LATERAL LOAD PERFORMANCE OF C SHAPED EARTH-FILLED WALL-PANELS WITH OPENING AND CONFINED BY GI WIRE MESH - AN EXPERIMENTAL INVESTIGATION

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Abstract—This experimental study investigates the response of a GI wire mesh enclosed earth-filled C-shaped panel to lateral loads. The outcomes of this investigation can be used to assess the strength and stability of this technology in comparison to conventional rural housing materials like compressed earth blocks, brick masonry, etc. Furthermore, the study aims to analyze the cracking pattern of the wall panel under lateral load. In rural regions, ground story masonry and clay structures are commonly used due to their simplicity of construction and accessibility of materials. These structures are typically constructed using traditional methods, with minimal engineering services required. The failure of such structures during an earthquake is often attributed to poor roof to wall connections, heavy roofing, and corner failures
Keywords—C-shaped wall panel, lateral load test, earth filled wire mesh, wall with opening.

I. INTRODUCTION

The construction industry is witnessing new innovations and their optimization, including the concept of industrializing construction technologies, which reduces the need for in-situ construction in building construction. However, it is important to recognize that this industrialization can lead to extensive natural resource exploitation and the production of hazardous waste products. Developing countries, such as India, where over 70% of the population lives in villages, face a significant housing crisis due to high demand resulting in increased costs. Traditional housing methods are often unsuitable for local environmental conditions and basic hygiene needs, and therefore cannot be considered a suitable solution.
The aim of this initiative is to develop an in-situ construction technology that addresses the housing crisis in developing nations while minimizing environmental damage. To achieve this, the focus is on creating a method that utilizes locally available materials, responsibly manages natural resources, minimizes costs, and produces a suitable technology. The study places significant emphasis on the earthquake-resistant features of the structure and the provision of basic hygiene needs to create a sense of security for the occupants. Furthermore, the study includes an analysis of the cracking patterns at openings, the failure mode of the wall-to-wall connection, and the lateral load-carrying capacity of a C-shaped earth-filled wall panel that is confined by GI wire mesh under lateral loads.
Numerous studies have been conducted to address the housing crisis in rural areas, many of which have focused on using precast panels as structural members. In 2015, L. Murari and E. John investigated the effectiveness of precast cement wall panels by examining the failure load of these panels through laboratory testing. Phalke R. and Gaidhankar D. (2014) tested the performance of flat cement roof panels under two-point loading to determine their strength. They also investigated the flexural strength of flat ferrocement panels and the impact of using various wire mesh layer counts. In addition, the study compared the ultimate strength and ductility of ferrocement roof panels with varying numbers of wire mesh layers and the use of steel fibers. Prefabrication can save time, while cement can help solve the cost issue. In 2012, P. Battarai et al. conducted an in-depth investigation of straw bale housing parameters and concluded that it is a good alternative as it is made from renewable resources, is affordable, has good thermal performance, is fire-resistant, lightweight, and environmentally friendly. Marcial et al. summarized various earth home strengthening techniques in 2003, including the causes of some historical mud structures' longevity and the failure patterns of contemporary earthen structures during seismic events. They found that adobe homes reinforced with welded wire mesh perform best in terms of earthquake resistance.

Tarque et al. (2010) investigated the in-plane behavior of adobe walls during seismic activity through numerical models. Illampas et al. (2013) developed a stress-strain equation for compressed adobe bricks to use in load and displacement control models. Schicker et al. (2009) demonstrated that the mechanical strength of adobe bricks can be improved by incorporating eco-friendly additives to enhance compressive and flexural strength. Silveira (2011) studied the characteristics of adobe bricks already present in buildings. Beatty et al. (2013) performed tests on the compressive strengths of confined Adobe. In 2001, a powerful earthquake with a magnitude of 8.4 struck Southern

Peru, and according to Marcial BLONDET (2004), the majority of adobe homes in the region were destroyed. The houses that remained standing had been strengthened with welded steel and were used as shelters.
Beria Bayizitliolu (2017) states that today, wall panels serve as a significant source for the development of affordable, energy-efficient, recyclable, and sustainable buildings that cater to human needs for comfort, health, and well-being while having a minimal environmental impact. Thanks to the advancements in the compaction of infill soil and its characteristics, these wall panels can be used in single-story houses with a focus on safety and performance under both gravity and lateral loads. Sandeep Ranshur (2022) discusses the use of Earth-filled wall panels reinforced with GI wire mesh to improve their quality.

OBJECTIVES OF RESEARCH

1. To modify, alter, or create a new technology using materials that are readily available locally for low-cost housing in rural India.
2. To cast and test the C-shaped wall panel with opening for lateral loads.
3. To incorporate a wall-to-wall connection to support the lateral stresses at the corner.
4. To examine how a C-shaped wall panel with an opening responds to lateral loads.
5. Observe how the wall panels behaved in the test.
6. Determine whether these wall panels can support lateral loads.

II. MATERIALS USED AND THEIR PROPEETIES

Soil

As per the findings of Angulo-Ibánez et al. (2012), approximately 30% of buildings worldwide incorporate at least one element made of earthen materials. The use of earth in construction is still prevalent today, particularly in impoverished and less developed countries, as highlighted by Jaquin et al. (2008) and Craterre (1987).
The primary advantage of using soil as a construction material is its easy availability locally. In the current experiments, soil was used as a filler for the sandwich panel. The mixture of soil, straw, and water in a specific ratio was hand compacted in layers to produce a sturdy and well-built unit. Hand compacted soil has lower density than compressed earth, which enhances stiffness and provides better thermal insulation. The soil used in the experiments underwent sieve analysis and standard proctor test, which showed that it had an optimum moisture content of 19%, a coefficient of gradation of 2.48, and a uniformity coefficient of 19.7. Additionally, Galvanized Iron (GI) Wire Mesh was employed.
The presence of GI wire mesh ensures sufficient rigidity of the soil-filled panel. A range of GI wire mesh openings, from 0.5 mm to 2.00 mm in diameter, is available in the market. The choice of wire mesh aperture was determined based on the soil's D30 values obtained from the sieve analysis, which ranged from 1.04 mm to 1.40 mm. For the current experiments, the available wire mesh with an 8 mm opening and a 0.8 mm diameter was selected. Similarly, a GI wire mesh with a 30 mm aperture and a 1.8 mm diameter was used to construct the wall-to-wall junction at the corners

Straw

Oloruntoba (2013) states that as far back as 1500 BCE, the Mesopotamians and Egyptians were utilizing straw. Straw was used to strengthen ancient objects such as boats and ceramics. After separating the chaff and grain, straw is considered a byproduct of the agricultural industry. This straw is then mixed with the soil to improve the characteristics of the hand-compacted soil.

Mortar

In this study, a cement mortar mixture of 1:4 was applied to the C-shaped earth-filled panel that was enclosed with GI wire mesh. The researchers opted to use cement mortar due to its various advantages, such as being non-corrosive, requiring no surface treatment, having increased strength over time, having low maintenance requirements, and providing an aesthetically pleasing appearance

Plain cement concrete

For the wall panel's base, M20 Grade plain cement concrete (PCC) was selected. Based on the concrete mix design, concrete has an average compressive strength (for 28 days) of more than 20 N/mm^2.

Specifications of earth panels

The lateral load test was conducted on a wall panel that measured 3.2 m x 1.7 m x 0.2 m (central long wall) and 1.4 m x 1.7 m x 0.2 m (adjacent side walls) as depicted in figure 1. The wall panel consisted of three layers, with the core being a hand-compacted earth-straw mixture contained within GI wire mesh. The exterior of the wall was plastered with a 12 mm layer of cement mortar, and the GI wire mesh and wall-to-wall connection were inserted into the PCC of the foundation block. GI wire spacers were placed at regular intervals of 0.5 m centre to centre throughout the length and height of the wall panel to ensure that the width of the GI wire mesh was aligned with the wall thickness.

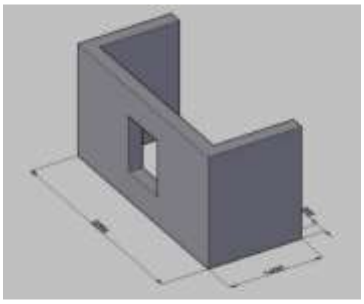

Fig.1 C shaped wall panel with opening

III. EXPERIMENTAL SETUP

To test the lateral load capacity of hand-compacted earth-filled panels, an experimental setup was created. The test specimens were constructed with dimensions of 3.2 m x 1.7 m x 0.2 m (for the central long wall) and 1.4 m x 1.7 m x 0.2 m (for the adjacent side walls). Figure 1 shows the cross-sectional view of the earth-filled wall panel, which comprises several layers

casting specifics

Initially, a formwork of the required foundation size based on the wall specimen size is prepared to embed the GI wire mesh in the foundation. The complete foundation formwork is placed suitably on the loading frame where the wall panel is tested at the casting location to avoid internal stresses during transportation. The GI wire mesh is then cut to the required dimensions for the wall's thickness and height and tied up with the help of GI wire spacers to maintain the required wall thickness. The corner connections, GI wire mesh, and foundation PCC are inserted into the formwork, as shown in Fig. 2. After curing the foundation PCC for 28 days, the soil and straw mixture is made at the specified Optimum Moisture Content (OMC) and laid out in layers of 300 mm height along the length of the wall panels up to a height of 1m. Each layer is carefully compacted using a temping rod for concrete cube compaction, and any extra soil particles oozing through the mesh aperture are removed. After that, cement mortar is used to plaster the 1 m high portion of the wall panel. This process is repeated up to the wall panel's entire height. The same GI wire mesh is used to seal the top of the wall panel, and more earth is added to fill it.

The application of cement mortar (1:4) with a 12 mm thickness to the top, sides, and bottom of the wall, as shown in Figure 2, was followed by drying the wall panel using gunny bags for a period of 28 days. The layers of the fully cast panels can be seen in Figures 2(a), (b), and (c), as well as Figure 3.

Assembly configuration for the lateral load test involved connecting the hydraulic jack to the loading frame. Angles were bolted to the base frame to secure the base of the wall panel and prevent overturning. The model was then fastened to the steel plate using nuts and bolts, which had been welded to the loading frame. A hydraulic jack applied a line load using an I section on the central long wall, 20 cm from the top. The applied load was measured by a proving ring located between an I-section and a hydraulic jack, as depicted in Figure 3.

Displacement sensors were installed at the back of the load application face to measure deflections at the top, middle, and bottom. Twelve ELAP PM 50 5K MR linear potentiometers and dial gauges were used for this purpose. Three potentiometers were placed at the end of each side wall, and another three on either side of the wall opening. All potentiometers were positioned at the same height in the central and side walls of the C-shaped panel, as shown in Fig. 3.

Fig.2 (a) Formwork for foundation and details of wall-to-wall connection

Fig.2 (b) provision of lintel at the opening

Fig.2 (c) Earth and straw filling, compacting and plastering of wall panel

configuration for the lateral load test assembly
For the lateral load test, the hydraulic jack was attached to the loading frame, while angles bolted to the base frame were used to secure the base of the wall panel and prevent overturning. The model was then fastened to the steel plate using nuts and bolts after it had been welded to the loading frame. To apply the load, a hydraulic jack was used to exert a line load on an I-section located 20 cm from the top of the central long wall. A proving ring was placed between the I section and the hydraulic jack to measure the applied load, as shown in Fig. 3.

Displacement sensors were installed on the backside of the load application face, and deflections were recorded at the top, middle, and bottom of the central and neighbouring side walls. To measure deflection, 12 dial gauges and linear potentiometers of PM 50 5K MR of ELAP were used. Three potentiometers were positioned at the end of each side wall, and another set of three potentiometers was positioned on either side of the wall opening. These potentiometers were located at the same elevation in the central wall and side walls of the C-shaped wall panel, as illustrated in Fig. 3

Fig.3 Finished wall panel

Fig.4 Loading arrangement with hydraulic jack

Fig.5 Arrangement of potentiometer and dial gauge

IV. RESULT AND DISCUSSION

At a lateral load of 29.17 kN, cracks began to appear and gradually increased thereafter. The maximum load applied was 52.7 kN. Initially, the increase in load was proportional to deflection. However, as the test progressed, there was a large deflection for a small change in load, as shown in figures 6 and 7. The formation of cracks began at the top edge of the opening in the central wall portion, and subsequently, cracks were observed on the bottom face of the opening. As the load increased further, the cracks widened, and delamination of plaster was observed at the crack locations. Despite being subjected to a maximum load of 52.7 kN, the wall panel did not collapse or disassemble. The corner joint between the walls was in good condition, and there was no distortion at any location. The maximum lateral deflection at the top of the side wall in the C-shaped wall panel was 12 mm, and that of the central wall was 80 mm.

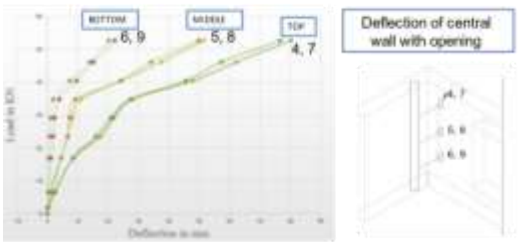

Fig.6Load vs deflection of central wall portion

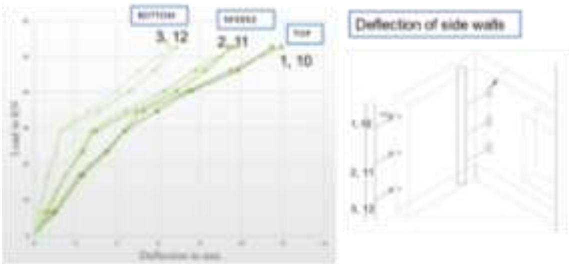

Fig.7 Load vs deflection of side wall portions

V. FUTURE SCOPE

It is necessary to investigate the performance of full-scale wall panels with different connections at the wall-to-wall and roof-to-wall junctions to ensure their successful implementation in practical applications.

VI. CONCLUDING REMARKS

1. The C-shaped soil infill panel, enclosed by GI wire mesh, began to break at the top corner during lateral load testing. Despite this, the panel continued to withstand the load with increasing deflections until the mortar began to crack and fall apart.
2. The monolithic behaviour of the full wall panels is significant to observe as the panel did not fall apart into parts even with increasing load and deflection.
3. The wall panel remained intact and did not collapse even when subject to significant loads.
4. GI wire mesh firmly rooted in the foundation provides confinement, preventing the wall from collapsing even if the mortar cracks and fails.
5. Mesh and mortar bear the majority of the lateral pressure as soil is weak in shear.
6. Mesh is linked together using ties to prevent wall buckling and is stabilised and given dead weight by the interior soil. It also offers stiffness.
7. GI wire mesh with a 1.8 mm diameter was used at the corner joint between the walls to strengthen the joint, and it was observed to be in good condition.
8. GI wire mesh with a 1.8 mm diameter was also used at the corner joint between wall and wall to strengthen the joint. At the maximum load of 52.7 kN, the joint was found to be in good condition.

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