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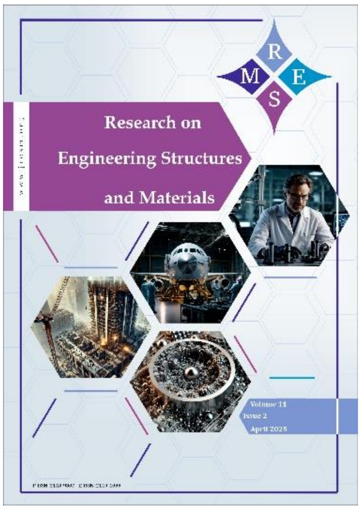

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Research Article

Physico-mechanical properties of autoclaved aerated concrete block as an alternative to traditional bricks

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Abstract

Autoclaved aerated concrete (AAC) can be treated as a sustainable construction material as it decreases environmental impact while enhancing urban development quality, aligning with sustainable development goal (SDG) 11 of United Nations. The present study aims to compare the properties of the AAC blocks with that of traditional bricks such as fly ash brick and clay brick to emphasize the distinct advantages and limitations of AAC blocks, proposing AAC as a potential alternative in construction sector. AAC blocks of different aluminum powder (0.025 % and 0.05 % Al) and the masonry prisms of these AAC blocks as well as fly ash bricks and clay bricks were prepared in the laboratory. The compressive strength of AAC block was found to be 5.01 N/mm2 which is higher than the minimum strength according to IS code. The compressive strength of a masonry unit was observed greater than that of masonry prisms in all cases. It was found that the AAC blocks contain minimal moisture, thus suitable for the walls subjected to damp environments continuously as compared to the walls prepared by using fly ash bricks and clay bricks. The microstructural morphology was also obtained using scanning electron microscope (SEM) equipment. It had been observed that the pore size enlarged with the inclusion of Al powder in AAC. As a result, the weight of AAC block reduced, thereby the density and compressive strength also decreased. Due to this characteristic, a masonry structure constructed with AAC blocks is recommended to perform well during earthquake in terms of seismic resistant compared to a structure prepared with traditional bricks. Furthermore, resource-based cost analysis method had been adopted to demonstrate with an example of model room that the cost of building construction can be reduced with the employment of AAC blocks by 29% and 36% as compared to clay bricks and fly ash bricks respectively.

1. Introduction

Due to the rapid expansion of urban areas, development of infrastructure is progressing quickly despite the global resource crisis. The rising demand for housing increases the need for walling materials, which is supplied by brick production in kilns. After China, India is the largest producer of burnt clay bricks, with around 100,000 brick manufacturing plants generating 250 billion bricks annually. These plants together burn approximately 35 million tonnes of coal every year, which is depleting coal reserves and also polluting the environment [1]. At the local level, traditional clay brick kilns pose significant environmental concerns due to the emission of harmful pollutants, including hazardous suspended particulate matter, carbon monoxide, and sulfur oxides. These pollutants negatively impact human health, as well as the health of animals and plants. Additionally, the substantial use of fertile topsoil in brick production presents major environmental issues, such

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as, erosion and land degradation, loss of agricultural productivity and impact on biodiversity [2, 3]. Fertile topsoil is necessary for the growth of crops, providing plants with vital nutrients and organic matter. Removing this layer for brick production reduces the agricultural potential of the land and can decline crop yields, thereby impacting food security and causing higher food prices in regions with severely eroded topsoil. Further, topsoil is rich in microorganisms and nutrients that support a variety of plant species. Its exclusion disrupts local ecosystems, leading to habitat loss and adversely affecting biodiversity that depends on the soil for survival.

On a global scale, emissions from brick manufacturing plants significantly contribute to global warming and climate change. The problem of global warming and environmental pollution has become critically important worldwide. Hence, it is crucial to prioritize finding environmentally friendly solutions and policies [4]. Several alternatives (namely AAC block and fly ash brick) to clay bricks [5-7] can help to mitigate pollution and the negative effects of global warming.

Autoclaved aerated concrete (AAC) block may be a good alternative to the clay bricks. The details of aerated lightweight concrete can be found in the refs. [8-9]. AAC was first commercially produced in Sweden in the year 1923 [10]. Since then, till date the research is going on AAC for its advancement. Narayanan and Ramamurthy [11] reviewed structure and properties of aerated concrete. The influence of waste materials and fibres addition on AAC has been studied by several researchers [12-18].

Most of the studies related to seismic analysis found that the in-plane, out-of-plane and combined in-plane and out-of-plane failure risk of AAC infill walls during earthquake are very low due to their lighter weight. On the other hand, fly ash bricks are a kind of brick prepared from fly ash, a byproduct of coal fired power plants. These bricks are sustainable alternative to traditional clay bricks [19, 20]. However, the AAC blocks are often preferred over fly ash bricks in seismically most active zones for seismic design due to their lighter weight and superior ability to absorb vibrations [21]. Costa et al. [22] assessed the seismic performance of autoclaved aerated concrete masonry buildings. Sucuoğlu and Siddiqui [23] demonstrated the influence of AAC infills on the seismic performance of frames and developed an AAC strut model. Kasapgil et al. [24] studied the seismic behavior of AAC infill walls insulated with cementitious lightweight panels in frames.

While existing works extensively discuss the conventional bricks, the comprehensive research on AAC blocks are lacking in the literature. Most of the previous studies report the properties of clay brick and fly ash brick individually, whereas the comparison of the properties of these bricks with AAC is scanty in the literature. The authors are comparing the properties of the blocks to emphasize the distinct advantages and limitations of AAC blocks relative to traditional bricks. This comparison is crucial to demonstrate how AAC blocks stand out in terms of physical and mechanical properties, and cost-effectiveness. A discussion on microstructural morphology is also presented. The authors aim to underline the potential of AAC blocks as an innovative and efficient alternative for contemporary construction needs, offering insights that are both practical and impactful for the construction industry.

2. Materials

2.1. Raw Materials

In the current investigation, the traditional burnt clay bricks and fly ash bricks were brought from the local market. The process of brick manufacturing started with the careful material selection, where natural clay is often mixed with additives like sand, lime or iron oxide to reach desired properties. The fly ash bricks were prepared by combining fly ash, cement, sand, lime and water.

On the other hand, AAC blocks were manufactured in the laboratory. These three different varieties of masonry blocks or units are shown in Figure 1. Further, physical and mechanical properties of the ACC blocks were compared with traditional bricks. The raw materials used in this research work for the preparation of autoclaved aerated concrete were sand, cement, lime, aluminum powder and water.

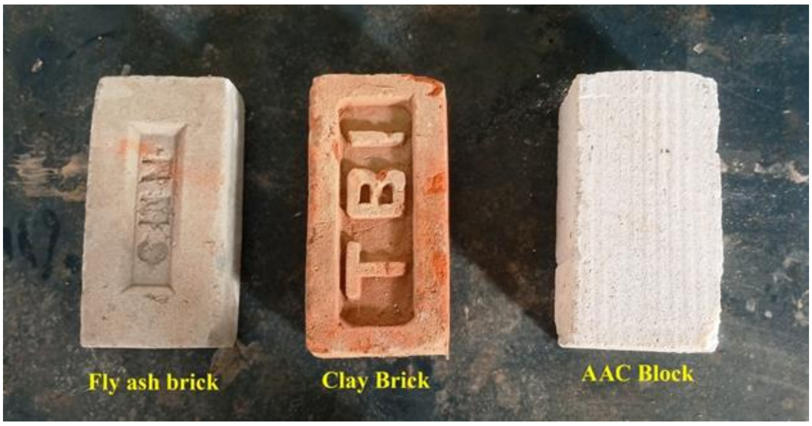


Fig. 1. Three different varieties of masonry blocks

2.1.1. Cement and Water

The testing of Ordinary Portland Cement had been conducted as per IS: 4032(1985). The percentage of Chemical compositions was verified based on IS: 8112 (2013). The fineness of the cement was 225 m^2/kg and the specific gravity 3.15. Chemical compositions of cement were presented in Table 1. Tap water was added to cement for creating a paste that glued all of the aggregates together. The measured pH value of water obtained from the laboratory experiment was equal to 7.7 [25].

Table 1. Chemical compositions of OPC 43 grade

Chemical composition	% (by weight)
CaO	60.22
SiO_2	20.86
Al_2O_3	5.84
Fe_2O_3	3.68
MgO	2.48
SO_3	3.35
Loss on ignition	3.57

2.1.2. Fine Aggregate

Locally available washed natural river fine aggregate or sand was utilized in the matrix of mortar. The specific gravity of the sand was 2.66 as obtained from the experiment. The zone III of the fine aggregate was confirmed by sieve analysis. The grading curve of fine aggregate or sand is depicted in Figure 2.

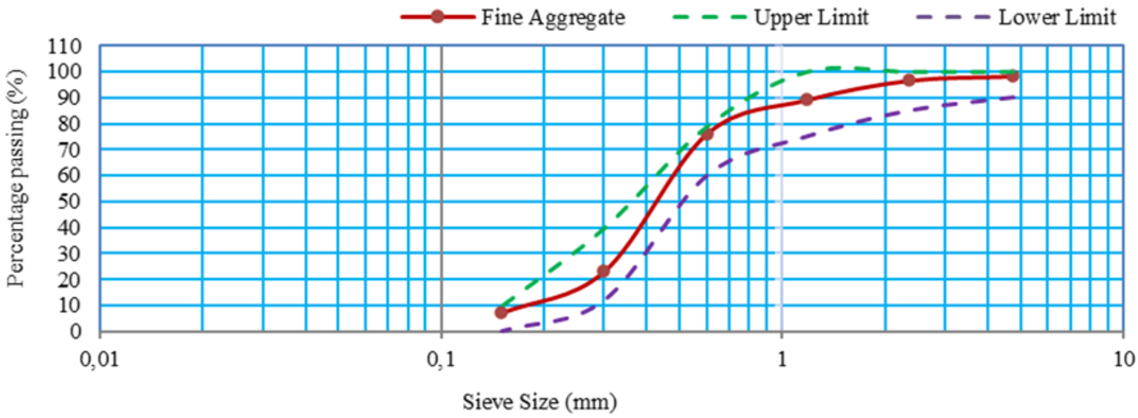


Fig. 2. Grading curve of fine aggregate

2.1.3. Lime

Lime is serving as a binding agent. This calcareous material reacts with SiO_2 and Al_2O_3 in siliceous materials under hydrothermal environments to produce hydrated calcium silicate and then built the strength of AAC blocks. It was prepared from limestone either by crushing to fine powder or by purchasing it in powder form from a local merchant.

2.1.4. Aluminum Powder

Aluminum is working as an expansion agent, which will affect the density of the AAC block. When aluminum powder was introduced in the raw materials, air bubbles were formed due to reaction between calcium hydroxide, aluminum and water; and released hydrogen gas. The aluminium powder used in the processes is presented in the Figure 3.

Fig. 3. Aluminium powder

3. Manufacturing Methods and Tests

The clay was collected from mines and then handled to eliminate impurities, developing a malleable paste or slurry. The clay was shaped into bricks through hand molding or machinery, and then dried under controlled conditions to eliminate moisture. The dried bricks were then fired in a kiln at temperatures between 800°C and 1100°C which strengthens and hardens them through chemical changes. Once cooled, the bricks were sorted by size, shape and strength, and underwent rigorous testing to meet safety and durability standards before being released to the market.

Fly ash bricks were prepared by mixing fly ash, cement, sand, lime and water. The mixture is poured into molds, compacted and cured for 7 to 14 days using either water or steam. After curing, the bricks were dried to decrease moisture and achieve strength. Finally, the bricks were tested for strength and durability, and if meeting the required standards, bricks were ready for use. In the present work a total of 1.055 kg of mixture was used based on ref. [26] for filling a single mould to prepare AAC block. Table 2 illustrates the material compositions of AAC block. Total 33 numbers of AAC blocks were manufactured. The prepared raw materials of mixture were weighed by using digital weighing machine with three decimal places of accuracy.

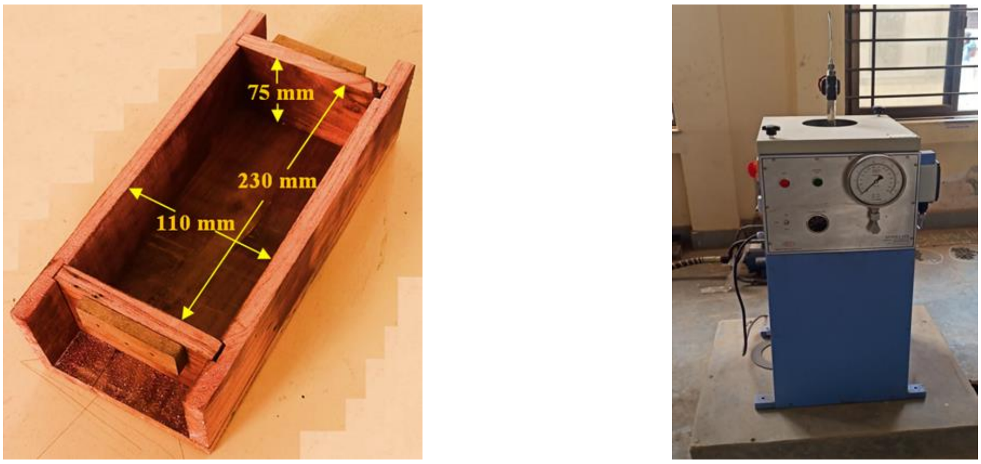
Table 2. Compositions of autoclave aerated concrete

Composition	% (by weight)
Sand	44.00
Cement	14.50
Lime	6.50
Water	36.50
Al powder	0.025 and 0.05

Thereafter, mixture of AAC was needed to pour in a wooden mould (Figure 4(a)). It had been observed that the poured material started to rise by producing air voids in it. This is due to the fact that when aluminum powder reacted with calcium hydroxide, it produced calcium aluminate hydrate ($3CaO.Al_2O_3.6H_2O$) as well as hydrogen gas (air voids), as shown in Eq. (1).

$$2Al + 3Ca(OH)_2 + 6H_2O \longrightarrow 3CaO.Al_2O_3.6H_2O + 3H_2 \quad (1)$$

Next step was demoulding of AAC block and this uncured block then sent to the autoclave for curing. Autoclave machine has been shown in Figure 4(b). It consists of one high pressure steam chamber 600 mm long, prepared of seamless stainless-steel tube with bolted steel cover, which is enclosed in heat insulated metal housing. The sample was then placed in an autoclave at 185°C, with a high steam pressure of 8 bar. It was maintained under these conditions for 5 hours. Thereafter, the AAC products within 24 hrs were ready for use.



(a) (b)

Fig. 4. Instrument used for manufacturing: (a) wooden mould and (b) autoclave

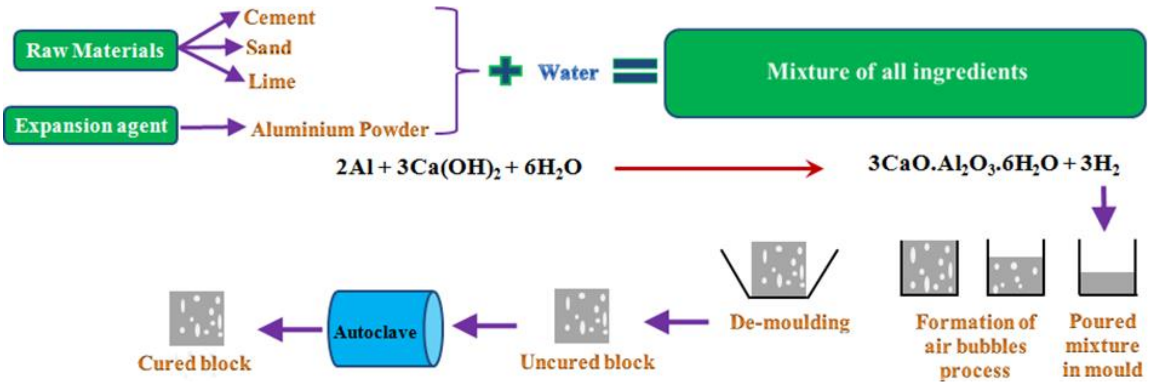


Fig. 5. AAC manufacturing process

In this case, the strength was usually equivalent to 28 days under ambient curing [27]. The flow diagram of AAC manufacturing process in laboratory has been shown in Figure 5. After manufacture process ends, the testing of AAC blocks begins. The tests listed below had been carried out to assess the physical and mechanical properties of three different types of masonry blocks - clay bricks, fly ash bricks and AAC blocks. For the AAC blocks, two different percentages of aluminum powder had been considered. The physical properties, namely, dry density and wet density had been calculated using following formulas:

$$Dry\ Density = \frac{Mass\ of\ the\ brick}{Volume\ of\ the\ brick} \quad (2)$$

$$Wet\ Density = \frac{Wet\ \ mass\ of\ the\ brick}{Volume\ of\ the\ brick} \tag{3}$$

Other physical properties such as moisture content and water absorption were evaluated using Eq. (4) and Eq. (5). Water absorption measures the amount of water that can be absorbed by a material when submerged in water for 24 hours with respect to its dry weight. The moisture content is the amount of water already exists in the material in its natural state relative to its dry weight.

$$Moisture\ Content\ (\%) = \frac{Natural\ \ weight\ \ of\ the\ material\ - Dry\ weight\ \ of\ the\ material}{Dry\ weight\ \ of\ \ the\ material} \times 100 \tag{4}$$

$$Water\ \ Absorption\ (\%) = \frac{Wet\ weight\ \ after\ \ water\ immersion\ - Dry\ weight\ \ of\ the\ material}{Dry\ weight\ \ of\ the\ material} \times 100 \tag{5}$$

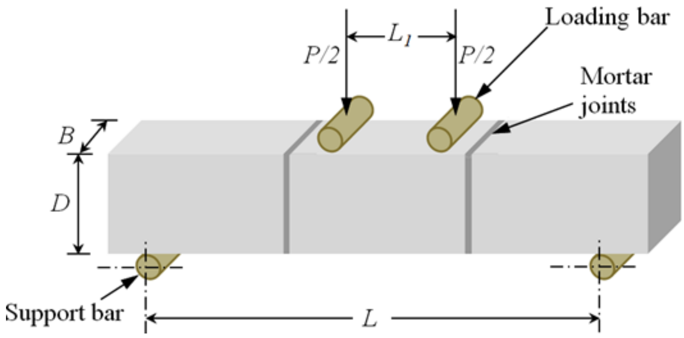
The mechanical property such as compressive strength was determined by placing brick/block in compression testing machine (CTM) or universal testing machine (UTM). Load is applied through the machine on it until brick breaks. In the present study, UTM with 600 kN capacity had been used in the laboratory. A test setup has been shown in the Figure 6(a). It is required to note down the value of failure load to find the compressive strength (Eq. (6)) of brick or block.

$$Compressive\ \ strength = \frac{Failure\ load}{Area\ over\ which\ failure\ load\ applied} \tag{6}$$

This mechanical property of masonry prisms was evaluated by testing three prisms of each variety (clay brick, fly ash brick and AAC block with 0.025% and 0.05% Al powder) subjected to monotonic uniaxial compression. The prisms, measuring 230 × 110 × 415 mm with a height to thickness ratio of 3.77, were built using a 1:3 cement-sand mortar mix with a bed-joint thickness 10 mm. The testing setup for the masonry prisms is presented in Fig. 6(b). The compressive strength of the prisms was determined by dividing the maximum recorded compressive load of each specimen by its gross cross-sectional area. Failure of masonry under compression occurred due to the interaction between the brick units and the mortar joints, which displayed differing deformation behaviors. Vertical compression caused the masonry assembly (bricks and mortar combined) to expand laterally. Since bricks were much stiffer than mortar, their lateral expansion was minimal, constraining the mortar which underwent triaxial compression.

(a) (b)

Fig. 6. Setup for compressive strength test for masonry: (a) unit and (b) prism



(a)

(b)

Fig. 7. Flexural strength test for masonry: (a) Schematic diagram and (b) test set-up

This confinement resulted in the mortar pulling the bricks laterally, subjecting the brick units to biaxial tensile forces in addition to the vertical compressive load. A four-point beam bending test was used for estimating the flexural strength of masonry units. The specimen consisted of three bricks or blocks bonded lengthwise with a 1:3 cement-sand mortar mix and 10 mm thick joints. A schematic diagram of the test setup is shown in Fig. 6(c). This configuration (Fig. 6(d)) is particularly applicable to unreinforced masonry walls subjected to out-of-plane bending, such as those influenced by wind or seismic forces. Finally, methods used to analyze costs for masonry brick buildings often depends on the scope, scale and purpose of the project. The resource-based cost analysis method was adopted to estimate the expenses by separately considering labor, materials and overheads. The details of cost analysis have been presented in the later section for masonry work constructed using different types of blocks.

4. Results and Discussions

The physical and mechanical properties as well as cost analysis results of different variety of masonry blocks, namely, fly ash brick, clay brick, AAC blocks prepared with 0.025% and 0.05% aluminum powder had been compared as well as discussed in this section.

4.1. Physical properties

The dimension and average weight of blocks are presented in Table 3. Subsequently, influence of physical properties, namely, weight, pore diameter, density, moisture content, water absorption and color on masonry blocks are demonstrated in this subsection.

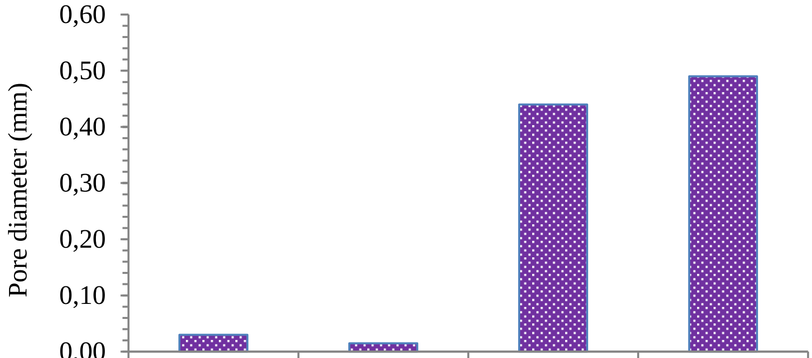
Table 3. Details of different variety of masonry blocks

Variety of blocks	Length (mm)	Breadth (mm)	Height (mm)	Dry weight (kg)	Moist weight (kg)
Fly ash brick	230	110	75	3.850	4.380
Clay brick	230	110	75	3.670	4.100
AAC blocks with 0.025%	230	110	75	1.190	1.250
AAC blocks with 0.05%	230	110	75	1.182	1.260

The average dry weight of AAC block was 1.19 kg whereas the fly ash brick 3.85 kg and clay brick 3.67 kg. It implies that the traditional fly ash brick and clay brick were 3.24 and 3.08 times heavier than AAC block. The average percentage difference between moist and dry weight (Table 3) for fly ash brick, clay brick, AAC blocks with 0.025% and 0.05% aluminum powder were 12.10%, 10.49%, 4.80% and 6.19% respectively. The existence of bigger pores in AAC block makes it lighter than other two varieties. These pore sizes were observed (Figure 8) to be increasing with the rise in Al powder percentage. The inspection of grain size of any materials can be conducted using inverted metallurgical microscope (IMM). In this work, IMM had been employed to measure the average pore sizes which were present in the different masonry blocks. The average pore diameters are depicted in the Figure 8. The pore diameter can be calculated by using Eq. (7).

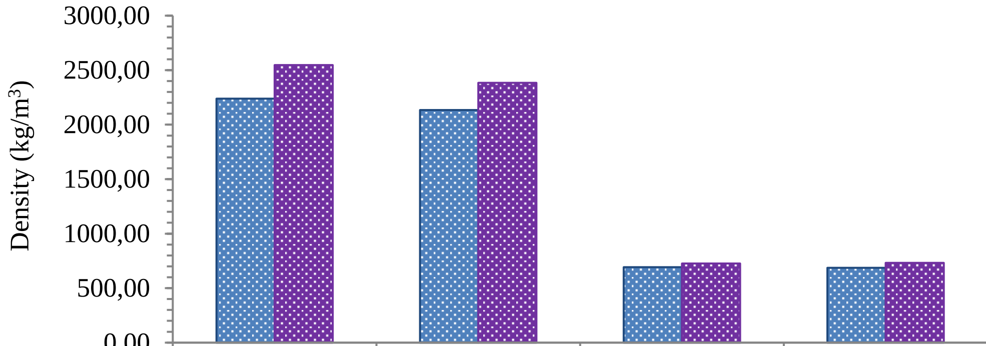
$$D_{avg} = \frac{\sum_{i=1}^{n} D_n}{\sum n} \tag{7}$$

where D_n is the pore diameter, n is the number of the pores and D_{avg} is the average pore diameter.



	Fly ash brick	Clay brick	AAC block (with 0.025% Al)	AAC block (with 0.05% Al)
Pore diameter (mm)	0,03	0,015	0,44	0,49

Fig. 8. Average pore diameters



	Fly ash brick	Clay brick	AAC block (with 0.025% Al)	AAC block (with 0.05% Al)
Dry density (kg/m3)	2238,37	2133,72	691,86	687,21
Wet density (kg/m3)	2546,51	2383,72	726,74	732,56

Fig. 9. Comparison of density

The dry density and wet density of different variety of blocks are shown in the chart data table and Figure 9. It can be observed from the figure that the dry and wet densities fly ash and clay bricks were more than three times higher than the AAC blocks. The traditional bricks and AAC block were taken for the moisture content test as per IS 6441 [28]. Fly ash brick and clay brick had average moisture content of 13.77% and 11.71% respectively.

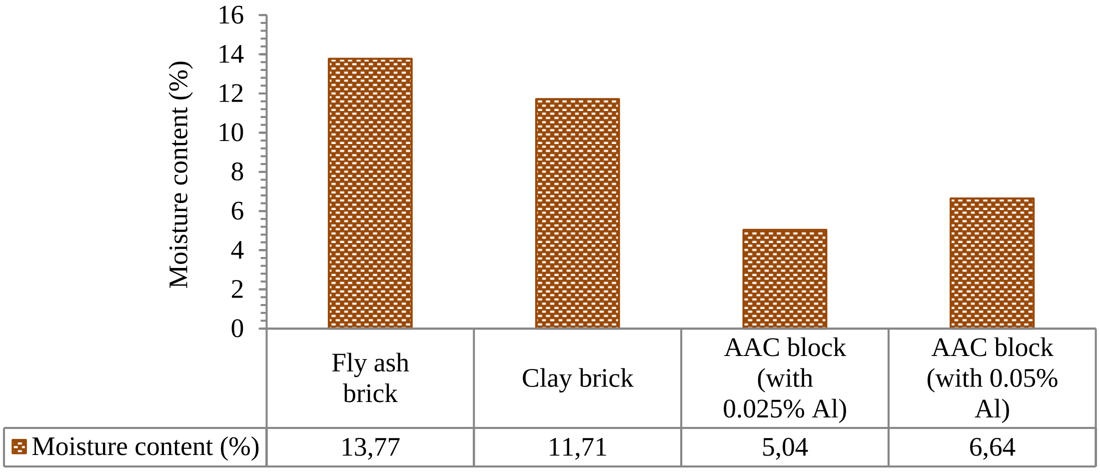


Fig. 10. Comparison of moisture content

On the other hand, AAC blocks with 0.025% and 0.05% aluminum powder hold the moisture content of 5.04% and 6.64% respectively (see Figure 10). Bhosale et al. [29] had reported the moisture content in their findings, ranging from 2.36% to 17.67%. It implies that the AAC block masonry wall does not hold water during curing process. This is particularly beneficial in situations where the wall is consistently exposed to damp conditions as a result of rain penetration. The pores existed in traditional bricks were capillary pores which bound water more tightly. Coarse pores present in AAC block were formed through the entrapment of air during the mixing process. The dry AAC blocks tended to entrain more air than wetter blocks [30] which resisted the water to entrain in those pores and this is the reason to hold less moisture in AAC blocks. Similarly, the water absorption of different types of masonry units is illustrated in Figure 11. It has been observed that the fly ash brick, clay brick, AAC blocks with 0.025% and 0.05% Al powder have average water absorption of 18.86%, 17.60%, 27.56% and 28.35% respectively. These water absorption values align fairly well with the results reported by previous researchers [7, 19, 29].

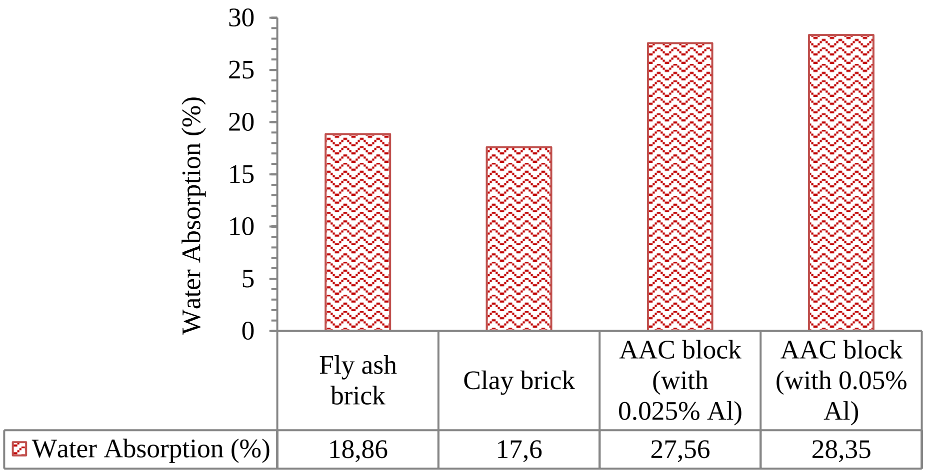


Fig. 11. Comparison of water absorption

Color testing is also performed to evaluate the physical properties of block. The color test is generally conducted under natural light, relying solely on visual inspection. In this study, the clay bricks exhibited a uniform red color. In contrast, the fly ash bricks and AAC blocks revealed a consistent pale gray tone and white to light gray shades respectively. These appearances served as indicators of good quality samples.

4.2. Mechanical Property

The compressive strength of concrete is closely related to its physical property like pore diameter and density. It had been observed that the presence of great numbers of pores highly reduced the strength of AAC. Subsequently, if the traditional bricks were compared with AAC blocks, it can be found that the density also greatly influence the compressive strength, that means less density implies lesser value of compressive strength.

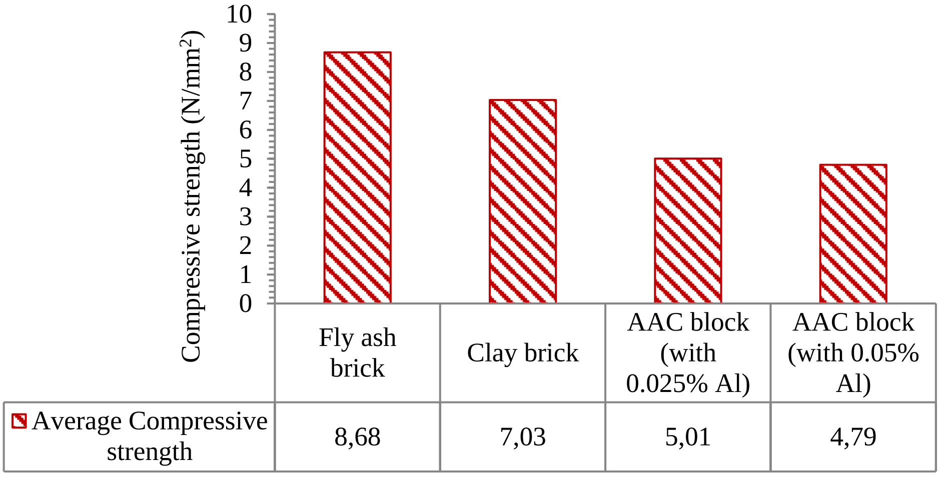


Fig.12. Comparison of compressive strength values of masonry units or blocks

The obtained average compressive strength for different variety of blocks is presented in the Figure 12. It can be observed that the strength of the AAC block was lesser compare to other two varieties of bricks. If it fails to achieve the required value, it is not useful for construction works. As per IS 1077 [31], masonry brick must achieve the compressive strength value equals to 3.5 N/mm^2. The compressive strength of AAC was found to be 5.01 N/mm^2 from the laboratory test. According to IS 2185-3 (1984), AAC blocks also fall under grade one. Thus, without any uncertainty, the AAC blocks can be easily utilized for construction purposes.

Checking hardness, alongside compressive strength, is also significant. Generally, this mechanical property test was conducted using a nail or a steel knife. If a scratch or dent found on the surface during testing, it designates inadequate hardness. However, in this work, no such imperfections were observed on any of the bricks or blocks samples. Thus, it can be concluded that all types of blocks exhibit good hardness.

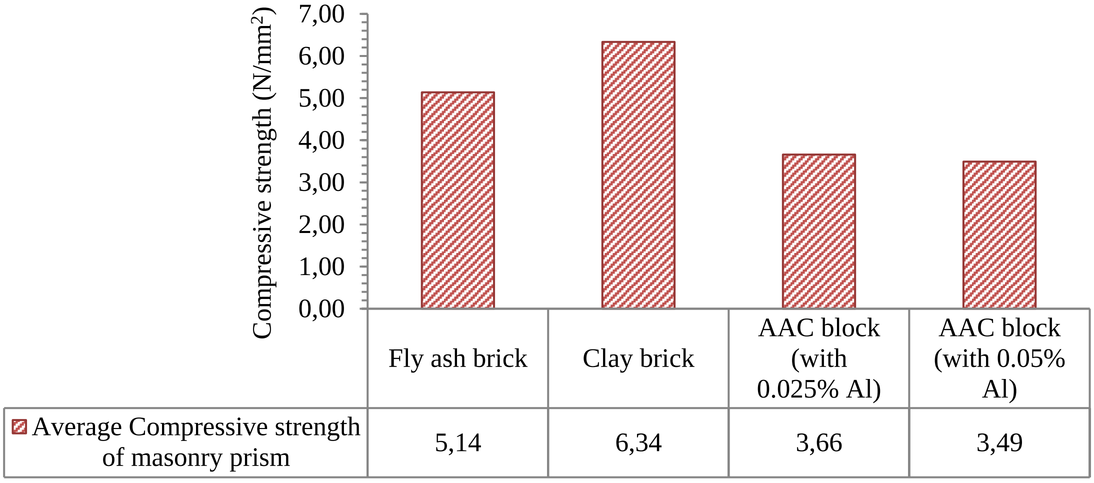


Fig. 13. Comparison of compressive strength values of masonry prism

The average compressive strength of masonry prisms prepared by fly ash bricks, clay bricks and AAC blocks with 0.025% and 0.05% of Al powder have been illustrated in the Figure 13. In this work, the compressive strength obtained from the brick unit was higher than that of the masonry prism in case of all types of bricks. A similar pattern had been reported in ref. [7]. The prisms are generally expanded in lateral direction due to Poissons effect when subjected to axial load. However, this lateral expansion was restrained at the top and bottom surfaces because of friction between the steel plates of the loading machine and the prism surfaces. Consequently, the top and bottom of the prism experienced confined compression, while the central portion of the prism experienced tensile force. The depth of the compressive zone was influenced by the dimensions of the loading surface. Since masonry is weak in tension due to the fragile brick-mortar interface, this tensile zone becomes susceptible to cracking.

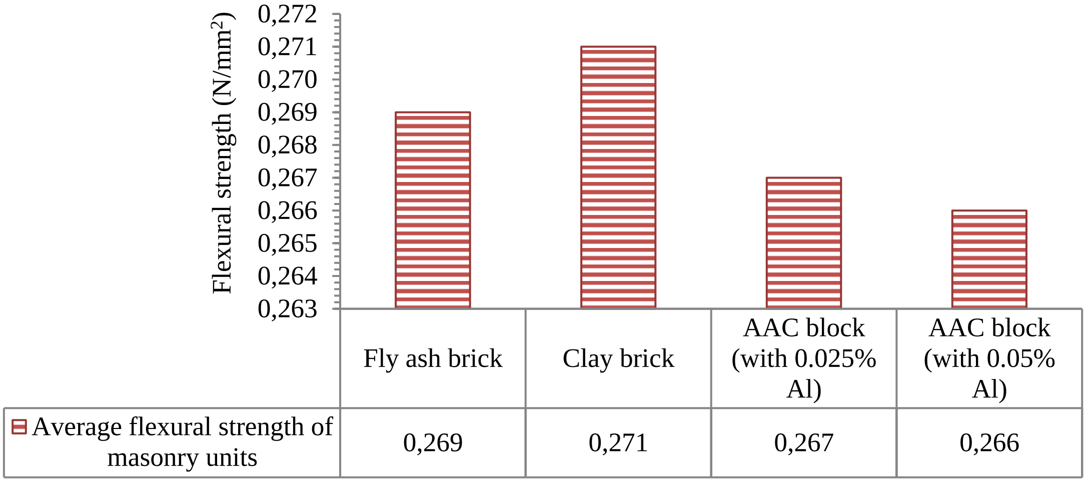


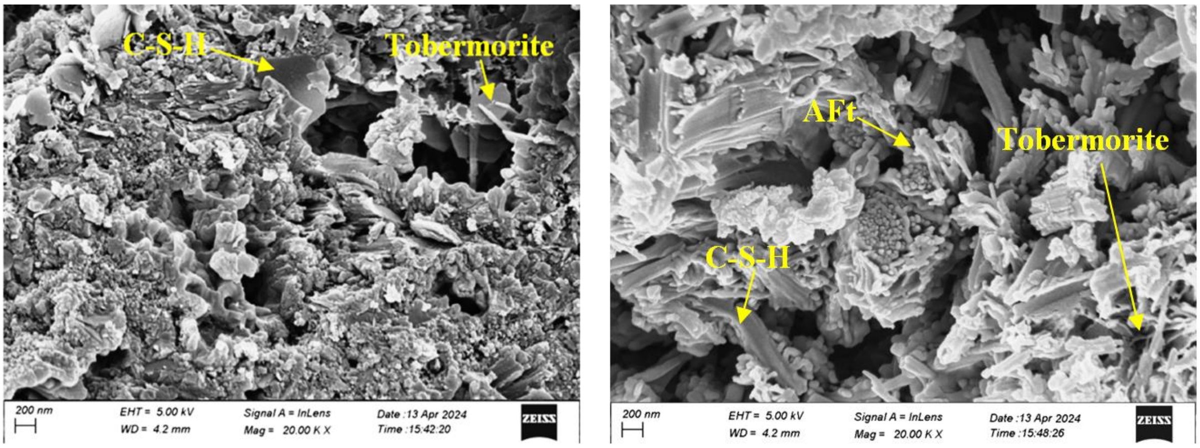
Fig. 14. Comparison of flexural strength values of masonry prism

On the other hand, the average flexural strength of masonry prisms prepared by fly ash bricks, clay bricks and AAC blocks with 0.025% and 0.05% of Al powder have been illustrated in the Figure 14. The flexural strength of fly ash bricks, clay bricks, and AAC blocks masonry was comparable, showing similar performance under bending forces. However, AAC blocks are gaining preference in the construction sector, particularly in seismically active areas, due to their exceptional technical advantages. In addition, their lightweight nature increases seismic performance by reducing the inertia forces subjected on a building during an earthquake. The lesser weight minimizes structural stress, decreasing the possibility of collapse.

4.3. Microstructural Analyses

The principal hydration products of AAC are tobermorite and C-S-H gel. Figures 15 (a) and (b) illustrate the scanning electron microscopy (SEM) images of the AAC samples containing 0.025% and 0.05% of aluminum powder by weight, respectively. As compared to AAC with 0.05 % aluminum powder (Figure 15(b)), AAC with 0.025% aluminum powder (Figure 15(a)) had greater hydration products. AAC sample with 0.025% aluminum powder interlaced to form a comparatively strong body.

It can be observed from Figure 15(b) that the surface morphology was uneven, and the structure was loose rather than densely packed. When more aluminum powder was added, the combination of micro and macro pores became more apparent. The porous nature of the AAC samples may result in a high-water demand during the experiment. As a result, increasing the amount of aluminum powder reduced the compressive strength. A similar tendency can be noticed in terms of density. This density reduction is helpful to the lightweight properties of AAC blocks, making them easier to handle and decreasing the load on structural components. However, it had been found from the literature [32, 33] that the microstructure of fly ash and clay brick had the minimal number of extremely small pores, thus the structure was densely packed and provided higher compressive strength.



(a) (b)

Fig.15. SEM images of the AAC samples containing: (a) 0.025% and (b) 0.05% of Al powder

4.4. Cost Analysis

The cost analysis of brick work included the expenses associated with materials such as brick, sand, and cement, as well as the expenses related to labor. To demonstrate that which variety of brick work is cost effective, an example had been considered in this study for cost analysis purpose. Assumed that a room of 3.6 m x 3.6 m internal dimensions. Wall thickness was considered 250 mm.

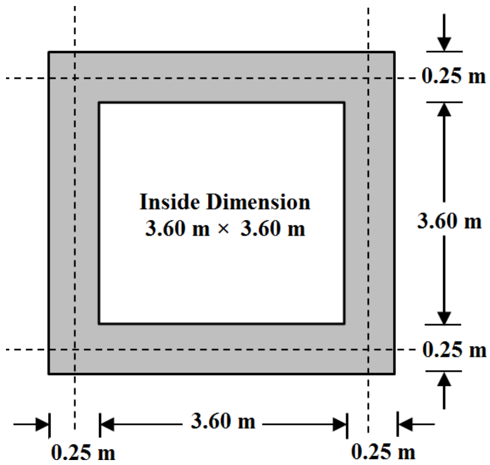


Fig. 16. Plan view of the room

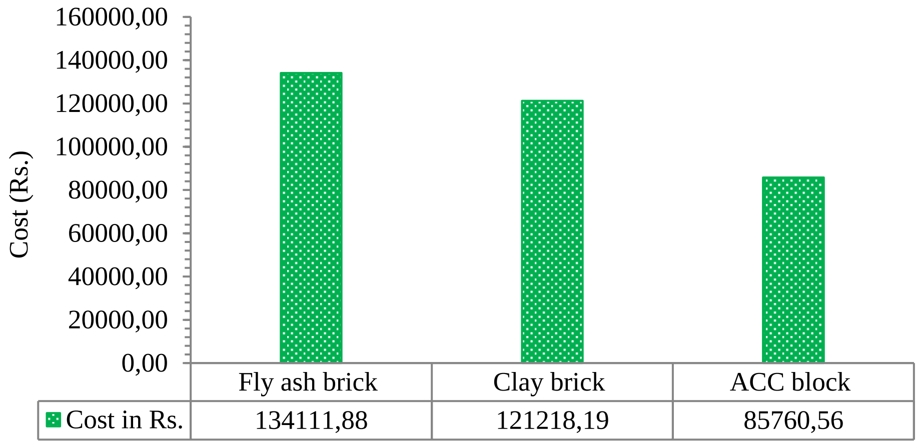


Fig. 17. Total cost for the estimated plan construction

Two windows of 1.5 m x 1.2 m and one door of 1.5 m x 2.1 m dimensions were provided to the room. The height between bottom of slab and top of plinth beam was taken 3.75 m. The plan view of the room has been shown in Figure 16. The detail estimation of the room has been given in Appendix A. The total cost comparison for the estimated plan is shown in the Figure 17. It has been observed from the cost analysis that the total cost for constructing the estimated plan using ACC blocks was 1.56 and 1.41 times lesser than fly ash bricks and clay bricks respectively.

5. Conclusions

The current work presents potentials of AAC block as an alternative in construction sector and compares it with traditional bricks such as fly ash brick and clay brick. AAC blocks of different percentage (0.025 % and 0.05 %) of aluminum powder and the masonry prisms of these AAC blocks as well as fly ash bricks and clay bricks were prepared in the laboratory. Masonry prism is a small-scale assemblage of masonry units and mortar, constructed to represent the material behavior of a larger masonry structure. As because of large pore diameters, AAC blocks exhibit lesser density and weight as compared to traditional bricks, causing it suitable for decreasing the structural self-load. A masonry structure constructed with AAC blocks thus performs well in terms of earthquake resistant compared to a structure prepared with fly ash bricks or clay bricks. The compressive strength of AAC block was observed to be 5.01 N/mm^2 higher than the minimum strength according to IS code. In addition, both the compressive strength and flexural strength of all varieties of masonry prisms were investigated. The compressive strength of a masonry unit was found higher than that of the masonry prisms in all cases. It was found that the AAC blocks contain minimal moisture, thus suitable for the walls subjected to damp environments continuously as compared to the walls prepared by using fly ash bricks and clay bricks. The microstructure analysis performed using SEM equipment, depicted that the inclusion of aluminum powder in the AAC led to formation of a greater number of micro and macro pores. Moreover, it had been observed that the pore size increased with the rising amount of Al powder in AAC. Finally, the study illustrated with an example the cost effectiveness of AAC. With the use of AAC, the construction cost was reduced by 29% and 36% as compared to clay bricks and fly ash bricks respectively.

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Appendix A: Detail Estimation of The Room

First of all, the calculation has been done for 1 m^3 of brickwork volume.

The size of brick with mortar = 0.24 m × 0.12 m × 0.085 m

The actual size of brick = 0.23 m × 0.11 m × 0.075 m

Numbers of brick required in 1m^3 with mortar = 1/(0.24 × 0.12 × 0.085) = 408 Nos.

The only volume of brick = 408 × (0.23 × 0.11 × 0.075) = 0.7742 m^3

Mortar quantity required = 1 – 0.7742 = 0.2258 m^3

Including 10% wastage of mortar (wet volume) = 0.2258 + (0.2258 × 10/100) = 0.2484 m^3

Dry volume of mortar = wet volume + 33% of wet volume

= 0.2484 + (0.2484 × 33/100) = 0.3304 m^3

Cement Mortar ratio taken = 1:3

Volume of cement = (1×0.3304)/4= 0.0826 m3

Number of cement bags = 0.0826/0.0347 = 2.38

Volume of sand = (3× 0.3304)/4= 0.2478 m^3

Once the material quantity is evaluated, the subsequent step involves calculating the material cost. This is then monitored by adding the labor charges to arrive at the total expense of the room brick or block work. Assumed that the brick or block price = X Rs. The cost analysis for the room brick work shown in the Figure 13 has been presented in the Table A. Hence, the total quantity of the masonry works for that particular room = 11.81 m3.

Table A. Cost Analysis for the room brick work

Cost Analysis for 1 m^3 of brick work	Unit	Quantity	Rate (Rs.)	Amount (Rs.)
Material for 1 m^3 of brickwork				
Bricks/Blocks	Nos.	408	X	408X
Cement for mortar	Bag	2.38	450	1071.00
Sand for mortar	m^3	0.2478	1130	280.01
Labor rate for brickwork per m^3				
Mason (brick layer) 1stclass	Day	0.4	700	280.00
Mason (brick layer) 2ndclass	Day	0.4	620	248.00
Coolie	Day	1.43	550	786.50
Bhisti/ Waterman	Day	0.20	550	110.00
Total				408X + 2775.51
Add for Water charges	@	1.00%		4.08X + 27.76
Total				412.08X + 2803.27
Add GST (multiplying factor)		0.1405		57.90X + 393.86
Total				469.98X + 3197.13
Add for contractor's profit and overheads	@	15%		70.50X + 479.57
Total				540.48X + 3676.70
Add cess	@	1.00%		5.40X + 36.77
Total cost of 1 m^3 of brickwork				545.88X + 3713.47

Fly ash brick price per piece = 14.00 Rs.
Clay brick price per piece = 12.00 Rs.
ACC block price per piece = 6.50 Rs.
Cost of 1 m3 of brickwork using fly ash brick = (545.88 × 14.00) + 3713.47 = 11355.79 Rs.
Cost of 1 m3 of brickwork using clay brick = (545.88 × 12.00) + 3713.47 = 10264.03 Rs.
Cost of 1 m3 of brickwork using ACC block = (545.88 × 6.50) + 3713.47 = 7261.69 Rs.
Total cost of 11.81 m3 of brickwork using fly ash brick = 11.81 × 11355.79 = 134111.88 Rs.
Total cost of 11.81 m3 of brickwork using clay brick = 11.81 × 10264.03 = 121218.19 Rs.
Total cost of 11.81 m3 of brickwork using ACC block = 11.81 × 7261.69 = 85760.56 Rs

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