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Compressive Stress-Strain Characteristics of Brick Masonry Used in Bangladesh

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Abstract

This article reports the findings of an experimental study into the response of brick masonry to compressive loads. Both brick prisms and brick walls, two types of brick masonry, have been studied in the study. Masonry prisms and walls have the following dimensions: 250x250x375 mm and 480x115x375 mm. In this investigation, we have compared three mortar ratios (using either 1:3, 1:4, or 1:6) and two brick kinds (coal-burned and gas-burned). In order to determine the stress-strain relationships, the load-displacement response of the masonry has been analyzed. Brick masonry's stress-strain characteristic has been found to be affected by the mortar ratio and brick type. It has been discovered that the mortar ratio has an effect on the ultimate strength of the prism and wall specimen. There is a strong relationship between the mortar ratio and the stress-strain relationships for gas-burned prisms. Maximum strength for prisms has been measured at a mortar ratio of 1:4. However, the 1:3 ratio has been evaluated to be optimal for both coal and gas-burned examples, yielding the highest ultimate strength of the brick wall.

Keywords: *Unreinforced Masonry; Coal Burnt Bricks; Gas Burnt Bricks; Mortar ratio; Stress-Strain.*

1 Introduction

Bricks have consistently occupied a significant role in the realm of construction over the course of history, owing to its extraordinary characteristics like as durability, accessibility, fire resistance, insulating capabilities, high compressive strength, and cost-effectiveness (Zhang et al., 2018). Nevertheless, it is commonly recognized that the production of burnt clay bricks has consistently been a technique that requires a significant amount of energy and resources. This has led to negative environmental impacts, including increased carbon footprint and emissions of greenhouse gases. In other locations, the process of preparing bricks typically entails the extraction of topsoil that is agriculturally fertile, characterized by high levels of clay and organic matter. In addition to the degradation of agriculturally productive land, (Nath et al., 2018) have observed that brick masonry constructions have remained the predominant form of structures in Bangladesh. This can be attributed to their advantageous characteristics, such as commendable heat and sound insulation properties, notable compressive strength, convenient availability of materials and labor, satisfactory structural integrity, commendable longevity, and cost-effectiveness. Masonry is a material that is commonly characterized by its inelastic, nonhomogeneous, and anisotropic nature. It is formed of two distinct materials, namely bricks and mortar, which possess significantly different properties. The bricks exhibit more stiffness, while the mortar is somewhat softer in comparison. In the presence of lateral loads, masonry exhibits non-elastic behavior, even within the realm of minor deformations. The tensile strength of masonry is notably low due to its composition of two distinct materials arranged in a regular pattern, resulting in a relatively weak link between them. Hence, it is customary and anticipated for masonry to primarily withstand compressive stresses. The mechanical features of brick masonry, such as compressive strength, stress-strain behavior, and the characteristics of its constituent elements, have been investigated in prior research conducted by (Kaushik et al., 2007) and (Sarangapani et al., 2005). In their study, (Sarangapani et al., 2005) examined the impact of flexural and shear bond strengths of masonry on the compressive-strain properties of brick masonry walls. They utilized several local brick and mortar materials for their investigation. According to (Silva et al., 2021), (Sing et al., 2017) conducted a study which highlights the enduring utilization of brick masonry as a construction material in Bangladesh, owing to its advantageous characteristics.

2 Research significance

The primary objective of this experimental investigation is to determine the mechanical properties of brick masonry, specifically focusing on stress-strain characteristics, compressive strength of brick walls, and brick prisms with varying mortar ratios. This research examines the variations in compressive stress-strain characteristics observed in walls and prisms constructed using bricks that are readily accessible within the local area. This research endeavor represents a comprehensive experimental study aimed at assessing the compressive stress-strain behavior of masonry composed of bricks burned with coal and gas.

3 Materials Properties

Brick

Brick has versatile properties which makes it a popular construction material in the whole world. It is strong, hard, fireproof, abrasion resistant, and provides some degree. In this study, several types of Bricks are used for constructing masonry specimens. There are readily available in Bangladesh, standard brick dimension is 9 .5 x 4 .5 x 2 .75 inches (length x depth x height).

(a) (b)

Figure 1. (a) Coal Burnt brick specimen (b) Gas burnt brick specimen

(a) (b)

Figure 2. (a) Coal Burnt brick specimen curing (b) Gas Burnt brick specimen curing

Cement
Masonry cement is a special blended cement that is mixed in specific proportions with sand and water to form a strong binding mortar. This mortar is notable for its strength, durability, aesthetic appeal, and resistance to atmospheric and chemical deterioration. It is widely used for mortar and stucco work in stonework, block, and brick masonry. Mortar mix consisting of cement: sand proportions (1:3, 1:4, 1:6) were prepared manually. Portland Composite Cement (PCC) as a binder and local sand for the fine aggregate was used to prepare the mortar specimens

Sand
Sand offers the requisite surface area for the film of cementing materials to adhere and to spread. Sand helps to prevent mortar shrinkage. It also prevents the cracking of mortar during setting. The presents of various particles in the unit mass or volume of the sand improve the workability of the mortar mix with minimum voids and make the mortar denser. To determine the particle size sieve analysis is done. Sieve analysis helps to confirm different sizes of particles. Sieves are arranged 4.75mm to 150 microns in ascending order and retained in each sieve is determined after two minutes of vibrating. This test is done by the standard code (ASTM CI36)

4 Experimental Program

The experimental program has been conducted to obtain the compressive strength of masonry from the stress-strain characteristic of brick masonry prism and wall. To gain the goal of the study, the experimental program is especially divided right into a definite sequence of work

Specimen Preparation
A total of 6 masonry prisms and 6 masonry walls Fig: 1 (a), (b) were fabricated using a combination of each kind of brick having three types of mortar to determine the compressive strength. The masonry prisms were cast with five bricks stack bonded and the masonry wall was with five bricks stretcher bonded with specific types of mortar. Bricks were immersed in water for 24 hours before manufacturing, to avoid the absorption of water from the fresh mortars. The thickness of the mortar was maintained from 10 to 12 mm. The size of masonry prisms and walls are 250 × 250 × 375 mm and 480 × 115 × 375mm, respectively. The physical properties of the mortar largely depend on the extent of hydration of cement and the resultant microstructure of the hydrated cement. The hydration of cement is activated in the presence of water. For this reason, curing of cement is obviously required. Structural design is generally based on the 28 days' strength, about 70 percent of which is reached at the end of the first week after placing. In this study wet covering curing method was used for curing (Fig: 2 (a), (b) of masonry prisms and walls.

Compressive stress-strain test of the specimen
Tests on masonry specimens have been conducted using a UTM machine. The brick unit and the structures have tested under load-controlled UTM.

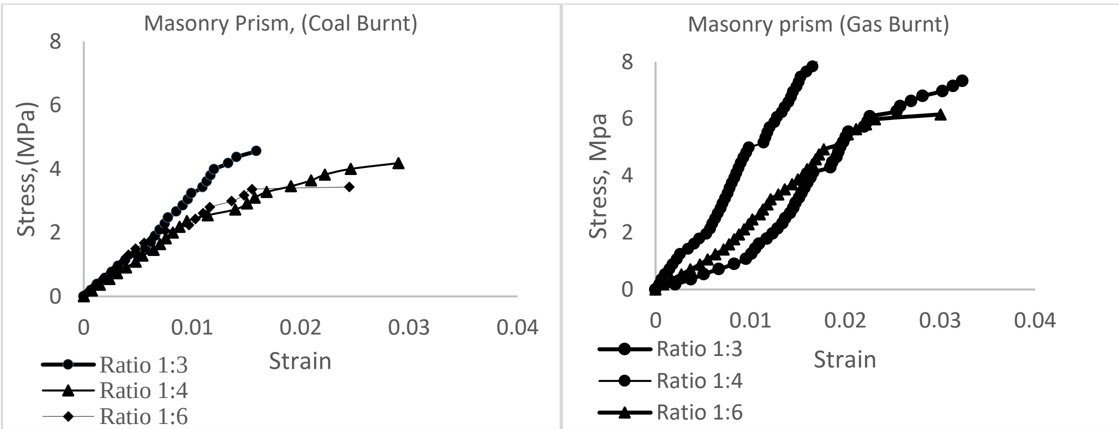
(a) (b)

Figure 3. (a) Instrument setup for prism, (b) Instrument setup for wall.Two Dial gauge readings are used to measure the change in height of the specimen.

Fig: 3 (a) and 3 (b) show the schematic and actual test setup used to test brick masonry prism and wall. The corresponding strains have been measured with the help of a dial gauge reading. Only longitudinal strains are measured using dial gauges, pellets fixed in a vertical direction. The data result is taken at every 10 KN interval. This test has been conducted following the standard method ((ASTM C1314 – 14)).

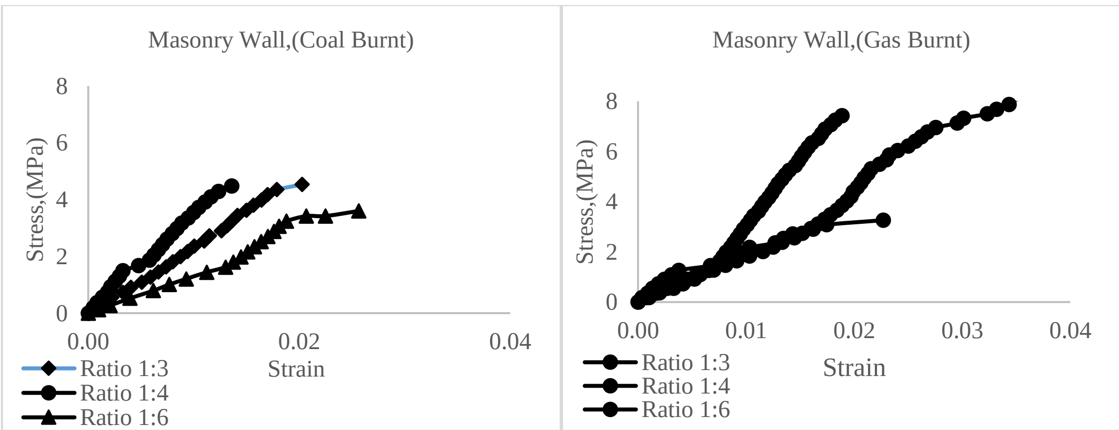
5 Results and Discussion

Stress-Strain responses of the prism having different mortar ratios of coal burnt are presented in Fig: 4 it is seen commonly for all mortar ratios from the Figure 4 (a) with the increase of stress, strain increases linearly at the initial stage, representing the elastic range and nonlinearly at the last stage. With the increase in richness of the mortar, for a particular strain can be seen to larger. As increasing of mortar strength for the specimens, the strength level of stress is amplified. In Fig. 4 (b) it can be seen that the stress value is increased when the ratio of mortar is changed from 1: 3 to 1:4 but this value is decreased at mortar ratio 1:6 up to the ultimate point for gas-burnt brick masonry prism. At some point, both graphs (mortar ratio 1: 3 and 1:4) overlap each other but the ultimate point of both cases is different.



(a) (b)

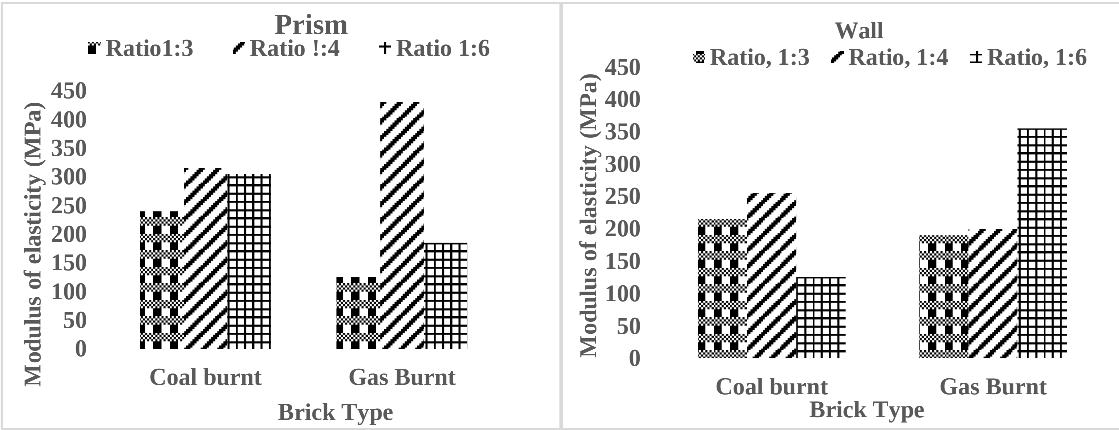
Figure 4. Stress-strain relations of masonry prisms made with different mortar ratios and bricks: (a) Coal Burnt (b) Gas Burnt under compression



(a) (b)

Figure 5. Stress-strain relations of masonry walls made with different mortar ratios: and bricks :a) Coal burnt (b) Gas Burn under compression.

The ultimate strength is decreased gradually when the mortar ratio is increased for coal-burnt masonry as observed in Fig:5(a) masonry wall. Fig. 5(b) presented that the ultimate strength is increased gradually when the mortar ratio is decreased gradually for a gas burnt masonry wall. Based on the experimental investigations in fig:6(a) shows that the modulus of elasticity of the gas-burnt masonry prism is greater than the coal-burnt prism. It is observed that the modulus of elasticity is increased from 240 MPa to 315MPa for coal-burnt brick masonry prism when the mortar ratio is changed from 1:3 to 1:4 but the modulus of



(a) (b)

Figure 6. Comparison of the modulus of elasticity and different types of brick: (a) Masonry Prisms (b) Masonry Walls

elasticity is decreased 305MPa when the ratio is 1:6.This Fig. also shows that ultimate strength is decreased when the mortar ratio changed from 1:3 to 1:4 but this ultimate strength value is increased at the time of mortar ratio 1:6 On the other hand, In Fig. 6 shows that modulus of elasticity is increased from 125MPa to 430 MPa when the mortar ratio is changed from 1:3 to 1:4 but the modulus of elasticity is decreased 185MPa when the ratio is 1:6 for gas burnt brick masonry prism.This Fig. also shows that ultimate strength is increased when the mortar ratio changed from 1:3 to 1:4 but this ultimate strength value is decreased at the time of mortar ratio 1:6. Fig: 6 (b) incorporates the test results in terms of modulus of elasticity, and brick types of masonry wall with several ratios of mortar. The modulus of elasticity is increased from 215MPa to 255 MPa when the mortar ratio is changed

Table 1: Experimental results of different properties of brick masonry specimens

Specimen Type	Brick Type	Specimen No	Mortar ratio	First Cracking Load (kN)	First cracking Strength	Ultimate Load Capacity (kN)	Ultimate Strength (MPa)	Modulus of elasticity (MPa)	Secant modulus of elasticity (MPa)
Prism	Coal Burnt	1	1:3	130	2.47	240	4.56	305	320
		2	1:4	180	3.273	230	4.18	240	240
		3	1:6	150	2.79	184	3.43	315	245
	Gas Burnt	1	1:3	260	4.65	410	7.33	125	275
		2	1:4	320	5.697	535	9.53	430	670
		3	1:6	180	3.165	350	6.15	185	255
Wall	Coal Burnt	1	1:3	110	1.99	250	4.523	215	235
		2	1:4	110	2.05	240	4.471	255	375
		3	1:6	110	1.99	200	4.529	125	170
	Gas Burnt	1	1:3	190	3.52	450	8.233	190	270
		2	1:4	100	1.80	420	7.609	200	400
		3	1:6	80	1.45	180	3.261	355	300

from 1:3 to 1:4 but the modulus of elasticity is decreased 125MPa when the ratio is 1:6 for coal burnt brick masonry wall. This Fig. also shows that ultimate strength is increased when the mortar ratio changed from 1:3 to 1:4 but this ultimate strength value is decreased at the time of mortar ratio 1:6. On the other hand, In same figure shows that the modulus of elasticity is increased from 190 MPa to 200 MPa when mortar ratio is changed from 1:3 to 1:4 but modulus of elasticity is increased 355MPa when the ratio is 1:6 for gas burnt brick masonry wall.

Fig. 6 also shows that ultimate strength is decreased when the mortar ratio is increased. Several types of Mechanical properties were observed from the tested specimens which were presented in Table 1.

6 Conclusions

The experimental study was conducted on masonry prisms and walls using two types of brick and three types of mortar ratios (1:3, 1:4 and 1:6). The following conclusions are obtained from this study.

1) For coal-burnt brick prisms the highest ultimate load is 240kN and the maximum ultimate strength is 4.56 MPa at a mortar ratio of 1:4. For the set of gas burnt prism maximum ultimate load is 535kN and maximum ultimate strength is 9.53 MPa at same mortar ratio.

2) For the set of coal-burnt brick walls maximum ultimate load is 250kN at a mortar ratio of 1:3 and the maximum ultimate strength is 4.529 MPa at a mortar ratio of 1:6. For the set of gas-burnt walls maximum ultimate load is 450kN and the maximum ultimate strength is 8.223 MPa mortar ratio1:3.

3) The stress-strain characteristic of brick masonry specimens is influenced by the mortar ratio.

4) The modulus of elasticity of coal-burnt brick prism varies between 240MPa and 320MPa and gas-burnt brick masonry prism varies between 255MPa and 670MPa. On the other hand, coal-burnt brick masonry wall varies between 170MPa and 375MPa, gas burnt brick masonry wall varies between 270MPa and 400MPa when the mortar ratio is 1:3, 1:4, and 1:6 respectively.

5) The first cracking load for the coal-burnt specimen (prism and wall) is high at mortar ratio 1:3 but in gas-burnt masonry prism and wall, the value is high at ratios 1:4 and 1:3 respectively**.**

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