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Comparative Study on the Strength of Cement-Sand-Gravel Blocks Prepared at Different Proportions

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Abstract— Cement-sand-gravel blocks were constructed at the Concrete and Materials Testing Laboratory in the Department of Farm Structure and Environmental Engineering, Bangladesh Agricultural University, Mymensingh. Local sand having a fineness modulus (F.M) of 1.44, ordinary Portland cement, and gravel stone having a fineness modulus (F.M) of 4.96 were used. For each block, three different proportions of cement, sand, and gravel were selected i.e., 1:2:4, 1:2:6, and 1:2:8. The dimension of the specimens was selected as 10" x 5"x 3" (length, width, and height) after 60 days of water curing the specimens were tested for unit weight, density, water absorption, and compressive strength. The test results showed that the unit weight and density are high for the proportion of 1:2:4 and low for the proportion of 1:2: 8. The water absorption for the proportion of 1:2:8 is more than others. For all types of blocks, compressive strength is more at 1:2:4, medium at 1:2:6, and less at 1:2:8. The cost for the proportion of 1:2:4 is more than others. It was also revealed that the cement-sand-gravel block at 1:2:6 proportion shows the best combination in terms of unit weight, density, water absorption, compressive strength, and unit cost.

Keywords— sand, cement, gravel blocks, strength

I. INTRODUCTION

Bangladesh is a developing country. Every stage of development results in a lifestyle change. Our country's population is increasing daily. Even though our country is becoming more populous, we continue to make great efforts to meet their five fundamental needs—food, clothing, shelter, and health care so they can enjoy better lives. As a result, we need to create more homes and other types of infrastructure to sustain their way of life. Again, to construct these structures, we need to use affordable, readily available materials. Bricks rank as the most important of these building materials. Both urban and rural areas of Bangladesh suffer from a serious dearth of permanent housing. This shortage is getting worse as a result of the relatively high cost of permanent construction supplies. The poorest residents of the neighborhood are most impacted by this housing shortage. Due to a severe shortage of supply and an enormous rise in demand, the price of construction materials is increasing every day. Finding affordable building supplies is currently becoming an important necessity. The soil has been utilized as a building material for countless years. Architecture made of dried earth is very common in some areas of the world and is commonly considered as being both aesthetically beautiful and suitable for the local environment and economic conditions. Traditional homes, which are still common in many parts of the world, are evidence that raw earth has been used to build houses ever since history began to be written down. It was neglected and abandoned when industrial building materials, particularly concrete and steel, were developed. Both developed and developing countries are rekindling their interest in this subject. Although previously criticized for its sensitivity to moisture and lack of toughness, this building material currently provides several advantages for the construction of enduring, comfortable, and economical dwellings. Between 1995 and 2005, the brick sector is expected to increase at a pace of 1-2 percent, which is consistent with the growth rate of the construction industry, which uses brick as its principal building material. According to BUET 2007, Bangladesh produces 17.2 billion burnt clay bricks annually, with an output value of Tk. 83 billion. Bangladesh's brick industry is significant, with over 1 million workers and 5,000 active kilns (The World Bank, ESMAP-2011). It makes up about 1% of the country's GDP. 45 million tons of clay, 3.5 million tons of coal, and 2 million tons of firewood are utilized to make these massive amounts of clay bricks. The fixed Chimney Kiln (FCK), which consumes a lot of energy and produces a lot of pollution, dominates the brick business in Bangladesh. 100 000 bricks are produced in the majority of operational kilns using 18–22 tons of coal (BUET 2007). Burning coal in kilns results in pollutants that harm agricultural productivity and human health while hastening climate change and global warming. Clay is also extracted from agricultural soil. Unplanned brickfields and the removal of clay from topsoil, according to a study, result in the annual loss of 42000 acres of agricultural land. If these processes continue, the safety of our food supply may soon be in danger. According to the aforementioned viewpoint, sand, cement, and gravel stone blocks are green building materials. In both pre-urban and urban environments, the blocks, which are made from local sand, are a common building material and are increasingly employed as the main walling material in these regions In a wide sense, "Sand-Cement-Gravel Stone Block" refers to a variety of building materials. In this context, a sand-cement building block is created by compressing a loose mixture of sand, cement, water, and gravel into a dense block. The block should have higher durability, dimensional stability when wet, and increased compressive strength. Thomas and Gooding (1995). This paper has discussed the manufacturing of building blocks from local sand in various quantities and their comparison. The physical properties, strength properties, and manufacturing costs of sand-cement-gravel blocks are all tested in this study. Here, regular Portland cement was chosen since it is widely accessible throughout Bangladesh, and local sand (F.M=1.44) was employed. Gravel and sand were combined in a variety of ratios, including 1:2:4, 1:2:6, and 1: 2:8. Utilizing a mold, three different types of blocks with dimensions of 10" x 5"x 3" (length, width, and height) were created. At 60 days old, the blocks were put to the test.

Objectives:

This study has two primary objectives. First, it seeks to conduct a comprehensive analysis of the physical properties of cement-sand-gravel blocks with varying proportions. Specifically, we will compare unit weight, density, and water absorption characteristics across these different mixtures. Secondly, our research aims to evaluate the compressive strength of cement-sand-gravel blocks with varying ratios. The findings from this study will provide valuable insights for construction professionals and engineers, assisting them in selecting the most suitable block proportions for specific projects based on their intended use and performance requirements.

II. MATERIALS AND METHODS

The materials

The basic materials for the construction of sand-cement-gravel blocks are local sands, cement, gravel, and water. A brief description of the materials used for sand-cement-gravel block construction is given below:

Cement

Cement is a hydraulic binder used to combine elements such as sand and gravel. It is made from calcareous materials and is comparable to very hydraulic limes in many ways, but it has been processed to have more hydraulic qualities (Kumar,1991). Throughout this experiment, ordinary Portland cement (Brand: Primer) was used. The cement appeared to be uniformly gray in color and free of lumps. Sand-cement-gravel blocks were constructed using regular Portland cement (Type-1), which passed an ASTM 300-micron sieve.

Sand

Sand is a crucial component of engineering construction since it is a useful engineering material. It is typically referred to as a fine aggregate in concrete work. According to its composition, sand, which is a type of silica (quarts), can be calcareous, argillaceous, or siliceous (Aziz, 1995). The sand grains could be spherical, angular, or pointed. In the Mymensingh district, there is river sand of the highest grade (Sarwar, 2005). For block formation, relatively coarse sand with a fineness modulus of 1.44 was used from a nearby river.

Water

To create adhesion, water is applied to the aggregate's surface. It is used to mix various materials into a plastic substance and is also required for the hydration of cementing material so that it will set and harden during the curing process. In this experiment, the concrete mixture was made using tap water that was provided. It was spotless and devoid of any dirt. It didn't seem to contain any oil, alkalis, acids, organic stuff from the earth or anything else that could be harmful.

Gravel stone

Natural gravel is gathered from quarries, created from crushed stones, or taken from riverbeds. River gravel, which is spherical and polished, is preferred to crushed gravel for construction. Only concrete is made with gravel (Dad, 1990). According to the construction's thickness and the preferred type of reinforcement concrete, different gravel sizes must be employed (Rahman, 1990). ACF suggests using gravel between the sizes of 6 and 25 mm to produce watertight concrete. In general, gravel size for concrete construction must be less than 1/5 of the construction's thickness. To achieve the desired granulometry, river gravel must be sieved (Remi, 2008).

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III. METHOD OF BLOCK CONSTRUCTION

Any engineering construction requires a skilled and experienced person and easily available construction materials at the construction site or near it. The quality of construction should be maintained. In the case of sand-cement-gravel block formation, the steps were-

- Mixing cement, sand, and gravel stone in the right proportion
- Formation of block
- Curing

A general description of these steps for block construction is given below-

Mixing cement, sand, and gravel stone in the right proportion

The proper proportions of cement, sand, and gravel should first be mixed. As a coarse aggregate, we used sand and gathered gravel, and as a fine aggregate, we used Primer Portland composite cement. Sand, gravel, and cement were distributed in the following ratios: 1:2:4, 1:2:6, and 1:2:8. Before spreading cement on top of the sand, the sand was thoroughly sieved and spread to a consistent thickness on a non-porous surface (i.e., tray). To create a dry mix, cement, sand, and gravel were thoroughly combined until the color was consistent. Half of the calculated amount of water (10% of the concrete's weight) was added to the dry mix. The concrete was finally prepared to form blocks.

Formation of block

At first, a concrete mixture of specific proportions (say 1:2:4) was poured into the wooden mold, which was placed on a polythene sheet and the concrete was compacted very carefully and thoroughly. The mold's top was leveled using a wooden float. The mold with the concrete inside is then carefully pulled up and set outside down to prevent breaking or cracking of the block's corners or edges. Finally, blocks were created for three ratios (1:2:4, 1:2:6, and 1:2:8).

Figure 1. *Freshly made cement-sand-gravel blocks.*

Curing

It is crucial to get good-quality hardened concrete curing in an appropriate setting (Pranama, 2010). Curing, often known as the process of encouraging the hydration of cement, involves controlling temperature and the transfer of moisture from one into the mortar or concrete. Concrete gains strength through proper curing (Minapu, 2006). The block was taken out of the molds a day after casting. The blocks were covered with jute sacks throughout the curing process. By using water, the blocks had been kept in this wet state for 60 days. Relative humidity and room temperature were adjusted to 28–30°C and 87–95%, respectively.

Figure 2. *Curing of cement-sand-gravel blocks by gunny bag*

IV. TESTING OF SAND-CEMENT-GRAVEL BLOCKS

The blocks were tested for: (1) unit weight (2) Density (3) Water absorption (4) Compressive strength. These tests were conducted in the Concrete and Materials Testing Laboratory of the Department of Farm Structure and Environment Engineering, Bangladesh Agricultural University.

Unit weight

Each sand-cement-gravel blocks weight was initially determined by a balance. We carefully calculated the value. The unit of weight is the pound (lb.). The average unit weight was computed for every cement: sand: gravel ratio.

Density

The density of a block is determined by diving the total weight of a block by total volume. At first each block was measured by a balance. Then the density was measured by using the following expression:

Density = weight/ volume

Here,

The volume of solid block=10″×5″×3″=150in3

= 0.002458 m3

So, density of block = Weight/0.002458 (kg/m3)

For each proportion of cement: sand: and gravel the average density of the block was calculated.

Water absorption

To determine water absorption, a 24-hour immersion test in cold water is done. Dry block specimen is placed in an oven that keeps the temperature between 1050C and 1500C till it reaches consistent mass (Roy, 1993). After the specimen (W1) was cooled to room temperature, its weight was recorded. The dry specimen was subsequently fully submerged in water for 24 hours at a temperature of 27.2°C (Saradhi, 2015). The specimen was then removed from the water, and a damp cloth was used to remove all of the surface moisture. Within three minutes of being removed from the water, the specimen was weighed. Weight (W2) was the name given to this weight. The connection is used to compute the water absorption percentage by mass following a 24-hour submersion in cold water.

$$\text{Water absorption}(\%) = \frac{W2 - W1}{W1} x100$$

Where,

W1= Initial weight (kg)

W2= Final weight (kg)

Figure 3. *Blocks were immersed in water*

Compressive strength

The block was put in a universal testing machine for compressive strength after 60 days of casting. The rate of applying loads was constant. The highest load that was applied was noted. The compressive strength was obtained by the following equation:

Compressive strength = P/ Average Area

Where,

P= Ultimate compressive load for which the block was crushed (kg)

An area of loading surface (m2)

Here, Loading surface area for block= 10 × 5 = 50 m2

So, Compressive strength of block = P/50 (kg/m2)

Figure 4. *Compressive strength test of blocks*

Cost determination

The cost was calculated based on the building of 100 blocks. For each ratio of cement: sand: gravel (1:2:4, 1:2:6, 1:2:8), the necessary amount of sand, cement, and gravel was calculated. The price of sand, cement, gravel, and labor was then added to determine the price of 100 blocks.

Total cost is calculated as follows: Sand + Cement + Gravel + Labor

V. RESULTS AND DISCUSSION

The test of gravel stone blocks for unit weight, density, water absorption, and compressive strength was conducted in the Concrete and Materials Testing Laboratory. The test results for the above tests are discussed under the following heading. The unit weight of gravel stone blocks at each proportion of cement: sand: gravel is presented in Figure 5. The average unit weight for gravel stone blocks at 1:2:4, and 1:2:6, 1:2:8 is 4.93 kg, 4.79 kg and 4.75 kg respectively.

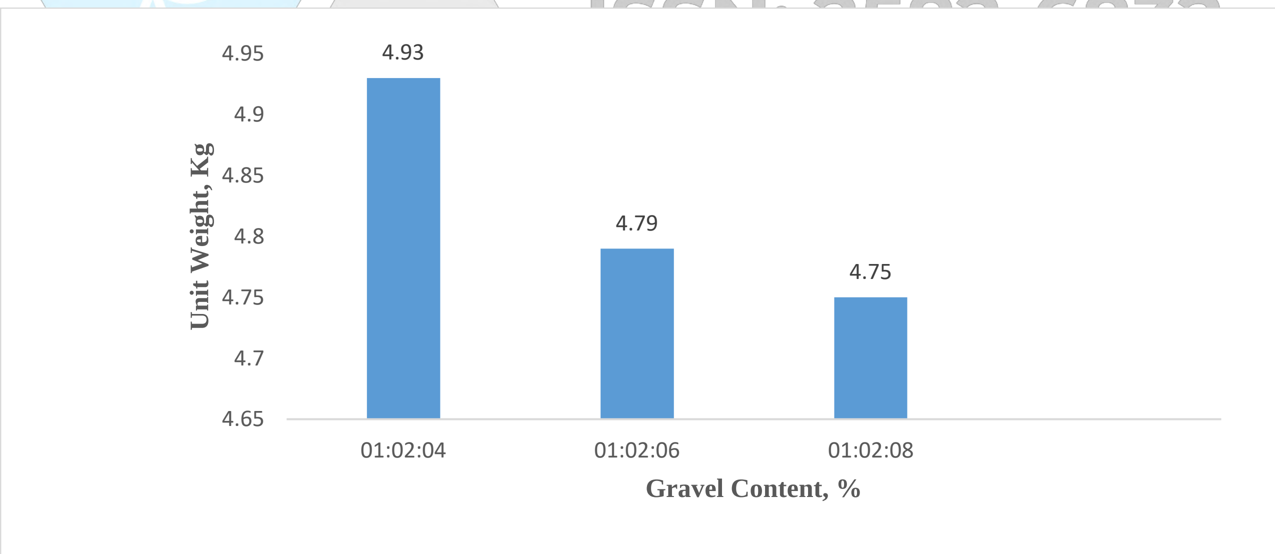

Figure 5. *Comparison of unit weight of different gravel stone blocks at different proportion*

Density

The density of gravel stone blocks at each proportion of cement: sand: gravel is presented in Figure 6. The average density for gravel blocks at 1:2:4, 1:2:6, 1:2:8 is 2018.32 kg/m3, 1968.34 kg/m3 and 1914.84 kg/m3 respectively.

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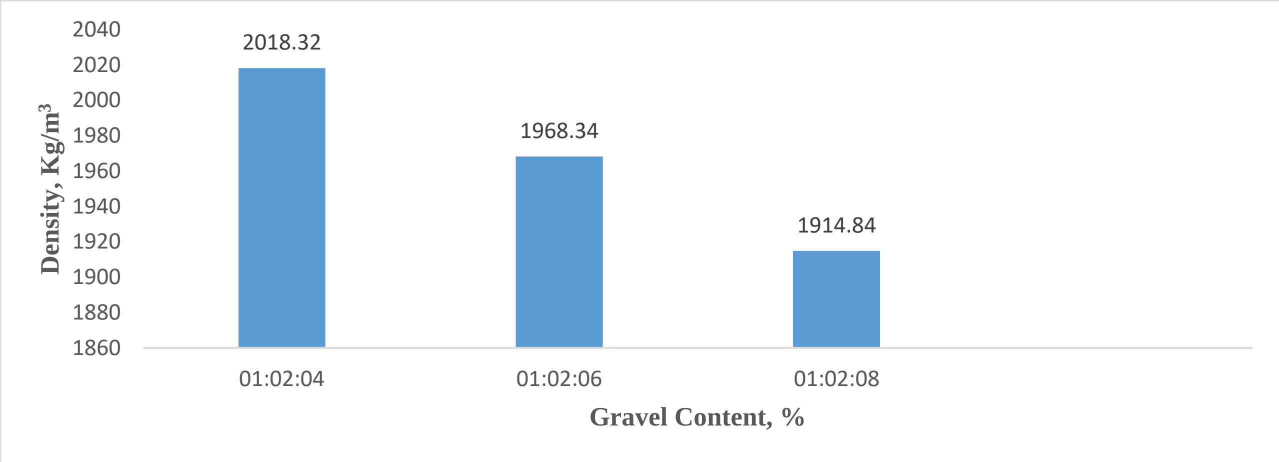

Figure 6. *Comparison of density of gravel stone blocks at different proportion*

Water absorption

The water absorption of gravel stone blocks at each proportion of cement: sand: gravel is presented in Figure 7. The average water absorption for gravel blocks at 1:2:4, 1:2:6, and 1:2:8 is 3.88%, 4.58%, and 4.92% respectively.

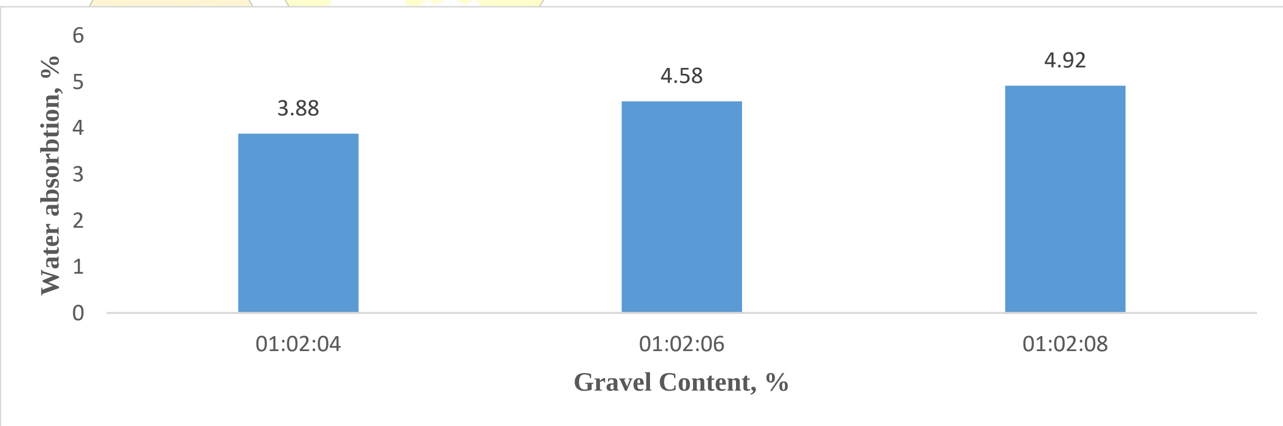

Figure 7. *Comparison of water absorption of gravel stone blocks at different proportions*

Compressive strength

The compressive strength of gravel stone blocks at each proportion of cement: sand: gravel is presented in Figure 8. The average compressive for gravel blocks at 1:2:4, 1:2:6, and 1:2:8 are 25.49 MPa, 19.77 MPa and 17 MPa respectively.

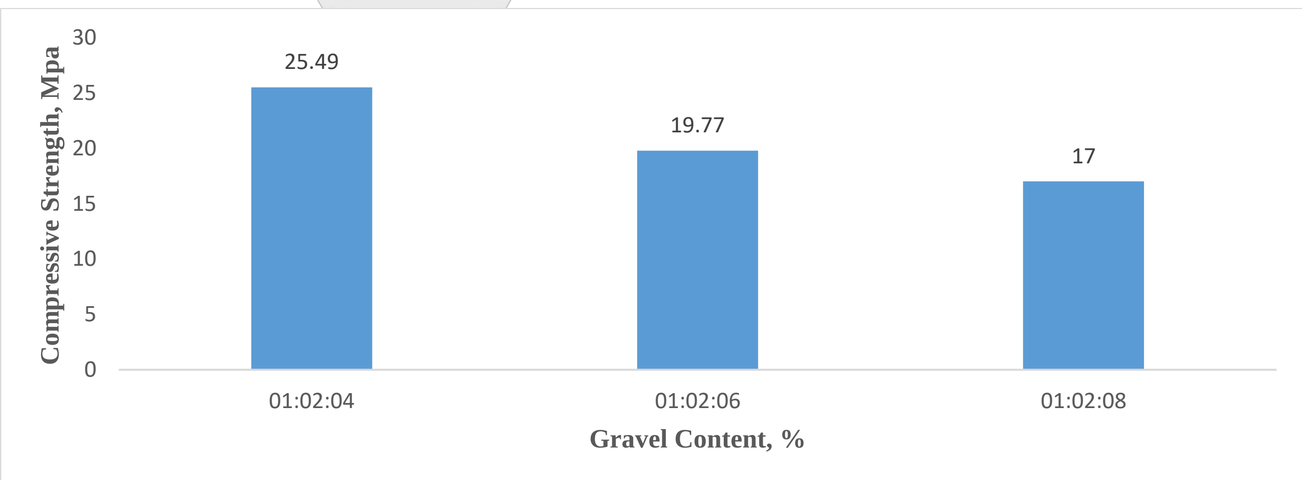

Figure 8. *Comparison of compressive strength of different gravel stone blocks at different proportion*

Cost determination

The cost of 100 gravel stone blocks at different proportions is represented in the following Figure 9. Based on 100 blocks of construction, the cost of gravel stone blocks at 1:2:4, 1:2:6, and 1:2:8 are 18 USD, 17.3 USD and 16.85 USD respectively.

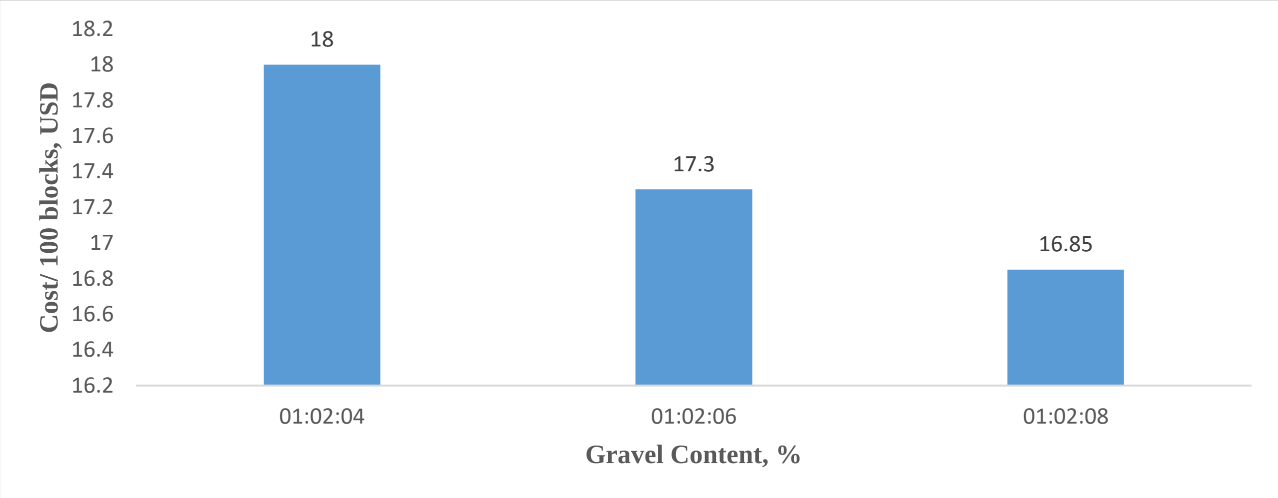

Figure 9. *Comparison of cost per 100 blocks at different proportions*

VI. DISCUSSION OF PHYSICAL TEST RESULTS

The unit weight, density, water absorption compressive strength, and cost of gravel stone blocks at each proportion are shown in Table 1.

Table 1. Combined representation of unit weight, density, water absorption, compressive strength, and cost of gravel stone blocks

Cement: sand: gravel	Unit weight (kg)	Density, (kg/m3)	Water absorption, (%)	Compressive strength, (MPa)	Cost, USD/100 blocks
1:2:4	4.93	2018.32	3.88	25.49	**18.00**
1:2:6	4.79	1968.34	4.58	19.77	**17.30**
1:2:8	**4.75**	**1914.84**	**4.92**	**17.00**	**16.85**

Table 1 reveals the unit weight of blocks at different proportions. It is clearly shown that the unit weight at 1:2:4 proportions (4.93 kg) is the highest among all. The lowest figure, is, however, obtained at 1:2:8 proportions (4.75 kg). It is seen that the unit weight at 1:2:6 proportion is close to the other. From Table 1, it is found that the density at 1:2:4 proportions (2018.32 kg/m3) is the highest among all blocks. The lowest value is obtained at 1:2:8 proportions (1914.84 kg/m3). It is seen that the water absorption at 1:2:8 proportions (4.92 %) is the highest among all blocks and the lowest value is obtained at 1:2:4 proportions (3.88%). All values of water absorption are acceptable for building blocks because a good brick does not absorb 15-20% of the water of its own weight when immersed in water for 24 hours (Aziz, 1990). In terms of the compressive strength of blocks at different proportions, from Table 1, it is clearly shown that the compressive strength at 1:2:4 proportions (25.49 MPa) is the highest among all blocks. The lowest figure is, however, obtained at 1:2:8 proportions (17 MPa). It is also shown that the compressive strength at 1:2:6 proportions (19.77 MPa) is medium among all. For each type of block, the cost of 100 blocks at 1:2:4 is higher and that of 100 blocks at 1:2:8 is lower. The cost at 1: 2:4 is the highest (18 USD) and the cost at 1:2:8 is the lowest (16.85 USD). There appears to be a good correlation between cement sand gravel proportions and the cost of blocks. The higher the proportions lower the cost. it is also seen that the cost at 1:2:8 proportions is the lowest among all other blocks.

VII. CONCLUSION

The blocks made with a proportion of 1:2:4 have a higher unit weight and density compared to the blocks made with proportions of 1:2:6 and 1:2:8. The blocks made with a proportion of 1:2:8 have the lowest unit weight and density. The water absorption of blocks for all proportions falls within acceptable limits. This indicates that the blocks have good resistance to water penetration, which is crucial for durability and preventing damage from moisture. The blocks made with a proportion of 1:2:4 exhibit the highest compressive strength, followed by the blocks made with a proportion of 1:2:6, and the blocks made with a proportion of 1:2:8 have the lowest compressive strength. The cost of construction is highest for the blocks made with a proportion of 1:2:4 and lowest for the blocks made with a proportion of 1:2:8. Based on these findings, it can be concluded that the cement-sand-gravel blocks made with a proportion of 1:2:6 exhibit the best combination of unit weight, density, water absorption, compressive strength, and unit cost. This proportion provides a balance between strength, cost-effectiveness, and other important properties.

VIII. RECOMMENDATION

The investigation conducted so far has focused on the compressive test with a single curing period due to time and scope limitations. Performing tests to analyze the strength of concrete under different curing periods will provide valuable insights into the relationship between curing time and compressive strength. Investigating the strength of concrete with different mix ratios will help us understand the impact of varying proportions of cement, sand, and gravel on the compressive strength. Exploring the heat conductivity of concrete with different mixture proportions can help assess its thermal performance. Investigation of the correlation between compressive strength and F.M. for uniform-grade sand. The discovery of a stronger correlation between compressive strength and fine aggregate grading (F.M.) for uniform-grade sand is significant. This information can be applied to improve concrete work and optimize the selection of fine aggregate in construction projects.

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