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Numerical Study on The Out-of-Plane Behaviour of Brick Masonry Walls Strengthened with Cement Sand Mortar

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ABSTRACT. *Masonry, as a building material, has a long history of usage in construction. The utilization of brick masonry in conjunction with mortar has been widely adopted due to its ease of implementation and structural durability. However, it has been observed that masonry structures exhibit significant vulnerabilities in the face of lateral loads, particularly regarding bending and shear. As seismic activity continues to pose a growing threat, the need for effective methods of strengthening masonry structures against earthquakes is becoming increasingly imperative. In this research, the Finite Element method is employed to assess the influence of the thickness of cement-sand (CS) mortar on the flexural capacity of cement-clay interlocking brick (CCIB) masonry walls through numerical modeling. In this study, three models of CCIB masonry walls with varying thicknesses of cement-sand (CS) mortar are analyzed. The models comprised of CCIB masonry walls with a one-sided application of CS mortar layers of 10mm and 20mm thickness. The findings indicate that the flexural capacity of the CCIB masonry walls can be improved by increasing the thickness of the CS mortar layer.*

Keywords: Masonry walls; CS mortar; CCIB; flexural capacity.

1. INTRODUCTION

Brick masonry is widely utilized in the construction industry but lacks seismic resilience and tends to collapse during earthquakes, posing a significant threat to human life and infrastructure. Urbanization, with its increase in the number of buildings and structures, has further exacerbated this problem, resulting in significant financial and human losses from seismic hazards. Brick masonry constructions exhibit a brittle and weak response to seismic loads, particularly in the absence of seismic. Even under moderately intense seismic activity, unreinforced masonry structures have the potential to sustain severe damage. This is evidenced by the extensive damage caused to brick masonry structures during past seismic events [1–3]. Brick masonry is considered a crucial component in most building structures due to its cost-effectiveness, ease of manufacture, construction, and durability. Several studies have investigated the use of Fiber-Reinforced Polymer (FRP) composites and rods of steel as a means of enhancing the strength of conventional brick masonry [4]. However, the excessive FRP composites cost negates their advantages, leading researchers to explore alternative methods for improving brick masonry. One such alternative is the use of interlocking bricks, such as CCIB, which are produced at a large scale and use less cement and sand during installation. While research has shown that CCIB masonry structures exhibit satisfactory behavior under compressive loads, their effectiveness under lateral, tensile, and compression stress along the diagonal is negligible [5–8]. Given the limited effectiveness of CCIB masonry under tensile, lateral, and diagonal compression stress, it is essential to investigate low-cost options for enhancing its load-bearing capability. Traditional reinforcing techniques, such as the use of CS mortar, offer a more cost-effective and durable solution than FRP composites [9]. To determine the effectiveness of this technology in comparison to traditional masonry constructions, it is necessary to investigate the brick masonry walls fortified with mortar and their out-of-plane behavior.

To achieve this, modern technology such as Finite Element Analysis (FEA) can be utilized to model the complexity of brickwork. The use of FEA allows for the numerical modeling of masonry and the investigation of the out-of-plane behavior of CS mortar strengthen brick walls. While sophisticated models can be developed to study each brick and joint independently, simpler models can also be used to reduce analysis time. For more accurate and precise analyses, software such as ANSYS, LS-DYNA, and ABAQUS can be utilized.

In this study, the numerical modeling of masonry was performed using ABAQUS, and the out-of-plane behavior of CS mortar strengthen brick walls were investigated.

2. NUMERICAL MODELLING

2.1 Models Description

The study employed a CCIB masonry wall as a target structure. Both the length and height of the wall are 1000mm and their thickness is 125mm. The wall is constructed in a pattern called a running bond. Additionally, spherical voids present in the walls are filled with a CS mortar. Before filling the grout, round steel bars (RSB)3 mm in the radius are inserted in the circular openings to strengthen the CCIB masonry walls.

Three reinforced CCIB masonry walls are modeled and subjected to three-point bending to analyze their behavior when subjected to out-of-plane forces. A control wall, lacking external reinforcement (CS mortar), was modeled to serve as a reference for comparison. In the reinforced setup (depicted in Fig -1), CS mortar is added to one side of the wall in two thicknesses: 10mm and 20mm.

The details of CS mortar strengthening are provided in Table -1.

2.2 Materials

The compressive strength of CCIB is taken as 6.7MPa and the density of 1850 Kg/m3. The mean compressive strength of the CS mortar stands at 50. While the yield and ultimate tensile strength of RSB are 400MPa and 550MPa, respectively.

Table -1: Detail of CS mortar strengthening.

Models	**CCIB Masonry walls**	**Thickness of CS Mortar (mm)**
Model-1	MW	-
Model-2	MW-CS10	10
Model-3	MW-CS20	20

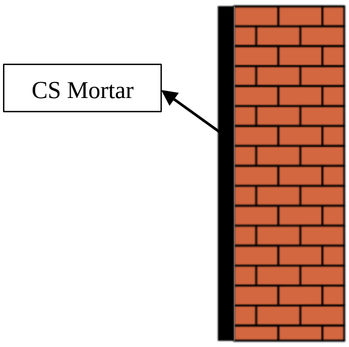

Fig -1: Typical details of strengthening CCIB masonry wall.

2.3 Loads, Boundary Conditions, and Interaction

The CCIB masonry walls are subjected to three-point bending tests as illustrated in Fig-2. A rigid steel beam loader with a height of 100 mm was utilized as the loading element and positioned at the summit of the CCIB masonry walls to ensure even distribution of load. The model is analyzed taking displacement control condition into account. A 55 mm displacement is given to the steel beam loader's midpoint. The embedded region interaction is used for RSB and grout. The load-bearing element and the CCIB masonry wall are connected through a tie constraint. The two bottom supports were analytically rigid and are fixed from the bottom. Additionally, a tie constraint is also established between the wall and the two fixed supports. The reference point and line elements were coupled to one another, in order to ensure accurate load distribution.

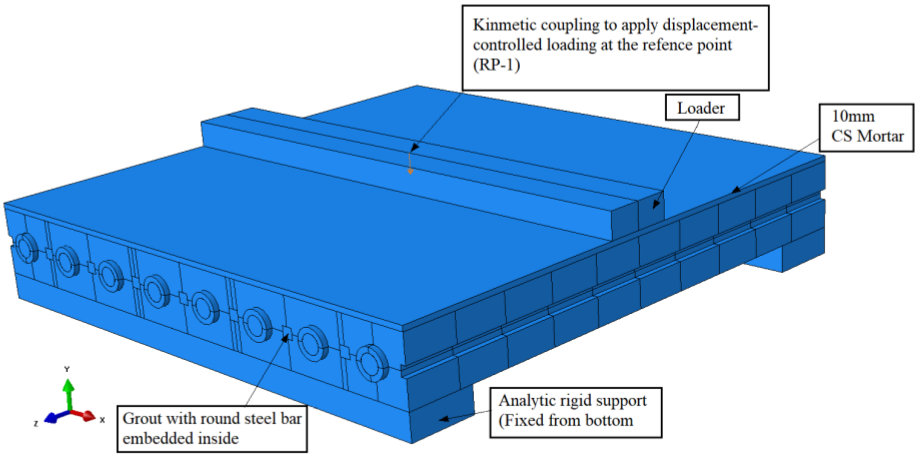

Fig-2: Model assembly, Loads, and boundary conditions.

2.4 Meshing

The CCIB, grout, and CS mortar are modeled as a 3D deformable solid element, whereas the RSB is modeled as a truss element. The mesh type used for a solid element is C3D8R, which is a linear hexahedral solid element in ABAQUS with reduced integration points. It offers a trade-off between computational efficiency and accuracy. The mesh type used for the truss element is T3D2, which are three-dimensional, two-node elements that are used to model reinforcing bars. The mesh size utilized for every component is as follows: 20 mm for CCIB, 80 mm for the CS mortar, and 70 mm for the grout, as depicted in Fig-3 Fig-4, and Fig-5 respectively. The general mesh sizes have been selected based on the geometry of different structural components.

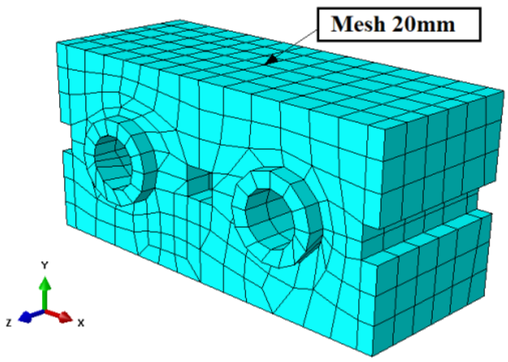

Fig-3: Meshing of CCI Brick

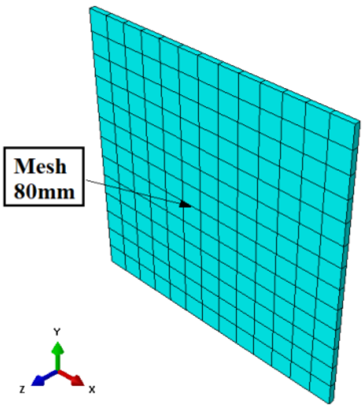

Fig-4: Meshing of CS mortar

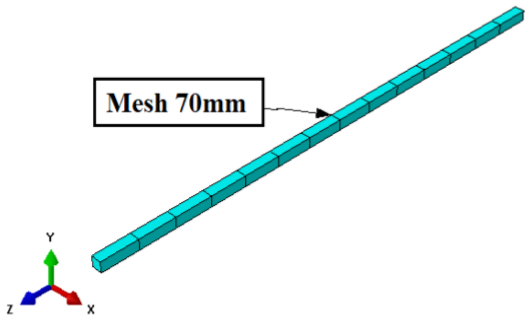

Fig-5: Meshing of grout

3. RESULTS AND DISCUSION

The use of CS mortar has been demonstrated to significantly enhance the flexural strength and initial rigidity of CCIB masonry walls. The reference wall (MW) has an ultimate load capacity of 66 KN as shown in Fig-6. The use of 10mm thick CS mortar resulted in a 16.67% increase in the ultimate load capacity, with the capacity reaching 77 KN. Increasing the thickness of the mortar to 20mm resulted in an even greater improvement in flexural capacity, that is 84.40 KN with a 28.88% increase compared to the reference wall and a 9.61% increase compared to the 10mm thick mortar application. The findings reveal that the thickness of the CS mortar is a critical factor in increasing the CCIB masonry wall's flexural strength.

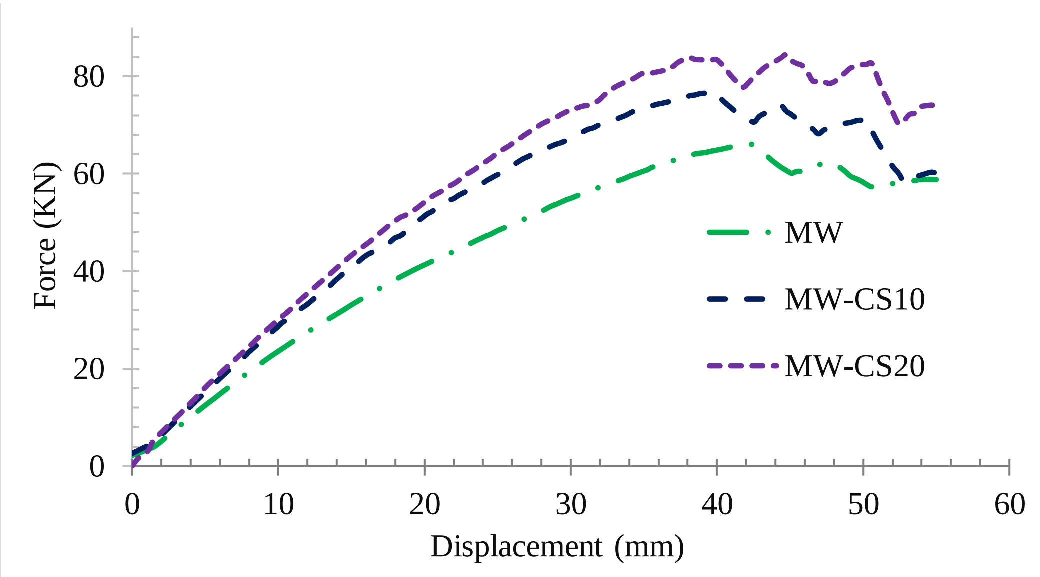

Fig-6: Force versus displacement responses of the CCIB masonry walls

4. CONCLUSIONS

The use of CS mortar has been demonstrated to be effective in increasing the ultimate load-carrying capacity of reinforced CCIB masonry walls.

The ultimate load capacity improved significantly with an increase in the thickness of the CS mortar, with the MW-CS20 strengthening configuration proving to be more effective than the MW-CS10 configuration. The masonry wall CS20 showed the greatest improvement in ultimate load capacity, with a 28.88% increase compared to the reference wall and a 9.610% increase compared to the MW-CS10 configuration.

Further study is advised to examine the behavior of CCIB masonry walls subjected to blast loading. An evaluation and comparison of various wire mesh layers added within the CS mortar to existing models should also be performed to assess their influence. Also, it is recommended to conduct future research focused on the dynamic behavior under seismic loads, as this will provide a more appropriate assessment of the response.

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