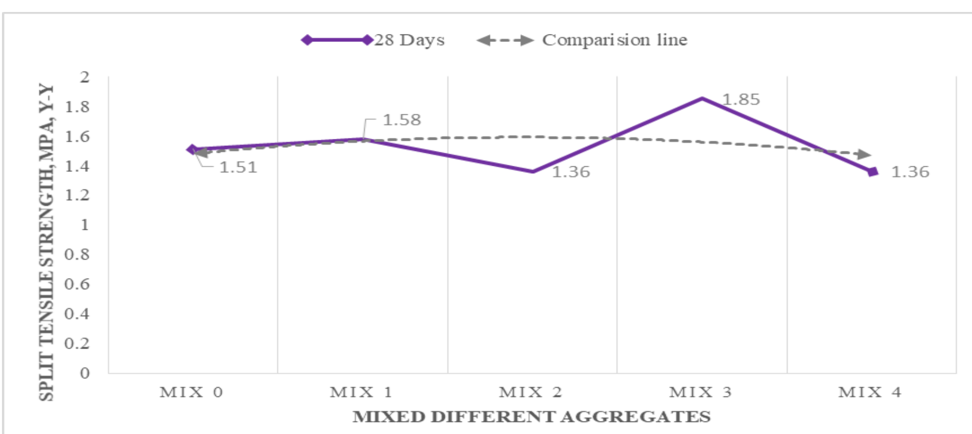

Figure 7: Variation of split tensile strength, Y-Y direction with mixed different aggregates

3.4 Water Absorption

The test results of the water absorption capacities of the sandcrete blocks samples as determined from the immersion are shown in Figure 8. The water absorption capacities for all the blocks reveals that almost all the sandcrete blocks were lower than the maximum limit recommended in ASTM C 140 of 240kg/m^3. Figure 8 illustrates the water absorption results of all mixes. The water absorption results are acceptable and way below the maximum allowed in ASTM C 140.

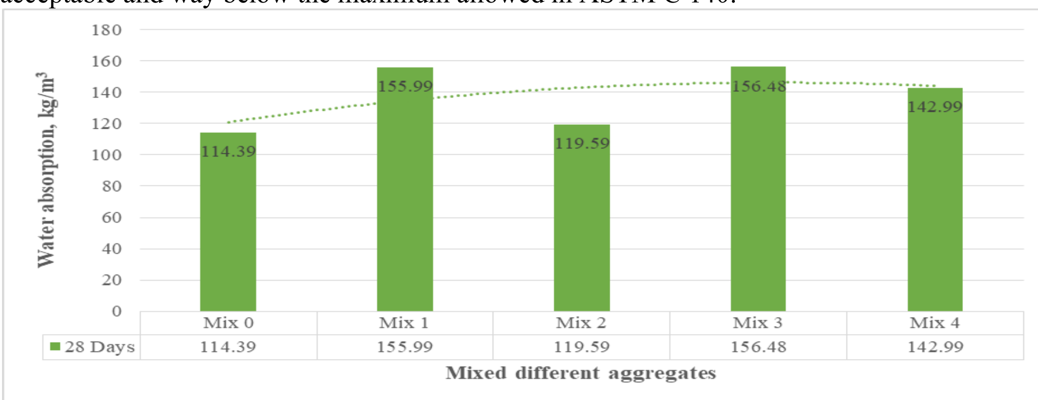

Figure 8: Variation of water absorption with mixed different aggregates

3.5 Unit Weight

ASTM C 90 and C 129 set minimum criteria for the oven-dry density of sandcrete blocks Accordingly, the oven-dry density ranges are below 1680, 1680 to 2000, and more than 2000 Kg/m^3 for light, medium, and normal weight sandcrete blocks, respectively. Thus, although the local blocks are used for non-bearing load applications, they can be considered as normal weight blocks instead of lightweight blocks, refer to Figure 8.

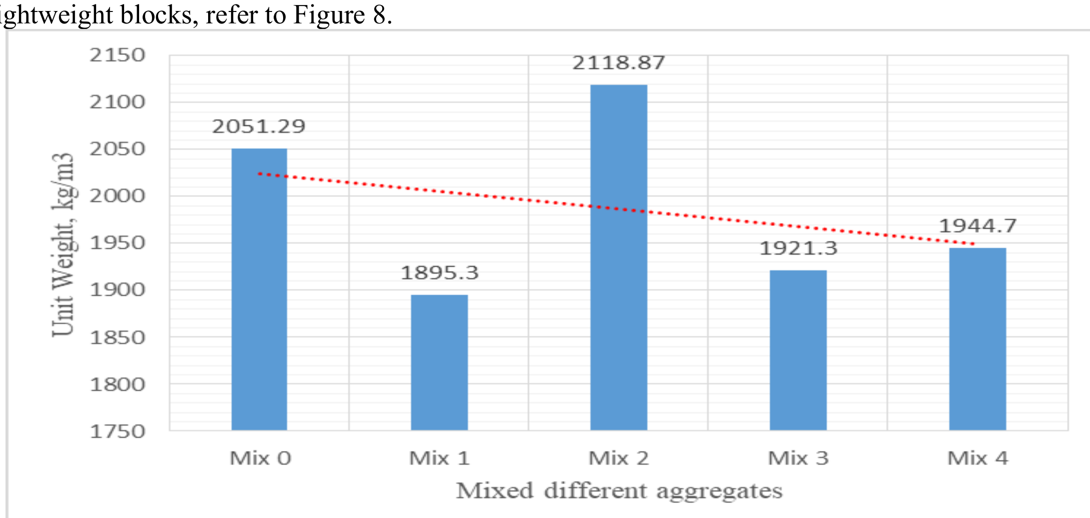

Figure 8: Variation of unit weight with mixed different aggregates

3.6 Cost Analysis of Sandcrete Blocks

The estimated cost of sandcrete blocks has been shown in Table 5. It has been found that, for each different aggregate, the cost per block at 1:1:1.33:3.33 mix proportions is higher (Tk. 11.02), and that of at 1: 9 is lower (Tk. 5.22). Among the four mixed different aggregates made sandcrete blocks with

1: 9 mix proportions were found to be the best combination in terms of unit weight, water absorption, strength and cost in this study.

Table 5: Cost of sandcrete blocks

Mix No	Materials	Ratio	Percentages (%)	Cost per block (Tk)
Mix 0	Cement Crushed sand Stone dust Gravel sand	1:1:1.33:3.33	15 15 20 50	11.02
Mix 1	Cement Sylhet sand Stone dust Gravel sand	1:1:1.33:3.33	15 15 20 50	10.52
Mix 2	Cement Crushed sand Stone dust Gravel sand	1: 2: 2: 5	10 20 20 50	9.17
Mix 3	Cement Sylhet sand	1: 5.67	15 85	7.84
Mix 4	Cement Sylhet sand	1: 9	10 90	5.22

CONCLUSIONS

The observation made in this study on compressive strength, split tensile strength, unit weight, water absorption and finally cost estimation of sandcrete blocks from mixed different aggregates with various mix proportions is quite promising.

- This study aimed to the effect of different aggregates sand on the quality of sandcrete blocks produced and their strength. The researchers obtained these findings based on the present experimental results: the results revealed that sandcrete blocks produced with different fine aggregates from the Dharala River, Lalmonirhat, and Someshwari River, Netrokona, Bangladesh, give compressive strengths of 28.67 MPa, 28.98 MPa, 21.50 MPa, 34.85 MPa, and 19.93 MPa at 28 days, reached the compressive strength criterion of the Department of Public Works (PWD). It is true that Mix 3 and Mix 4 are cheaper than Mix 1, Mix 2, and Mix 3, but Sylhet sand is not suitable for the production of proper sandcrete blocks. Generally, Sylhet sand is used in concrete work. As a result, Mix 2 may be the most appropriate ratio for producing sandcrete blocks given the cost consideration. Therefore the study concluded that different aggregates used in sandcrete blocks production are suitable and do not affect the quality or strength of the blocks.
- The study suggested that further research could be conducted on the sand must be tested to be of the appropriate quality (slit and organic contents) before being used to produce sandcrete blocks.
- The study indicated that the compressive strength, unit weight, and water absorption of sandcrete blocks mixed with different aggregates were comparable with the Department of Public Works (PWD) schedule Bangladesh for 2022 and ASTM standards.

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