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Stress-Strain Behaviour of Fly Ash Brick Masonry with Rat Trap Bond

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Abstract: This research examines the compressive strength and stress-strain behaviour of fly ash brick masonry built using the rat trap bond technique. Due to its distinctive arrangement of vertically oriented cavities, the rat trap bond offers notable thermal performance and material efficiency. Three masonry prisms were built using fly ash bricks and a cement-sand mortar mix with a ratio of 1:5. After curing for 28 days, the specimens were subjected to axial compression testing with a Universal Testing Machine. The experimental results indicated that although the compressive strength of rat trap bond masonry was lower than that of conventional bond masonry, it was still within acceptable limits for non-load-bearing and low-load applications. The stress-strain curves showed a linear-elastic behaviour until a certain load level was reached, after which nonlinear deformation and brittle failure occurred. According to the study, rat trap bond masonry using fly ash bricks provides a sustainable and economical option for low-rise buildings, particularly in developing areas. Nonetheless, additional studies are advisable to evaluate its performance when subjected to lateral and cyclic loads, and to advocate for its incorporation into building codes and design guidelines.
Keywords: Rat Trap Bond, Fly Ash Bricks, Compressive Strength, Stress-Strain Behaviour, Sustainable Construction

I. INTRODUCTION

One of the most popular building methods in the world today is brick masonry [1], particularly in developing countries like Bangladesh, Sri Lanka, India, and Pakistan. Its affordability, ease of building, fire resistance and raw material availability are the reasons for its appeal [2,3]. The rat-trap bond (RTB), one of the various bonding patterns used in brick masonry, is becoming more popular due to its effectiveness and sustainability. By positioning the bricks on edge, this bond type creates a cavity in the wall section. These cavities have a major positive impact on construction speed, dead load reduction, thermal insulation, and material savings [4,5,6]. Originally employed in the 19th century in the United Kingdom and former British colonies, RTB was later brought back to India in the 1970s by architect Laurie Baker, who promoted economical and ecologically friendly construction methods [7,8].

Rat-trap bond brickwork is often constructed with clay-burned bricks. Despite being publicly accessible, these bricks are made by blazing them at high temperatures in kilns, which consumes fertile topsoil and produces significant carbon emissions [9,10]. Researchers and industry professionals are looking for alternative masonry units that are both technically feasible and sustainable in light of growing worries about resource depletion and environmental degradation. Fly ash, a byproduct of burning coal, is combined with lime, gypsum, and occasionally cement to create fly ash brick, one such substitute [11]. When compared to conventional clay bricks, these bricks are less water-absorbing, homogeneous in strength and shape, and energy-efficient [12]. They are a good alternative in many construction applications because of their exceptional fire and sound resistance.

Given the growing need for environmentally friendly building materials, this research focuses on the mechanical characterization of rat-trap bond masonry made using fly ash bricks. Although the mechanical properties of clay brick RTB brickwork have been studied in the past, little research has been done on the characteristics with fly ash bricks. It is crucial to determine if fly ash bricks can satisfy the structural requirements when utilized in rat-trap bond masonry systems, given their growing availability and environmental advantages.

This study aims to experimentally examine the stress-strain behaviour of rat trap bond masonry with fly ash bricks under axial compression. The results are examined and deliberated upon regarding typical masonry performance and pertinent code provisions, including those from the Building Code of Pakistan (BCP), ASTM, and EN standards. The study aims to promote the wider use of fly ash bricks in rat trap bond masonry, especially for low- to mid-rise buildings where cost-effectiveness, resource efficiency, and thermal performance are crucial factors, by concentrating on the mechanical response of this sustainable construction technique.

II. EXPERIMENTAL PROGRAM

The aim of this experimental program was to examine the stress-strain behaviour of fly ash brick masonry built with the rat trap bond technique. The research encompassed the preparation, testing, and examination of masonry prisms subjected to axial compression in order to find compressive strength and stress strain behaviour.

A. Material used

1) Fly Ash Bricks

Locally sourced fly ash bricks that meet the standards of IS 12894 were utilized. Before masonry construction, the bricks, which had standard dimensions of 9” × 4.5” × 3”, were tested for compressive strength, and modulus of rupture according to the standard, American Society for Testing and Materials (ASTM) C-67 [13].

2) Mortar

A mortar mix of cement and sand in a 1:5 ratio (by volume) was employed, where cement is the primary component. To ensure uniformity, the water-cement ratio was kept at 0.6. Mortar was tested in accordance with ASTM C-109 [14] for compressive strength by casting and testing cubes. Figure 1 displays the mean values of the test conducted.

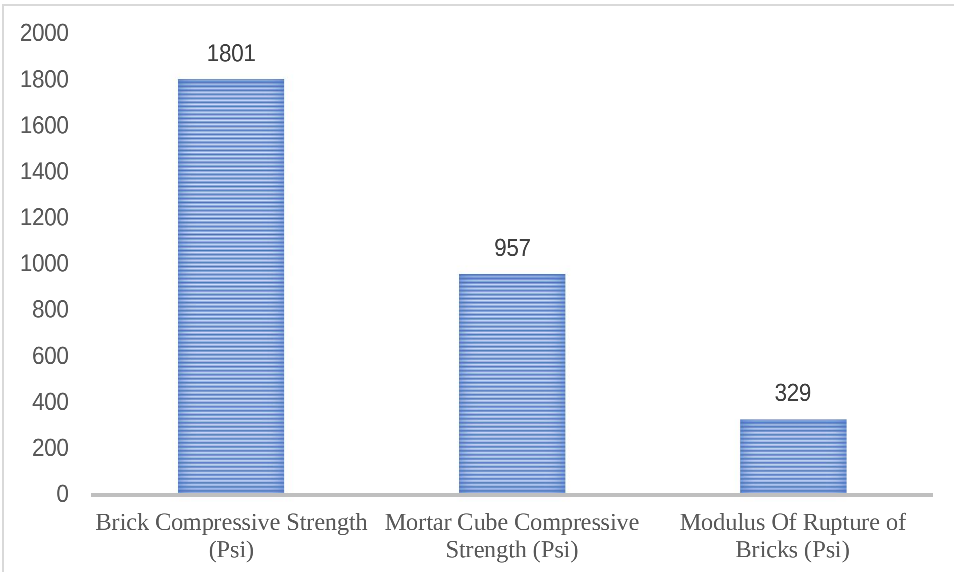

Fig. 1: Material’s Test Results

B. Masonry bond configuration

The masonry prisms were built using the rat trap bond. This bond entails laying bricks on their edges to form vertical and horizontal cavities, thereby enhancing thermal insulation and material efficiency.

C. Prism Preparation

The height of the masonry prisms, built with five brick courses and four mortar joints, is around 24 inches. A uniform bed joint thickness of 3/8” was upheld throughout. To ensure sufficient strength development, all specimens were cured for 28 days in moist conditions.

D. Testing Procedure

The rat trap bond masonry prisms were subjected to compressive strength testing, in accordance to ASTM C-1314 [15], using a Universal Testing Machine (UTM) that had an appropriate load capacity. After a moist curing period of 28 days, each prism was subjected to axial compression testing. To guarantee a uniform load distribution, a steel plate having enough strength was placed at the top of prism before loading. A vertical load was applied until failure happened. To document axial deformations and enable precise stress-strain curve creation, Linear Variable Differential Transformers (LVDTs) were affixed to the specimens. During the entire duration of the test, load and displacement data were recorded on a continuous basis in order to ascertain crucial parameters including peak load, compressive strength, and failure pattern.

III. RESULTS AND DISCUSSION

The results of compressive strength testing on rat trap bond fly ash brick masonry prisms are detailed in this section. The results encompass the assessment of peak compressive strength, and stress-strain behaviour noted during testing.

A. *Compressive Strength of Masonry Prisms*

Masonry prisms built with the rat trap bond exhibited an average compressive strength of 500.02 Psi. The outcomes indicated a relatively lower strength compared to conventional bond masonry, owing to the hollow structure of the rat trap bond that inherently creates voids.

Nevertheless, the strength values were acceptable for non-load-bearing and moderate load-bearing walls, indicating that the rat trap bond is appropriate for sustainable and cost-effective construction when high compressive strength is not a primary requirement. Results are shown in Table 1.

Table 1: Results of Compressive strength test

Specimen ID	Peak Load (ton)	Compressive Strength (Psi)
CT-1	23.11	536.47
CT-2	17.50	406.24
CT-3	24.01	557.36
Average	21.54	500.02

B. *Stress Strain Behaviour*

Masonry prisms made of rat trap bond exhibited a typical brittle stress-strain response when subjected to axial compression. The curve's initial segment displayed linear elastic behaviour, suggesting a strong interaction between the bricks and mortar. With the increase in load, the response turned nonlinear, initiating micro-cracking mainly at the brick-mortar interface and around the unsupported mid-span of the rowlock bricks. Because of the cavity in the rat trap bond, these rowlock bricks functioned as areas of reduced structural integrity.

As additional load was applied, vertical cracks became visible and spread along the prism's height. The central area of the prism, where the rowlock bricks had less support, showed a greater concentration of cracks. Upon attaining the peak load, the specimens underwent a rapid strength loss, resulting in a brittle and progressive failure with minimal deformation. This conduct highlights the effect of bond geometry and internal cavities on the load-carrying mechanism of rat trap bond masonry.

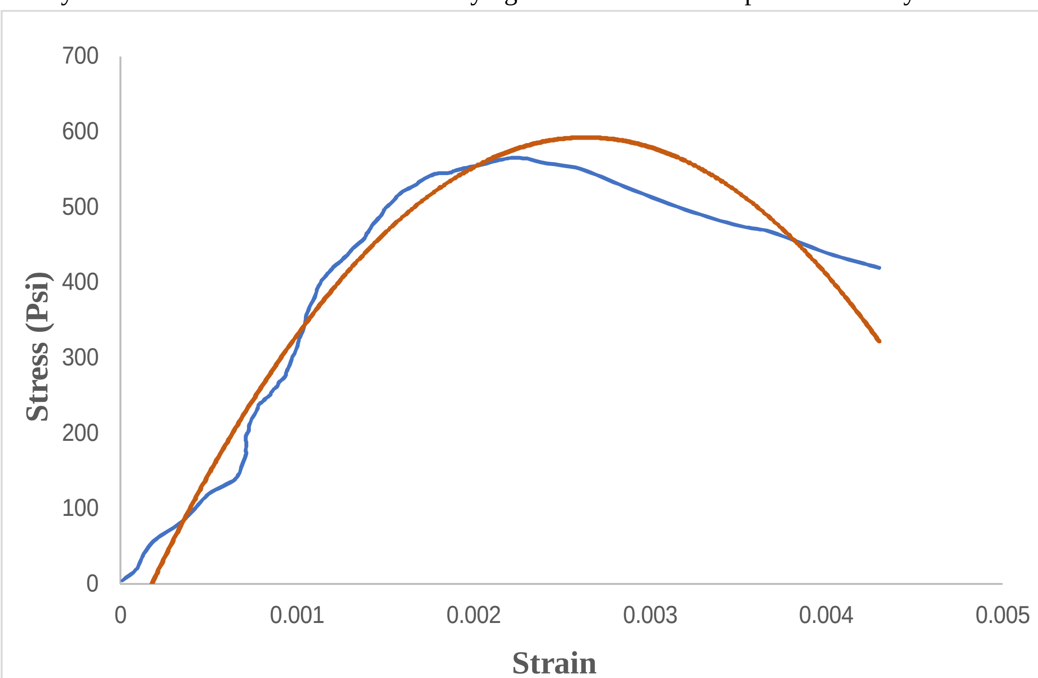

Fig. 2: Stress-Strain curve

C. Discussion

Even though the rat trap bond has a lower compressive strength, it shows an effective use of materials and provides environmental advantages, especially when used with fly ash bricks, which are a sustainable alternative to clay bricks.

The stress-strain profile indicates that the rat trap bond, although unsuitable for high-load-bearing walls, is structurally sufficient for low-rise, non-load-bearing masonry. Using fly ash bricks in conjunction with the rat trap bond fits nicely with green building practices, providing a performance-sustainability balance.

IV. CONCLUSION

1) Due to internal cavities, the compressive strength of rat trap bond masonry was lower than that of conventional bonds; however, it was still sufficient for non-load-bearing and low-load applications.
2) Stress-strain curves revealed: An initial linear elastic phase, a nonlinear softening phase leading to brittle failure.
3) Utilizing fly ash bricks with a rat trap bond resulted in reduced material usage (less mortar and fewer bricks), enhanced thermal performance (due to air gaps), improved sustainability, and greater cost efficiency.

V. RECOMMENDATION

1) Employ rat trap bond with fly ash bricks in non-load-bearing walls, partition walls, and low-rise housing projects that are cost-effective and sustainable.
2) Carry out additional experimental research on shear strength, lateral load behaviour, durability, and thermal and acoustic insulation performance.
3) Conduct comparative studies with traditional bonds (e.g., stretcher, English) using identical materials.

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