RESEARCH ARTICLE

INTERNATIONAL RESEARCH JOURNAL OF MULTIDISCIPLINARY TECHNOVATION

Asian Research Association

DOI: 10.54392/irjmt2442

Stress Strain Behaviour of Solid Block Masonry Prism under Axial Compression

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DOI: https://doi.org/10.54392/irjmt2442

Received: 29-02-2024; Revised: 20-04-2024; Accepted: 25-05-2024; Published: 14-06-2024

Abstract: Masonry is possibly the primary construction element currently in widespread use throughout the world. Load-bearing masonry building is prevalent in developing countries for home construction. When properly constructed, masonry is frequently a more cost-effective and energy-efficient alternative to reinforced concrete for wall building. In addition to performing the dual roles of supporting weight and enclosing space, structural masonry boasts a high level of fire resistance, thermal and acoustic insulation, and exposure protection. The remarkable durability and low maintenance costs are further evident benefits. Masonry has a significant role in building construction, particularly in structures, as it is regarded as the primary component of the building. The eco-friendly solid block is prepared by adding the following by-products like coal ash, granite powder, olivine sand etc., all these ingredients used for manufacturing the solid block are waste materials from various industries. Thus, extensive testing is necessary to assess their load carrying capacity and secant modulus accurately. Masonry prisms were developed with five-layer solid blocks and tested for their stress-strain characteristics and secant modulus and the test outcomes were compared with conventional fly ash cement blocks. Eco-friendly solid blocks offer a persuasive substitute for ecologically conscious approaches to building by preserving structural integrity and functionality while promoting sustainability.

Keywords: Masonry Prism, Coal Ash, Olivine Sand, Stress-Strain and Secant Modulus.

1. Introduction

Brick masonry is the chief building element and it provides several utility to the building. The Brick Masonry is a mixture of bricks and mortar that creates a distinctive material. Brick units are generally easy to build and handle, have strong compressive strength, and can easily bond with a mortar. Masonry is typically weak in tension because to the weak interface between two distinct material phases. Thus, it is anticipated that masonry structures will withstand solely compressive forces [1]. It is because of the laying pattern and the relationship between the units that masonry walls and columns behave as integral elements. The stability of a masonry wall depends on elements such as the type and thickness of mortar, the shape, size, and strength of the masonry unit, and the quality of craftsmanship. In this study, masonry blocks are made of fly ash, coal ash, lime, olivine sand granite powder and quarry sand in various proportions. All the material used for making of block is the by-product which is available from the local industries. Therefore, the eco-friendly solid block is very cost effective and available in abundance at cheap cost. The propensity of the masonry element to fail by lateral splitting will increase as the proportion of mortar joint thickness to height of the unit increases, hence the influence of the mortar joint is much less in block masonry. Because mortar joints are often the weakest element of masonry, fewer joints result in a higher efficiency factor. Masonry is the main part of the building components, which is widely used in industry as an infill material. Cost is the important aspect in the construction industry, any new material which is came into construction market for sale, its price and performance will determine the success of the material. Material with high cost and better performance, low cost and poor performance will not more attractive in market, material which have low cost with better performance will attract more customers. By using the waste materials, in the construction industry, the natural resources are kept in a sustainable way [2]. Previous studies have examined the properties of masonry, including its compressive strength and stress-strain characteristics, as well as its components, such as mortar and brick [3-7].

Prisms are compact structures made of masonry units with a thickness of one to three units, while masonry wallettes are short walls made of many courses with a width of three units or more [8].

Eco-friendly blocks provide promising solutions for sustainable construction by reusing industrial waste materials, lowering environmental impact, and increasing resource efficiency. However, a lack of extensive research into their stress-strain behavior creates a huge information gap. Understanding the mechanical properties, especially compressive strength, of masonry blocks created from industrial by-products is critical for their widespread use in construction projects. Furthermore, understanding their durability, bond strength with mortar, and compatibility with various structural systems is critical for making educated decisions in sustainable construction methods. Addressing this research gap would not only help to advance eco-friendly construction approaches, but will also make it easier to develop design guidelines and standards for properly incorporating these new materials into structural applications.

2. Literature Review

Kim Hung Mo and Tung-Chai [9] examined the impact of fly ash and bottom ash on the manufacturing of bricks and blocks. The test findings suggested that bottom ash might be utilised as an aggregate to reduce the density bricks and blocks. Wasim *et al*. [10] examined the mechanical properties of coal ash bricks. As a result of their porous microstructure, unburned coal ash bricks were lighter in weight. Shamiso *et al.* [11] studied the impact of lime-coal fly ash-wood aggregate combinations on mechanical strength properties. Singh *et al.* [12] carried out tests on cement mortar (CM) specimens. The compressive strength of CM has decreased as the percentage of cement and sand in the mixture has increased. To produce workable mortar, ideal water content must be calculated. Reduction in cement content necessitates further water to make mortar workable. Gourav and Reddy [13] observed that fly ash brick masonry possesses better flexural bond strength compared to burned clay brick masonry. Freeda Christy *et al*. [14] examined the compressive strength and modulus of elasticity of fly ash brick masonry and clay brick masonry. This study found that incorporating fly ash into brick masonry enhances bond strength and alters the microstructure of the brick-mortar interface. The adobe block and masonry units were created by Feng Wu *et al.* [15]. The ratio of mortar to block strength influences the strength and stress-strain behaviour. The study displays that the relationship between mortar strength and block strength affects the compressive strength, initial tangent modulus, and Poisson's ratio of a prism. Nwofor [16] presented experimental findings on the mechanical characteristics of brick work. These results indicate that the compressive strength of brick units and mortar can reliably predict the elastic property of masonry. Superficial relationships have been established to calculate the modulus of elasticity of bricks, mortar, and masonry based on their compressive strengths. Mosalam *et al.* [17] examined the mechanical properties of masonry. Prism by 30 percent Normal stress has an effect on masonry shear behaviour with high normal stress, dilatancy was minimal. Venkatarama Reddy found that the strength parameter of the brick and the shear bond significantly affect the strength of the masonry [18]. Test outcomes indicate that the shear bond strength can be changed without altering the masonry unit and mortar. Mehar Babu & Subramaniam performed an experimental research on the compressive collapse of masonry prepared from soft clay bricks [19]. Masonry built with soft bricks exhibited a lower strength compared to masonry composed of both bricks and mortar, irrespective of the strength of the mortar. Gumaste *et al* aimed to investigate the characteristics of two types of brick masonry [20]. The study also examined the size effect, bonding arrangement, and failure patterns. The primary issue for the failure of masonry is the breakdown of binding between brick and mortar when lean mortar is used. When 1:6 mortar is utilized, the specimen fails because of brick splitting.

Gihad Mohamad *et.al* [21] investigated the concrete block masonry which is constructed with two different blocks with four distinct kinds of different mortar. Hemant *et.al* [22] developed a Masonry prism were constructed using hand-moulded clay bricks. The experimental stress–strain graphs shows that prism strength, failure strain, and modulus of rupture. Using intermediate mortar resulted in masonry with an approximate 13% reduction in prism strength compared to using strong mortar. However, strain failure was observed to be 50% higher. Sarangapani *et al* [23] explored the effect of several types of brick mortar on masonry prisms. Masonry prism compressive strength is directly proportional to bond strength. It is evident from the data that masonry compressive strength rises as bond strength increases, while mortar strength remains the same.

Nalon *et al* [28] performed a study to investigate several factors that affect the strength of masonry prisms. They concluded that blocks exhibit significantly greater strength and rigidity compared to mortar, and vice versa. Baneshi, *et al* [29] examined the compressive stress-strain characteristics of brick masonry prisms without reinforcement. The study determined that the strength characteristics of masonry are impacted by the specific type and shape of bricks and mortar employed. Yu and Ji [30] constructed brick prisms by including several types of mortar and augmenting them with steel fibres (SF) as an additional constituent. The strength of SF's mortar was enhanced in comparison to traditional mortar.

3. Experimental Investigation

3.1 Casting and testing of coal ash based solid blocks

Eco friendly solid blocks were prepared with the combination of coal ash, lime, gypsum, fly ash, granite powder, olivine sand and quarry sand in different combinations. The Olivine sand is sourced from the Salem magnesite firm located in Salem, India. The source of fly ash is MTTP, located at Metturdam, India, Coal ash is obtained from SIPCOT, located in Perundurai, India. Locally sourced slaked lime, quarry sand and gypsum are procured. The waste powder of granite is obtained from a nearby granite mill. The properties of all ingredients are listed in Table 1. The process of casting and curing solid blocks involves several steps. Initially, the various raw components and water are thoroughly blended in a mixer machine to produce a homogeneous mixture. This combination is then transferred to a belt conveyor, which takes it to the hydraulic press. In the press, the mixture is compacted under high hydraulic pressure into block moulds, resulting in the required shape and density. Once moulded, the blocks are taken from the moulds and allowed to cure.

To begin curing, the blocks are set in open air for two days to dry. After that, they are stacked and covered with a damp towel or sprayed with water to keep moisture in, then left for another 14 days to cure completely. This curing process maintains the durability and endurance of the eco-friendly solid blocks. The dimensions of the solid blocks are 230mm x 230mm x 75mm [2]. Three variants of blocks were used in this work. These blocks were compared with conventional solid blocks. These eco-friendly solid blocks were designated as GSB1, GSB2, and GSB3, and conventional solid blocks were designated as CFAB. The mix combinations of the solid blocks are listed in Table 2 and Figure 1 illustrates solid blocks following removal from the mould.

Figure 1. Casting of eco-friendly solid blocks

Table 1. Properties of materials

Properties	Fly ash	Coal Ash	Lime	Gypsum	Granite powder	Quarry sand	Olivine sand
Specific gravity	2.21	2.27	2.18	2.39	2.87	3.07	2.86
Surface area(m^2/kg)	344	302	308	329	283	287	298
Bulk density(kg/m^3)	1135	998	673	893	1493	1977	1433
Composition (%)							
SiO_2	45.53	56.52	0.27	2.98	66.14	57.66	37.12
CaO	20.50	16.82	73.10	30.11	2.19	8.25	0.40
MgO	1.18	4.20	0.67	3.46	1.07	5.45	49.61
Fe_2O_3	3.54	13.18	0.30	0.80	2.83	7.97	12.14
Al_2O_3	18.44	3.40	0.41	1.03	13.75	16.85	0.30

Table 2. Mix combinations of solid block

Mix ID	Ingredients (%)						
	FA	CA	L	G	GP	OS	QS
GSB1	55	-	15	-	10	10	10
GSB2	40	15	10	5	10	5	15
GSB3	30	25	5	10	10	15	5
Ingredients (%)	C	FA	L	QS	-	-	-
CFAB	40	20	10	30	-	-	-

FA - Fly Ash, CA- Coal Ash, L - Lime, G - Gypsum, GP- Granite Powder, OS - Olivine sand, QS - Quarry Sand, C-Cement, GSB- Green solid block, CFAB- Conventional fly ash block

Table 3. Properties of solid blocks

Properties of blocks	Solid block ID			
	GSB1	GSB2	GSB3	CFAB
Compressive strength N/mm^2	15.88	15.25	16.75	13.70
Water absorption %	9.22	9.13	9.01	13.87
IRA kg/m^2/min	3.39	3.20	3.15	5.10
Density Kg/m^3	20.88	20.50	20.07	23.81

The properties of solid blocks were examined in accordance with BIS 2185: 2005 [24] and it is listed in Table 3. The mechanical properties of blocks were assessed using a total of 96 solid blocks. According to the findings, the GSB3 type blocks acquired the highest compressive strength. Compared to conventional solid blocks, it is raised by 22.2%. GSB3 has 35.03 percent less water absorption than CFAB. The density of blocks of the GSB variety varied between 20.07 kg/m^3 and 20.88 kg/m^3. Conversely, the CFAB possessed a density of 23.81 kg/m^3. The IRA of GSB3 was 3.15 kg/m^2/min, which is lesser than the IRA of the other type blocks.

3.2 Mortar preparation

Mortar is the paramount material to keep the masonry block in the rigid position. It acts as glue between the masonry blocks. In this work the mortar ratio was chosen as 1:3, 1:4.5, and 1:6 and the proportions were taken by mass. According to BIS1905 :1987 [31], CM 1:3 and CM1:4.5 are classified as high mixes, while CM1:6 is classified as a medium mix. The mortar consists of cement and M- sand in the above-mentioned proportions. Cubes measuring 70.6 mm were cast in the laboratory to examine the strength and other properties of mortar. In accordance with Indian Standard BIS 2250:1981 [25], batching, mixing, cube casting, and curing are performed. A total of 27 mortar cube specimens have been developed for this investigation to assess mortar strength.

3.3 Stress strain behaviour of solid block and mortar

The stress-strain behaviour of cement mortar cubes and solid blocks was evaluated using a compressive testing machine. Dial gauges were mounted in the horizontal and vertical planes in order to quantify the deflection of each specimen. This investigation employed a dial gauge with a 0.01 mm minimum count. Mortar and solid block specimens were subjected to a progressive axial compressive load. The loading rates for testing mortar and solid block are 1.16 KN/sec and 12.34 KN/sec, respectively. Using dial gauges, periodic deflection measurements were taken. Figures 2a and 2b illustrate the experimental test configuration employed to assess the stress and strain characteristics of solid blocks and mortar cubes, accordingly.

3.3.1 Secant modulus

The secant modulus of a masonry prism is a key factor in understanding how the material behaves under stress. It essentially tells us how stiff the masonry is when subjected to different levels of loading. Unlike other measures like the chord modulus, which only considers a single point on the stress-strain curve, the secant modulus gives us a broader picture, accounting for the material's response across a range of stress levels. The secant modulus refers to the gradient of a line connecting the point of origin of the stress-strain relationship with a point where the stress-strain curve intersects with a predetermined stress value, often around 25% of the maximum stress. Typical different elastic modulus graph is exemplified in Figure 3.

3.4 Test Results on Stress-Strain Behaviour of Coal Ash Solid Blocks and Mortar Mix

3.4.1 Stress-strain behaviour of coal ash solid blocks

The summary of test results for the different solid blocks evaluated under the monotonic vertical loading condition. Table 4 presents the findings of tests performed on the stress-strain behaviour of various solid block types and mortar.

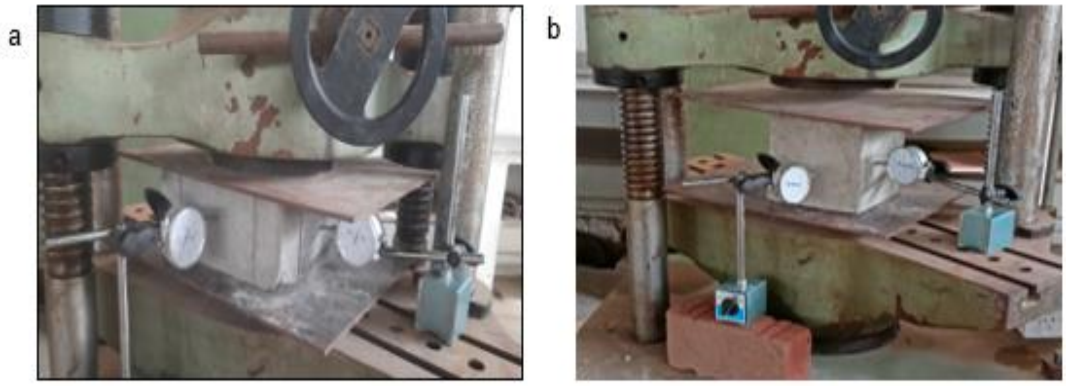

Figure 2. a) Stress- strain test setup of solid block, b) Stress- strain test setup of mortar cube

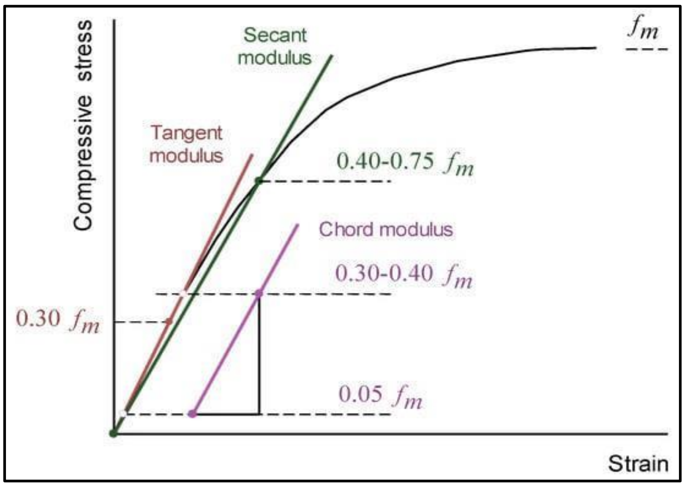

Figure 3. Types of elastic modulus [32].

Table 4. Summary of test outcomes for solid blocks under uniaxial loading

	Coal ash based solid block				
Mix ID	**Ultimate load (KN)**	**Ultimate stress (N/mm²)**	**Failure strain**	**Secant modulus (N/mm²)**	**Energy absorption capacity (kN-m)**
GSB1	807	15.25	0.0190	5745	4.24
GSB2	840	15.88	0.0120	5925	4.91
GSB3	886	16.75	0.0095	6356	6.26
CFAB	727	13.75	0.0210	4325	2.98

According to the findings, the GSB3 solid block exhibited the highest peak stress when compared to other types of blocks, including conventional fly ash blocks (CFAB). GSB3 blocks have 21.8% more strength than CFAB and 4.6 % more than GSB2 blocks. The GSB3 block has the lowest strain at failure compared to other blocks. The failure strain of the GSB3 block is 38% less than that of the GSB2 block. The GSB1 block was identified in the investigations to have 54.76% more failure strain than the CFAB block. GSB3 blocks have a secant modulus that is much greater than that of any other sorts of blocks. The secant modulus of GSB3 is 11 %, 8 %, and 47 % greater than those of GSB2, GSB1, and CFAB, respectively. The results demonstrate that GSB3 has more energy absorption capacity than GSB1, GSB2, and CFAB, respectively.

The correlation between a high modulus of elasticity (MOE) and the equivalent compressive strength in solid blocks can be attributed to the microstructure of the material and its capacity to withstand deformation when subjected to compressive forces. When a solid block is subjected to a load, it undergoes compressive stress, resulting in deformation of the material. A higher MOE indicates enhanced resistance to deformation, resulting in reduced strain and ultimately increased compressive strength.

3.4.2 Stress-strain behaviour of various grades of mortar mix

The summary of test results for the different various mortar grades are evaluated under the monotonic vertical loading condition. Table 4 presents the findings of tests performed on the stress-strain behaviour of various grades of mortar.

Figure 4 illustrates the stress-strain behaviour of various mortar mix proportions. Cement mortar 1:3 has 86 % more ultimate compressive strength than CM 1:4.5. Cement mortar 1:6 has a compressive strength that is 55.53 % and 76 % lower than mortar grades 1:4.5 and 1:3, respectively. C.M 1:3 has a compressive strain that is 11.76 % and 30.13 % more than mortar grades 1:4.5 and 1:6, respectively. CM 1:3 has a modulus of elasticity that is 43.58 % more than CM 1:4.5 and 75.77 % greater than CM 1:6. The 1:3 cement mortar has a greater Secant modulus value than other cement mortar grades. Energy absorption of CM 1:3 is higher than that of other mortar types.

3.5 Casting and testing of solid block prism

The combinations of three distinct mortar mix proportions and four distinct block masonry prism types were cast. Figure 5 represents the casting of masonry block prisms with various mortar mixtures. For prism construction, a 400 mm-high, five-block masonry wall with a 10mm-thick mortar thickness was utilised. 60 specimens were constructed to investigate the stress–strain characteristics of block masonry prisms in this study.

In order to construct a masonry prism using solid blocks arranged in five layers, it is important to first ensure that the surface is clean and level for the construction process. Lay the first layer of solid blocks in a straight line, using mortar to secure them firmly in place. The process of stacking successive layers should be continued, with the joints being staggered to enhance stability and strength. To ensure a firm binding between each layer, it is recommended to apply mortar. After the construction of the prism, it is imperative to ensure that it undergoes a suitable curing process. The process of curing entails maintaining a wet environment for the masonry in order to promote adequate hydration of the mortar and concrete blocks. Curing can be accomplished through the consistent application of water over the surface or by employing damp blankets to effectively maintain moisture. Following the curing phase, it is necessary to subject the masonry prism to testing in order to verify its structural performance.

The prisms made from solid block masonry were examined in compliance with ASTM C1314-21.[26]. Analysed the stress-strain characteristics of the masonry block prism using a 100-ton Universal Testing Machine (UTM). Utilizing a five-layer height, the stress-strain behaviour of masonry prisms and the secant modulus of a block masonry prism were determined.

Table 5. Summary of test results for various mortar grades under uniaxial loading

Mortar grades				
Mortar mix	**Ultimate stress (N/mm^2)**	**Failure strain**	**Secant modulus (N/mm^2)**	**Energy absorption capacity (kN-m)**
CM 1:3	20.50	0.0094	3654	5.92
CM 1:4:5	11.02	0.0085	2545	3.83
CM 1:6	4.90	0.0073	885	1.59

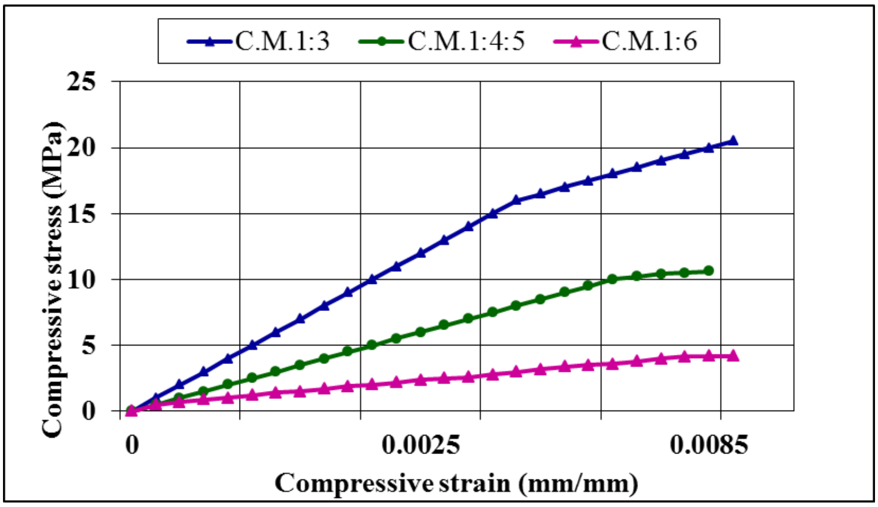

Figure 4. Stress-strain behaviour of various mortar mix proportions

Figure 5. Casting of solid block masonry prisms

Figure 6. Experimental setup for testing of solid block masonry prism

The stress-strain behaviour of different solid blocks, including GSB1, GSB2, GSB3, and CFAB with different mortar grades for CM 1:3, CM 1:4.5, and CM 1:6, respectively, is shown in Table 5. The prism's deflection was measured using a 0.01 mm least count compressometer. Figure 6 depicted the experimental test setup for the solid block masonry prism.

3.5.1 Stress-strain performance of solid block masonry prism

Table 6 indicates the summary of test results for various types of block masonry prisms. The GSBM3 has higher ultimate stress than any other C.M 1:3 masonry prism. GSBM3 has strength of 12 %, 9 %, and 18 % more than GSBM2, GSBM1, and CFABM, respectively. In CM1:3, the GSBM3 has 2.34 %, 10.62 %, and 5.83 % less ultimate stress than the GSBM2, GSBM1, and CFABM.

Figure 7 shows the Stress-Strain plot of solid block masonry prisms with C.M 1:3. The masonry prism of GSB3 blocks has a higher failure strain compared to other blocks of mortar grade 1:3.

The failure strain of GSBM2 is 6%, 2%, and 28% higher compared to GSBM3, GSBM1, and CFABM, respectively. The masonry prism of GSB3 has 20%, 12%, and 26% higher secant modulus than GSB3, GSB1, and CFAB, respectively.

Figure 8 illustrates the stress-strain behaviour of a solid block prism made with cement mortar 1:4.5. In CM 1:4.5, GSBM2 attained the highest ultimate stress value. The maximum stress of GSBM2 is 16 %, 13 %, and % greater than GSBM3, GSBM1, and CFABM, respectively. CFABM has a lower failure strain than other prisms made of masonry. The secant modulus of the GSBM3, GSBM1, GSBM2, and CFABM were 4210, 4305, 4525, and 3810 N/mm², respectively.

The stress-strain behaviour of a solid block prism made of 1:6 cement mortar is shown in Figure 9. The ultimate stress of GSBM3 has 8%, 2%, and 36% more than GSBM2, GSBM1, and CFABM respectively. The masonry prism of GSB3 blocks has a lower failure strain compared to other blocks of mortar grade 1:6. The lower failure strain of GSB3 is 12%, 7%, and 7% lower compared to GSB1, GSB2, and CFAB, respectively. Compared to other mortar grades 1:6, the masonry prism of GSB3 blocks has a reduced failure strain. GSB2 has a lower failure strain than GSB3, GSB1, and CFAB by 12 %, 7 %, and 7 %, respectively.

Table 6. Summary of test results for various types of block masonry prisms

Mortar grade	**Type of masonry**	**Max. stress (N/mm²)**	**Failure strain**	**Secant modulus (N/mm²)**	**Energy absorption (kN-m)**
Prism made with 1:3 Mortar	GSBM1	7.25	0.0089	4335	14.31
	GSBM2	7.42	0.0085	4664	16.21
	GSBM3	8.12	0.0065	5212	11.25
	CFABM	6.85	0.0091	4120	10.42
Prism made with 1:4.5 Mortar	GSBM1	6.15	0.0083	4210	9.45
	GSBM2	6.35	0.0078	4305	9.97
	GSBM3	7.15	0.0071	4525	14.40
	CFABM	5.75	0.0089	3810	8.40
Prism made with 1:6 Mortar	GSBM1	4.85	0.0077	4009	7.09
	GSBM2	5.15	0.0075	4100	7.43
	GSBM3	5.24	0.0070	4215	9.08
	CFABM	3.85	0.0081	3450	6.40

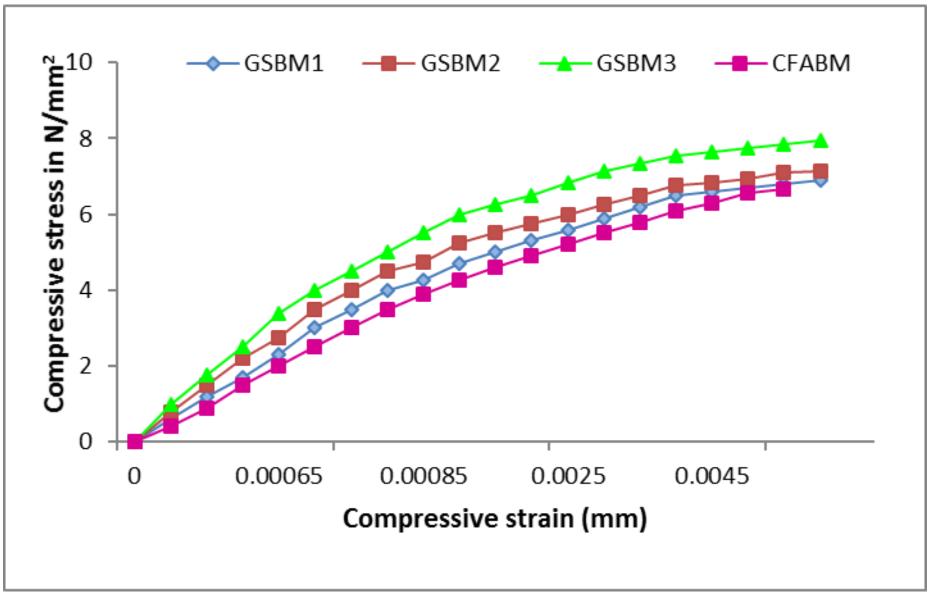

Figure 7. Stress-Strain plot of solid block masonry prisms with C.M 1:3

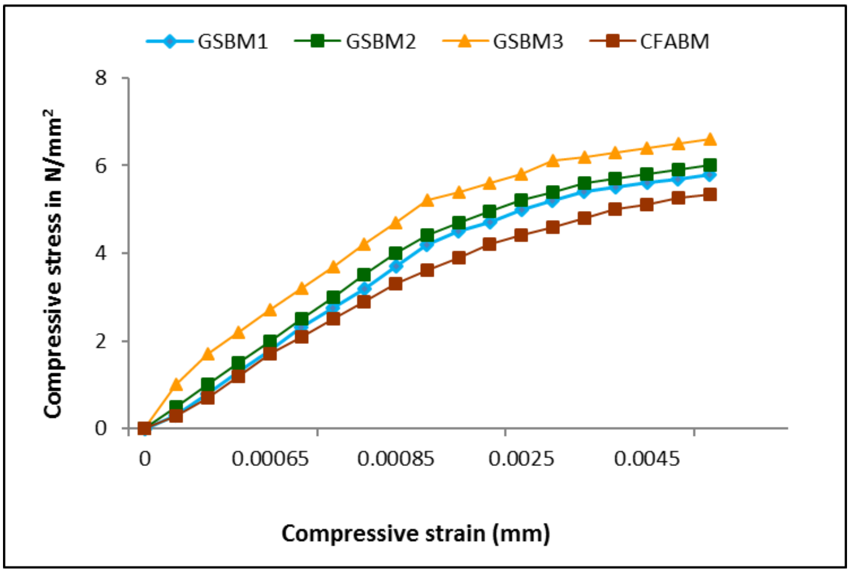

Figure 8. Stress-Strain plot of solid block masonry prisms with C.M 1:4.5

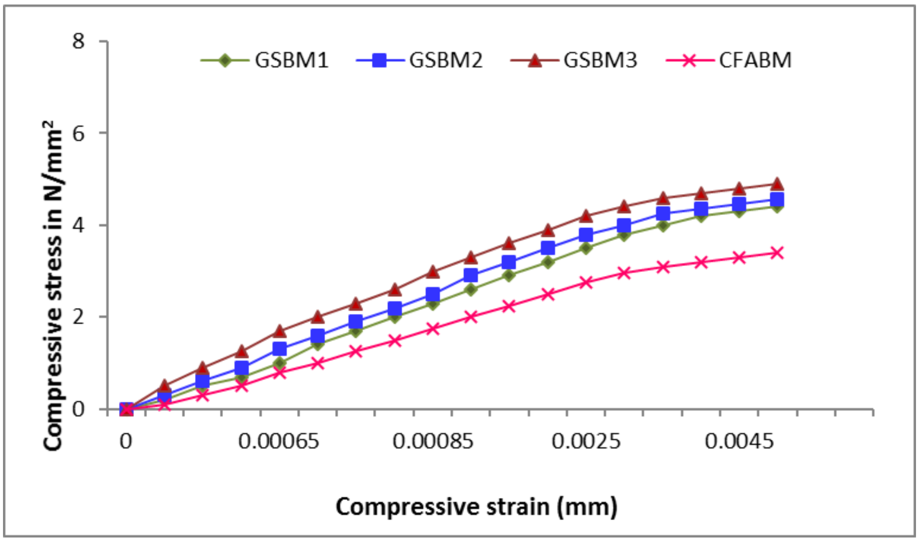

Figure 9. Stress-Strain plot of solid block masonry prisms with C.M 1:6

The secant modulus values range from 4215 kN-m to 3450 kN-m. GSBM1 and CFABM have the most significant and lowest secant modulus values for mortar grade 1:6. It was discovered that improvements in mortar strength and block compressive strength led to an increase in the compressive strength of masonry [27].

4. Conclusions

The experimental investigation was carried out on prisms composed of solid block masonry, employing three varieties of mortar and four distinct types of solid blocks. The subsequent inferences are derived from this investigation:

- ❖ The solid block (GSB3) composed of 25% coal ash, 15% olivine sand, and 10% granite powder has superior strength properties compared to other types of solid blocks.
- ❖ The enhanced compressive strength of green solid blocks (GSB) is primarily attributable to the amalgamation of material characteristics, specifically the fineness of the components employed in their fabrication. Better interlocking qualities and a denser, more homogenous microstructure lead to increased strength
- ❖ The secant modulus of GSB3 blocks is significantly higher than that of all other types of blocks.
- ❖ The results confirm that GSB3 has a higher capability for energy absorption than GSB1, GSB2, and CFAB, respectively.
- ❖ A significant determinant in the determination of the compressive strength of masonry prisms is the compressive strength of the brick and mortar. It gains value in proportion to the

increase in mortar grade and compressive strength of the blocks.

- ❖ The secant modulus of the mortar rises in proportion to the richness of the mortar grade. The 1:3 cement mortar exhibits a greater Secant modulus in comparison to other cement mortar grades.
- ❖ A higher modulus of elasticity (MOE) indicates enhanced resistance to deformation, resulting in reduced strain and ultimately increased compressive strength.
- ❖ The energy absorption of CM 1:3 is more significant than other grades of mortar.
- ❖ Compared to other mortar grades, CM 1:6, the masonry prism of GSB3 blocks has a reduced failure strain
- ❖ Limitations in the investigation of the stress-strain characteristics of solid block masonry prisms that are environmentally favorable may include restrictions on specimen size, discrepancies in material properties, and fluctuations in testing environment.
- ❖ Moreover, the applicability of the study might be constrained by the particular composition and manufacturing techniques employed in the blocks under investigation, which could impede the development of more general conclusions in the domain of masonry engineering.

4.1 Recommendation for future works

An investigation can be conducted to examine the behaviour of solid block masonry using various grades of cement mortar and alternative materials. The failure pattern of the mortar prism can be analysed and numerical studies can be performed. The analysis of several types of brick sand blocks masonry prisms can be conducted.

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Conflicts of Interest

There are no conflicting interests stated by the authors.

Funding

There was no external funding received for this research.

Authors Contribution Statement

E. Kavitha: Writing - Original draft, Methodology, Investigation, Conceptualization; C. Vinodhini: Editing, Validation, Supervision; R. Elavarasan: Writing – Review & Editing; R. Udhayasakthi: Supervision, Methodology.

Data Availability

The data supporting the findings of this study can be obtained from the corresponding author upon reasonable request.

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