PHYSIO-MECHANICAL PROPERTIES OF AUTOCLAVED AERATED CONCRETE MASONRY UNIT

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ABSTRACT

The autoclaved aerated concrete (AAC) block is a recently introduced construction material that has recently become available in Bangladesh on a limited basis. The lightweight concrete block used in the present study is typically subjected to autoclaving to accelerate the process of achieving strength. The composition consists of a cementitious material like fly ash, diverse aggregates like dredged sand, or other sources of silica, pore formers such as aluminum powder or paste, and chemical admixtures. The blocks are commonly used in the construction of both load-bearing and non-load-bearing masonry walls. The increasing popularity of these blocks can be attributed to their environmental benefits such as their lightweight, energy-efficiency, and fire-resistance. Moreover, there are numerous constraints and factors to be taken into account in particular environmental conditions. Therefore, it is imperative to perform an investigation on the characteristics exhibited by AAC blocks produced in Bangladesh. Furthermore, there exist many considerations about the development and construction of these entities under specific environmental contexts. This study provides a summary of the results obtained from an experimental investigation conducted on AAC blocks manufactured in Bangladesh, focusing on their physico-mechanical properties. The properties investigated in the present study include the dry density, bulk density, water absorption, initial rate of absorption, compressive strength, and tensile strength of the blocks. The AAC blocks exhibited the following characteristics: the average dry density is 667 kg/m3, the moisture content is measured at 10%, the Initial Rate of Absorption (IRA) is determined to be 2.21 $kg/m^2/min$, and the compressive strength is recorded as 3.23 MPa. The results indicate that it is viable to compare the physical and mechanical characteristics of AAC Blocks' test data with global standards, as they have undergone the process of foaming.

Keywords: *AAC block, Dry Density, IRA, Compressive Strength. Modulus of Rupture.*

1. INTRODUCTION

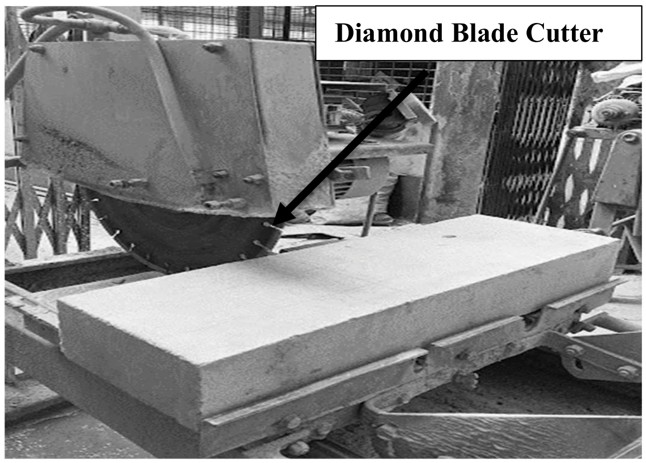
Masonry is utilized worldwide for the construction of load-bearing and partition walls. Traditionally, Bangladeshi masonry has utilized coal-burnt clay bricks. The nation produces 32.4 billion bricks each year (Alam et al., 2019) by utilizing 3350 million cubic feet of clay and 7.4 million tons of coal (Roy et al., 2023) resulting in the emission of 22.4 million tons of carbon dioxide (Abbas et al., 2023; Haque et al., 2022) Coal-burnt clay brick kilns are the primary source of environmental pollution (DoE, 2017). Therefore, it is imperative to implement measures to make the brick industry more environmentally friendly in order to reduce pollution, attain additional advantages, and fulfill target climate objectives (Haque et al., 2023). Bangladesh has implemented a technological requirement to make brick manufacture more environmentally friendly (Haque et al., 2016). In pursuit of this objective, Bangladesh has already commenced the utilization of environmentally sustainable kiln technology and substitute materials for the production of bricks, thereby reducing reliance on coal combustion. Autoclaved clay bricks, cement-sand mortar blocks, fly-ash clay bricks, concrete blocks, Automated Aerated Concrete (AAC) blocks, and other options are being evaluated as substitutes for coal-burnt clay bricks. The AAC blocks have become one of the most promising options in the global construction industry (Raj et al., 2020) because of no requirement for cement whose production is associated with enormous carbon emission, and utilization of waste or industrial byproducts without affecting the environment adversely. Apart from the ingredient materials, their lightweight nature, excellent thermal insulation, and effective soundproofing capabilities have made the AAC blocks very potential for versatile applications in construction (Saad et al., 2022) including residential, commercial, educational, industrial, and infrastructure projects. Prior to the potential utilization of AAC blocks, there is an urgent need to investigate the physio-mechanical properties of AAC blocks for their application in the construction sector of Bangladesh. This will enable AAC blocks to contribute significantly to sustainable and efficient building materials, aligning with the goal of sustainable development.

In order to verify the resiliency of masonry structures made with AAC blocks, the engineers are required to develop mathematical models of the structures (Saad et al., 2022) Mathematical modeling of masonry structures requires the material properties and their constitutive relationships of masonry structures and their constituents, i.e., AAC blocks (Saad et al., 2022; D'Altri et al., 2020). However, these are not easily available due to the scarcity of controlled experimental tests and the significant variation in material properties for different ingredients and manufacturing processes (Nguyen et al., 2019). Numerous studies have been conducted in the past to examine the physical and mechanical characteristics of AAC. (Narayanan et al., 2000) conducted research work on the microstructure and compositional analysis of AAC and non-autoclaved aerated concrete (NAAC). The compressive strength of AAC is significantly influenced by its density and porosity. As porosity increases and density decreases, the compressive strength decreases as well (Alexanderson,1979) A few researchers (Devi et al., 2022; Raj et al., 2022; Jasinski et al., 2019; Małyszko et al., 2027) have conducted mechanical characterizations of AAC masonry, but there is limited information available regarding the physical properties of AAC masonry units based on their dimensions. Additionally, there is a lack of literature in Bangladesh that explores the impact of mechanical properties on the overall performance of AAC masonry. This experimental study aims to bridge that knowledge gap by examining the valuable mechanical and physical properties of AAC blocks. The physio-mechanical properties include both physical and mechanical properties of AAC block which are very important to determine their suitability for various construction applications. Among different key physio-mechanical properties of bricks are: size, texture, color, water absorption, and initial rate of absorption are the main physical properties, while compressive strength, tensile strength, elastic modulus, and modulus of rupture are the main mechanical properties that affect brick masonry.

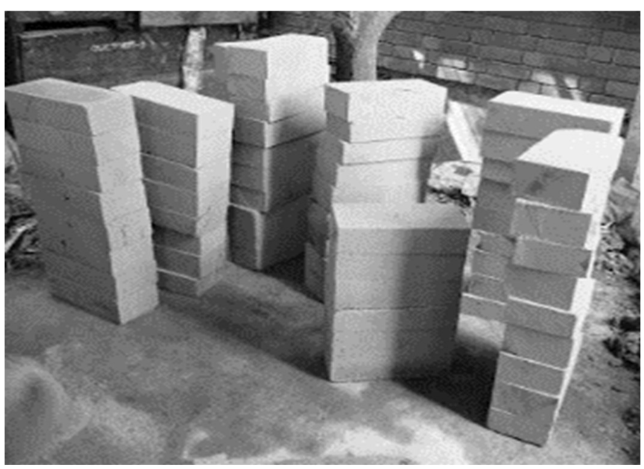
2 MATERIALS AND METHODS

2.1 Autoclaved Aerated Concrete (AAC) Blocks

In this study, commercially available AAC blocks of dimensions 600 × 200 × 110 mm were collected from the manufacturing industry Eco-Friendly Green Brick Limited (Bangladesh) to prepare the specimens for this research work. The AAC blocks are made in different sizes in the manufacturing industry. Testing a large-sized block may not be feasible in some laboratories due to the limitation of testing equipment as well as according to ASTM C1693, ASTM C 67, and ASTM C1006 Code. Conventionally, the specimens are prepared with the standard brick of size up to 241.3×114.3×69.83 mm^3. The cube specimens of size 100 mm were cut from AAC blocks using a diamond blade cutter (Fig.: 1). Similarly, block units of size 241.3×110×69.83 mm^3 were cut to prepare the AAC IRA Test. The blocks and cube of AAC blocks considered for experimental work are shown in Fig. 2. The standard brick size in Bangladesh on average is 241.3×114.3×69.83 mm however, there is no uniformity of brick size in Bangladesh as the size of bricks is different in different places inside of the Country. A general perception among customers is that thicker bricks are stronger and more cost-effective. As a result,



(a)



(b)

Figure 1: AAC blocks (a) A standard-sized masonry unit is collected by cutting the full-size AAC block; (b) The block's dimensions are reduced due to the cutting operation.

there is a growing tendency to produce thicker bricks to attract customers. For better comparison with clay bricks, researchers prefer to use almost the same-sized bricks to test the AAC blocks. For example, Ferretti et al. (Ferretti et al., 2015). carried out the mechanical characterization of AAC masonry using the AAC unit of size 250×100×50 mm^3. Hence, in the work, it has been preferred to employ the non-standard AAC blocks of 242×110×69 mm^3

3. EXPERIMENTAL PROGRAM AND TEST PROCEDURE

The present study investigated the properties of AAC block units. A detailed literature review revealed no consensus about the specimen size of the AAC block unit to be tested. ASTM C1693 (ASTM 2017a). recommends a prismatic block specimen for the evaluation of dry density and moisture content. These blocks were used for preparing prismatic specimens of 40 x 40 x 160 mm^3 for determining dry density, moisture content, and 100 mm cube specimen for compressive strength as per ASTM C1963. The cubes were cut from the bottom (the mold base side), middle, and top (open side of the mold) portions of AAC blocks of size 600×200×110 $mm^{3.}$

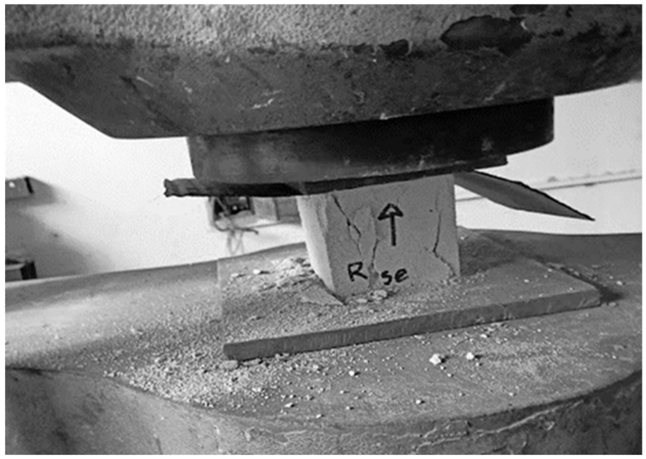


Figure 2: Compression test of AAC cube units.

To measure the dry density and moisture content, the specimens were completely dried out by maintaining a temperature of 105 ºC for about 24 hours. Subsequently, the compressive strength of these cubic specimens was determined after room temperature curing for 10 days. Further, five samples of size, 241.3×110×69.83 mm^3 were prepared to find the initial rate of absorption (IRA) of the AAC block as per ASTM C 67 – 05. The block specimens were immersed in water for one minute up to 3 mm depth after drying for the Initial Rate of Absorption [IRA]. The blocks' mean dry density was determined to be approximately 667.34 kg/m^3. The average moisture content of the blocks was determined to 10.01%. The Initial Rate of Absorption (IRA) was evaluated (as shown in Fig. 3.) of five AAC blocks to 1.29 $kg/m^2/min$. Masonry units are said to be highly absorptive when IRA is greater

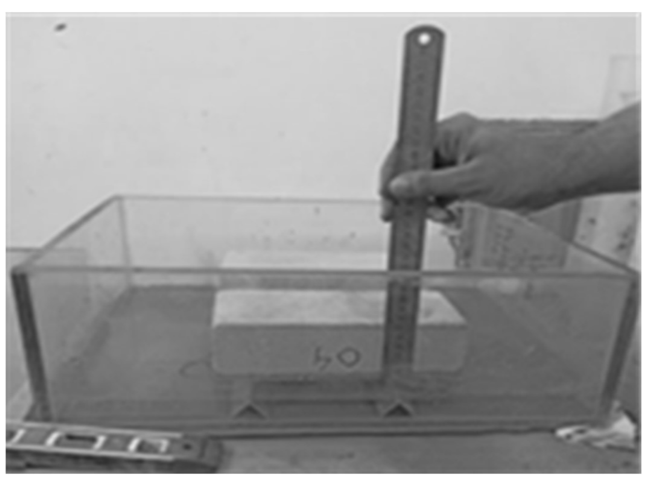


Figure 3: Procedure for determining to initial rate of absorption (IRA)

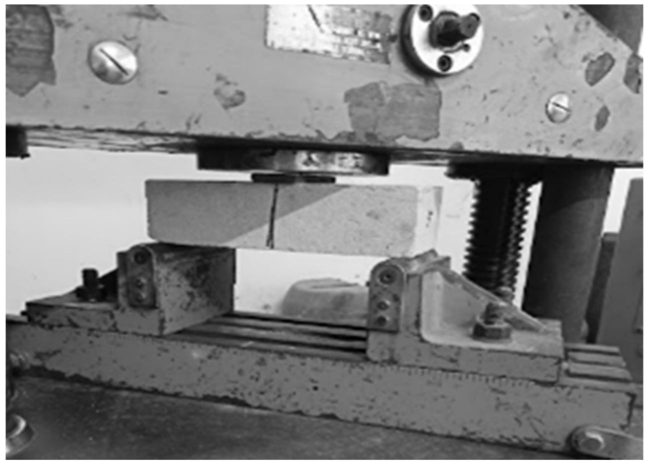


Figure 4: Test setup of Determining the Modulus of Rupture (Flexure) Strength,

Figure 5: Procedure of Determining the Splitting Tensile Strength

than 1.5 kg/m2/min and hence should be moistened prior to laying for realizing better bond strength. Fig. 2 shows that The compressive strength of 3 cubic AAC specimens lay within a range of 2.96-3.23 MPa The Procedure of modulus of rupture, and length of span was around 220 mm, and a universal testing machine was prepared for finding the Modulus of Rupture (Flexure) Strength of the AAC block as per ASTM C 67 – 05 is shown in Figure: 4. Similarly, to determine the results of splitting tensile test was followed to the experimental procedure of ASTM C 1006 – 07 is shown in Figure: 5.

4. RESULT AND DISCUSSION

4.1 Dry Density

The dry Density of the Autoclaved Aerated Concrete (AAC) block is an important physical property that determines the durability of the block. The blocks density is low, cannot sustain sufficient load. The dry density of the cubes was determined by dividing the dry weight of each cube by its volume C1693 – 09. The scope of the present study was kept limited to evaluate the effect of Dry Density of AAC specimens. The dry Density of different Experimental results is shown in Fig: 4

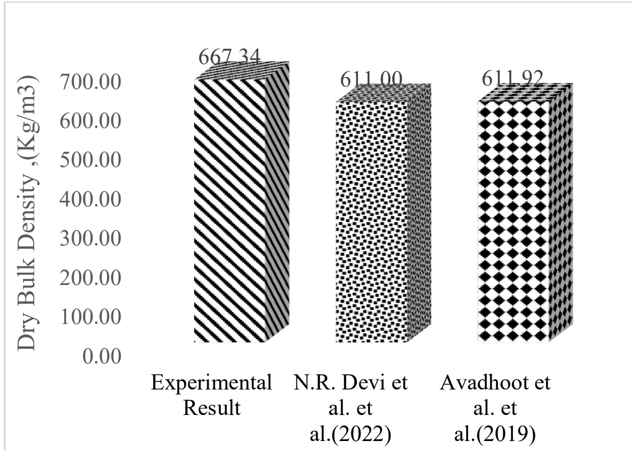


Figure 4: Dry Bulk Density of Different experimental results of AAC block

Dry bulk density was observed the maximum result is 667.34 kg/m^3 for AAC block in this present Study (N. R Devi et al.,2022) and (Avadhoot et al., 2019) showed the results on dry bulk density of AAC Block is 611.00 kg/m3 and 611.92 kg/m^3 respectively based on experimental observations. In terms of density in literature, the experimental results were almost the same as shown in Figure: 4 which is 8.41% Less than our Experimental findings.

4.2 Moisture Content (%)

The Moisture Content of the Autoclaved Aerated Concrete (AAC) block is another factor that determines the durability of a block. The block in which Moisture Content is raised, cannot sustain more compressive strength. Determine the mass of the specimens, and then dry them in a ventilated oven at 110°C for the determined mass of the specimen as ASTM C1693 – 09. The Moisture Content of different Experimental results is shown in Fig: 5 Moisture Content was calculated that the minimum result is 10.01 % for AAC block in this present Study. (N. R Devi et al.,2022) and (Avadhoot et al., 2019) showed the results on dry bulk density of AAC Block are 14.54% and 17.67 % respectively based on experimental observations. In terms of Moisture Content in literature findings were 56.64 % greater than our Experimental result.

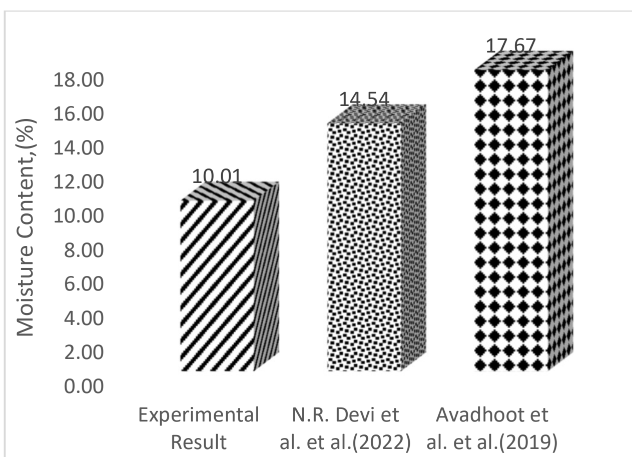


Figure 5: Moisture Content of Different experimental results of AAC block

4.3 Initial rate of absorption [IRA]

The IRA value gives in-hand knowledge about the absorptive capacity of the test specimen. Five samples of size 241×110×69 mm^3 in Fig.1(c) were prepared to find the initial rate of absorption (IRA) of the AAC block as per ASTM C 67-00 (ASTM 2001c). The IRA test setup is shown in Fig. 6. The scope of the present study was kept limited to evaluate the effect of the Initial rate of absorption of AAC specimens. IRA of different Experimental results are shown in Fig: 6

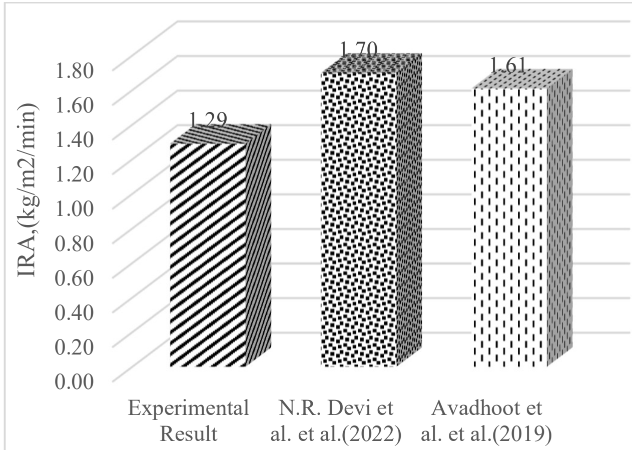


Figure 6: Initial Rate of Absorption of Different experimental results of AAC block

The IRA observed that the minimum value is 1.29 $kg/m^2/min$ for the AAC block in this present Study. (N. R Devi et al.,2022) and (Avadhoot et al., 2019) showed the results on IRA of AAC Block are 1.70 $kg/m^2/min$ and 1.61 $kg/m^2/min$ respectively based on experimental observations. In terms of IRA in the literature were mentioned the experimental results are almost the same as shown in Figure: 6 which shows 24.11% increases in the absorption capacity than our Experimental findings.

4.4 Compressive Strength

The compressive strength of the Autoclaved Aerated Concrete (AAC) block is an important factor that determines the mechanical properties of the block. If the block attributes are low Compressive Strength, cannot sustain sufficient load. The Compressive Strength of the cubes was determined by applied forces on the cube specimen divided by its area C1693 – 09. The scope of the present study was kept limited to evaluate the effect of Compressive Strength of AAC specimens. The compressive strength of different Experimental results is shown in Fig: 7

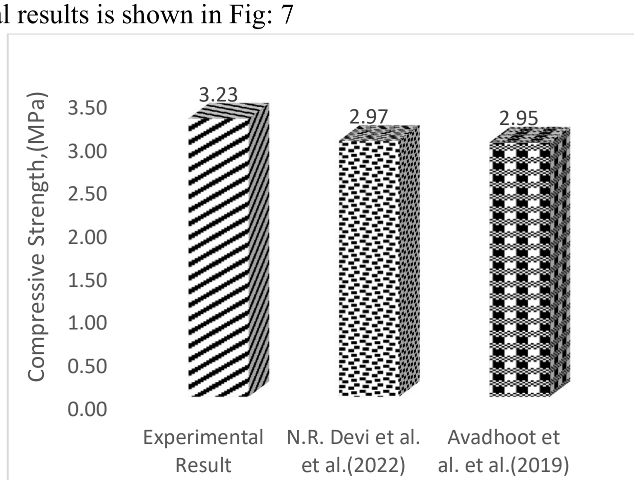


Figure 7: Compressive Strength of Different experimental results of AAC block

Compressive Strength was observed and the maximum result is 3.23 MPa for AAC block in this present Study. (N. R Devi et al.,2022) and (Avadhoot et al., 2019) showed the results on dry bulk density of AAC Block are 2.97 MPa and 2.95 MPa respectively based on experimental observations. In terms of

Compressive Strength in literature, the experimental results were almost the same as shown in Figure: 7 which is 8.04 % Less than our Experimental results

4.5 Modulus of Rupture and Splitting Tensile Strength

The results of Modulus of Rupture and Splitting Tensile strengths as determined during experimental tests are presented in Table 1The experimental results indicate better performance compared to the findings in the literature. Table 2 presents a summary of the findings from the current study in conjunction with various literature sources.

Table :1

Comparison of mechanical properties of Present study with literature

Mechanical properties type	**Present Study**	**Literature**
Modulus of Rapture (MPa)	0.691	0.350 - Chaipanich et al.(2017)
Splitting Tensile Strength (MPa)	0.429	0.337 - Leszek et al.(2015)

Table: 2

Summary of the current study's findings alongside various literature sources.

	Present Study AAC Block	Khaleel et al. (2020) Clay brick	Sathiparan et al. (2018) Clay Brick	Sahu et al. (2019) Clay brick	Amoudi et al. (2014) Concrete Block
Dry Density kg/m^3	667.34	1820	1658	1539	2411
Moisture Content (%)	10.01	----	2.53	---	2.77
IRA kg/ m^2/min	1.29	1.173	---	3.84	---
Compressive Strength (MPa)	3.23	6.76	6.57	7.61	18.08
Modulus of Rupture (MPa)	0.691	1.478	---	---	---
Splitting Tensile Strength (MPa)	0.429	---	---	---	0.127

5. CONCLUSIONS

The following conclusions can be prepared from the investigations carried out on the physical and mechanical properties of Autoclaved Aerated Concrete (AAC) block in comparison with several literatures. The following conclusions are mentioned from this study:

1. The Moisture Content and Initial Rate of Absorption (IRA) in the AAC block were evaluated and compared with experimental results from existing literature. In this AAC block, Moisture Content and IRA were recorded to be 10.01% and 1.29 kg/m^2/min, respectively. In contrast, the literature indicates Moisture Content and IRA values of 17.67% and 1.70 kg/m^2/min, respectively. This suggests that Autoclaved Aerated Concrete (AAC) block units demand less moisture during the construction of AAC block masonry structures compared to what is reported in the literature.
2. Typically, AAC blocks with lower density struggle to bear adequate load. In this study, the highest recorded Dry Bulk Density for an AAC block was 667.34 kg/m^3, which is 8.41% higher than the values reported in the existing literature.
3. The maximum moisture content was inversely correlated with the density of AAC, and moisture considerably decreased the strength of AAC when tested under air-dry conditions.
4. The compressive strength of an AAC block rises with an elevation in dry density. The current findings reveal that both the compressive strength and dry density of AAC blocks surpass the values reported in the literature.

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