

Evaluating the Performance of CSEB Masonry under Axial and Shear Loads with Granite Waste-Enhanced Thin-Layered Mortar

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Abstract—The depletion of river sand, which is commonly used as fine aggregate in construction, has raised significant environmental concerns and escalated material costs. Simultaneously, the granite industry produces large quantities of waste dust, contributing to environmental pollution.

This study examines the feasibility of utilizing locally sourced granite dust as a replacement for fine aggregates in cementitious materials, with the dual aim of mitigating environmental impact and addressing the scarcity of natural resources. Granite dust was incorporated into production of cement paste at varying cement-to-dust ratios (1:1, 1:2, and 1:3), and the performance of these mixtures was compared to conventional cement mortar. Results demonstrated that a 1:1 cement-to-granite dust ratio exhibited strength properties comparable to those of conventional mortar. Using this mix, compressed stabilized earth blocks (CSEBs) were produced and assembled into masonry prisms.

After 28 days of curing, these prisms were subjected to axial and shear load tests to evaluate their mechanical behavior. The findings reveal that granite dust effectively enhances the strength characteristics of masonry while offering a sustainable and cost-efficient alternative to river sand. This research underscores the potential use of granite waste to reduce dependency on natural resources and provides a viable eco-friendly solution for masonry construction, particularly in regions such as Karnataka, where the demand for construction materials is high and the preservation of natural ecosystems is critical.

Keywords— Compressed stabilized earth block masonry; axial behaviour; shear strength; granite dust based thin mortar.

I. INTRODUCTION

Compressed Stabilized Earth Blocks have gained significant attention in the construction industry as a sustainable alternative to conventional masonry units. Its inherent thermal and sound insulating properties, along with low embodied energy, makes it an attractive choice for environmentally-conscious building practices. However, the mechanical performance of CSEB masonry assemblages is a crucial consideration, particularly when subjected to axial loading.

Granite industry generates vast quantities of waste during quarrying and processing activities, particularly in regions like Karnataka, India, where granite extraction is a significant industry. Granite dust, a fine by-product of this process, is often discarded, leading to environmental challenges such as land pollution and dust emissions. Literature reviews suggest that granite waste can be effectively utilized as a partial replacement for natural sand in cementitious materials, contributing to both waste management and resource conservation. Hence the present study attempts to evaluate the performance of CSEB masonry made with granite dust thin mortars.

II. LITERATURE REVIEW

This literature review examines the mechanical properties and bond characteristics of CSEB masonry assemblages incorporating granite waste-modified thin-layer mortar. The review explores the selection and processing of suitable soil for CSEB production, the influence of interlocking design features, and the unique challenges in evaluating the strength and durability of these non-standard masonry units (Uzoegbo, 2016). Studies have demonstrated the potential of leveraging artificial neural networks to optimize the mix design of CSEBs, incorporating supplementary cementitious materials like rice straw and cement to enhance the mechanical and durability performance of these earth-based construction units (Gapuz & Ongpeng, 2017).

The strength of hollow compressed cement-stabilized earth-block masonry prisms has been investigated, highlighting the importance of eliminating undesirable soil properties and leveraging the advantages of cement stabilization to achieve higher and faster strength gain, as well as improved durability. (Yang & Wang, 2019) Dry-stack and compressed stabilized earth-block construction methods have been explored, with particular attention given to the selection, processing, and properties of suitable soil, the design and influence of interlocking features, and the assessment of durability characteristics (Gapuz & Ongpeng, 2017) (Elahi et al., 2021) (Yang & Wang, 2019) (Uzoegbo, 2016).

The incorporation of granite waste as a partial replacement for conventional mortar has emerged as a promising approach to enhance the sustainability of CSEB masonry assemblages. The mechanical and bond characteristics of these modified thin-layer mortars under axial loading have been investigated, providing insights into the performance and potential limitations of this eco-friendly construction technique. (Gapuz & Ongpeng, 2017) (Syiemiong & Marthong, 2020) (Sachin & Kavitha, 2019) (Yang & Wang, 2019).

The mechanical performance of CSEB masonry assemblages, particularly under axial loading, is a critical factor in their acceptance and widespread adoption. The compressive, split tensile, flexural, and shear strength characteristics of CSEBs have been extensively evaluated, demonstrating the potential of incorporating cement and fly ash as stabilizers to improve the overall mechanical properties (Elahi et al., 2021).

Research on compressed stabilized earth blocks (CSEB) and concrete masonry has shown promising results for sustainable construction. CSEB offers eco-friendly alternatives to traditional bricks, with compressive strengths of 9.587 MPa and elastic modulus of 1550 MPa (Murthy & Pandurangan, 2019). Incorporating sand and used motor oil in CSEB can improve dry unconfined strength by 88.2%, though wet strength decreases by 19.5% (Kolawole et al., 2020). For concrete blocks, using different mortar ratios and incorporating khaka (stone crushing by-product) can enhance masonry mechanical properties (Rizwan, 2021). Granite waste powder, a significant pollutant, shows potential as a partial replacement for fine aggregates in concrete masonry. Initial tests on walls constructed with granite waste-modified concrete masonry subjected to out-of-plane loading indicate promising results for its utilization in construction (Elsobky et al., 2019). These studies demonstrate the potential for improving masonry performance and sustainability through innovative material combinations and waste utilization. The bond characteristics between the CSEB units and the mortar play a crucial role in the overall performance of the masonry assemblage. Studies have explored the use of granite waste-modified thin-layer mortar as an eco-friendly alternative to conventional mortar, examining its impact on the mechanical and bond properties of the CSEB masonry system under axial loading.

Studies by researchers have been primarily on the axial load carrying capacity of CSEB masonry. However the behaviour of masonry under flexure and shear are also important. The present study attempts to evaluate the performance of masonry made with CSEBs and granite dust based thin mortars under compression and shear.

III. OBJECTIVES

To investigate the mechanical behavior of compressed stabilized earth block (CSEB) masonry prisms bonded with granite waste-enhanced thin-layered mortar under axial and shear loading conditions.

To evaluate the comparative performance of granite waste-enhanced thin-layered mortar against conventional cement mortar in terms of strength, deformation, and crack propagation in CSEB masonry.

IV. MATERIALS AND THEIR PROPERTIES

A. Compressed Stabilized Earth Blocks

Compressed Stabilized Earth Blocks (CSEBs) were manufactured using locally sourced red clayey soil which had an initial composition of 55% sand and 45% silt and clay content. To achieve optimal block properties, the soil composition was modified to contain a minimum of 70% sand content. Sand content in soil was enhanced using manufactured sand which conformed to Zone II gradation as per IS 383. Ordinary Portland Cement (OPC), complying with IS 12269 specifications, was incorporated at 7% by weight as a stabilizer for the mix.

The blocks were produced with dimensions of 230 mm × 190 mm × 100 mm under controlled conditions to maintain a consistent fresh density of 2.05 g/cc. Following production, the blocks underwent a 28-day curing period under wet burlap. The cured blocks exhibited a dry density of 1.88 g/cc, water absorption of 14%, and achieved a wet compressive strength of 3.10 MPa. Figure 1 represents a typical image of the blocks produced using ITGE VOTH.



Fig 1: ITGE VOTH machine for CSEB production

B. Mortar

Two mortar types were investigated in this study: conventional cement-sand mortar (CCM) and thin-layered cementitious mortar (TLM). The CCM was proportioned at 1:6 (cement: sand) by volume, representing the most commonly used mortar specification in Indian masonry construction. For the innovative TLM, a 1:1 ratio of cement to granite waste was adopted to produce a cementitious paste suitable for thin-joint applications.

Mortar workability was assessed through flow table tests conducted in accordance with BS: 4551 1980. The CCM achieved optimal workability at 115% flow value. The TLM mixture, designed for reduced joint thickness, demonstrated suitable workability at a flow value of 125%. Compressive strength tests performed on 70mm mortar cubes at 28 days revealed significant performance differences: CCM achieved 3.5 MPa while TLM exhibited considerably higher strength of 30 MPa.

C. Experimental Programme

The structural performance characteristics of CSEB masonry were evaluated through compressive strength tests and shear strength tests on stack-bonded prisms, following the recommendations of Bureau of Indian Standards (1987). Stack-bonded masonry prisms were constructed for two distinct loading and testing configurations. For axial compression testing, prisms were built to a height of four blocks, maintaining the standard-specified height-to-least lateral dimension (h/t) ratio of 2.

For shear strength assessment, three-block-high prisms were constructed. Both configurations were tested using the two mortar types: conventional thick-joint masonry (12mm CCM) and innovative thin-joint masonry (2mm TLM incorporating granite waste).

D. Specimen casting and testing procedure

Masonry compressive strength

Masonry prisms were cast to maintain a height-to-least lateral dimension (h/t) ratio of 2, as specified by code requirements (h/t ratio is 2-5), rather than using a fixed number of blocks. This approach accounted for the variation in overall height due to different mortar joint thicknesses (12mm CCM and 2mm TLM). The specific prism dimensions and corresponding h/t ratios for each configuration are detailed in Table 1.

Prior to construction, blocks were pre-soaked in water for 5 minutes to achieve initial surface saturation. The mortar joints were prepared with water-cement ratios of 1.85 and 2.05 for CCM (12mm) and TLM (2mm) respectively. Block frogs were filled with the corresponding mortar type to ensure flat bearing surfaces for testing. After initial 24-hour curing, prisms were wrapped in wet gunny bags for the remaining 27 days. Compression testing was conducted under a loading frame with hydraulic jack and proving ring arrangement. Three specimens were tested for each configuration, with results reported as average values. Figures 2 and 3 exhibit the typical masonry prisms cast to evaluate the compressive strengths under axial load.



Fig 2: Typical specimen cast for masonry compressive strength test using TLM



Fig 3: CSEB with application of thin layered mortar produced using granite dust



Fig 4: Typical Failed specimen under axial loading of CCM

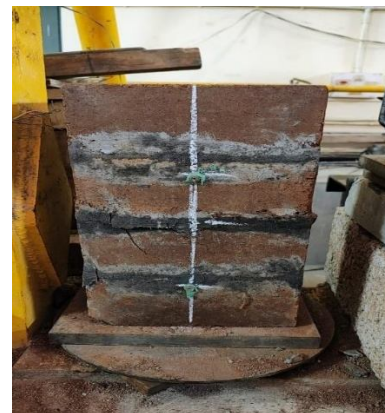


Fig 5: Typical failed specimen under axial loading of TLM

Shear Strength

Shear strength at the block-mortar interface was evaluated using triplet specimens with mortar joint thicknesses of 12 mm and 2 mm. All material properties and mixing parameters (water-cement ratio, flow value, strength, and density) were maintained constant across test combinations.

The test setup consisted of 10mm thick wooden moulds supporting the end blocks, with dimensions matching the block sizes. Load application to the middle block was achieved through a similar wooden mould, ensuring direct load transfer to the units. The testing arrangement is illustrated in Fig 6. A constant pre-compressive stress of 0.06 N/mm² was maintained throughout testing using a jack and proving ring arrangement, while shear load was incrementally increased until failure. Specimen preparation followed the same protocol as compression specimens: 5-minute block pre-soaking, 28-day curing under gunny bags after 24 hours of initial set, and testing in wet condition. Three specimens were tested for each mortar configuration to ensure statistical validity.

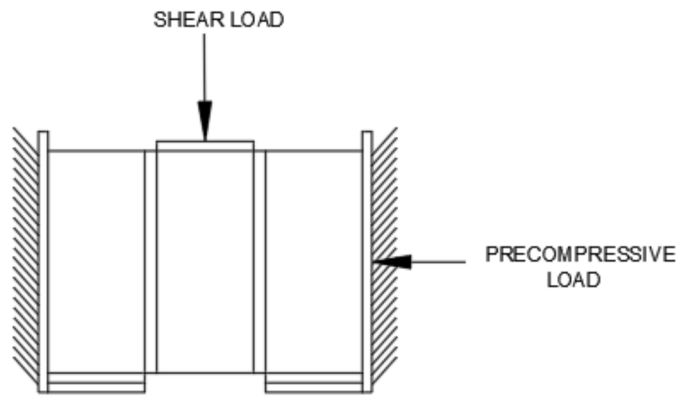


Fig 6: Shear strength test set up



Fig 7: Typical failure pattern of CCM under shear



Fig 8 : Typical failure pattern of TLM under shear

E. Results and discussions

Table I provides a comparative analysis of masonry compressive strength between the Thin-Layered Mortar (TLM) system and the Conventional Cement Mortar (CCM) system. The TLM specimens exhibited a compressive strength of 1.78 MPa, representing a 2.89% increase over the CCM specimens which reached 1.73 MPa.

TABLE I: MASONRY COMPRESSIVE STRENGTH USING CCM AND TLM

Sl. No.	Mortar type	Specimen dimensions mm	Total courses	h/t ratio	Masonry compressive strength (MPa)
1	CCM	230 X 190 X 438	4	2.30	1.73
2	TLM	230 X 190 X 406	4	2.13	1.78

This performance enhancement is significant for two key reasons. First, the TLM system achieves higher strength despite using substantially thinner mortar joints (2mm versus 12mm), indicating more efficient stress distribution through the masonry assembly. Second, the TLM formulation eliminates the need for manufactured sand (M-sand), demonstrating that granite waste can effectively replace conventional fine aggregates while maintaining structural performance.

Table II describes shear strength behaviour of the two types of mortars considered. The study revealed a substantial performance advantage for the Thin-Layered Mortar (TLM) system over the Conventional Cement Mortar (CCM). TLM specimens achieved average shear strength of 0.11 MPa, representing a 25% increase compared to the CCM specimens which showed 0.088 MPa.

TABLE II: COMPARISON OF SHEAR STRENGTH SPECIMENS CASTED USING CCM AND TLM

Sl. No	Mortar type	Specimen dimensions (mm)	Avg. Shear strength (MPa)
1	CCM	230 X 190 X 325	0.088
2	TLM	230 X 190 X 306	0.110

This enhancement in shear resistance can be attributed to several factors. The reduced joint thickness (2mm versus 12mm) in TLM specimens appears to promote more efficient stress transfer across the block-mortar interface. Additionally, the incorporation of granite waste in TLM, replacing conventional manufactured sand, appears to contribute to improved bond characteristics. The superior performance may also be linked to the higher cementitious content in TLM, which could enhance the mechanical interlocking between mortar and masonry units.

These results suggest that TLM systems not only offer environmental benefits through waste utilization but also provide superior structural performance in terms of shear resistance - a critical parameter for masonry structures subjected to lateral loads.

V. CONCLUSIONS

The investigation into TLM incorporating granite waste as an alternative to conventional masonry mortar yields three key findings:

The thin-layered system demonstrates comparable compressive strength to conventional mortar while significantly enhancing shear resistance. This dual performance characteristic validates TLM's suitability for both gravity and lateral load applications.

The 2mm TLM system achieves superior mechanical properties with substantially less material than traditional 12mm CCM joints, demonstrating more efficient material utilization.

TLM successfully incorporates granite waste as an alternative to manufactured sand, offering a sustainable solution which reduces dependency on conventional fine aggregates; thereby providing an avenue for industrial waste utilization.

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