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Performance of Confined Masonry in Seismic Zones

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Abstract: Confined masonry is found to be a better alternative for sustainable housing in seismic-prone regions of India. This paper presents a comprehensive review comparing the seismic performance and construction methods of confined and unreinforced masonry walls. Confined masonry construction is a viable alternative for safe and economical construction in seismic areas and this paper discusses various aspects of it. Also presents a review of the design and construction guidelines for confined masonry buildings which are developed by the Confined Masonry Network. This review is to analyze and compare the earthquake resistance of confined masonry walls and distribution methodology for seismic design forces to different members of confined masonry like tie-columns, which add to structural strength. The review also provides the ductile behavior of confined masonry buildings in seismic areas. This paper presents a review of the test results which are carried out to study the seismic behavior of confined walls constructed from a single wythe of masonry units and the performance of concrete tie-beams and tie-columns and to develop a method for modeling the seismic behavior of confined masonry walls of trilinear models also.

Keywords: confined masonry, seismic behavior, confined walls, tie-column, masonry wall, reinforced masonry, brick wall ductility, seismic design

I.INTRODUCTION

India is highly vulnerable to earthquakes, and past disasters have exposed the risks associated with unreinforced as well as non-ductile reinforced concrete (RC) frame construction, resulting in a high loss of life and property. However, constructing safe and affordable housing for economically weaker and lower-income groups remains a challenge due to the high cost of properly constructed reinforced concrete buildings. Confined masonry is a viable alternative building technology with improved seismic performance, providing durable walls and roofs for safe housing in both urban and rural areas.

Confined masonry construction is a type of building that has masonry walls with reinforced concrete columns and beams surrounding them on all sides. These columns and beams help to strengthen the walls and keep them from collapsing during earthquakes. The vertical columns are called tie columns and the horizontal beams are called tie beams.

Confined masonry (CM) is an economic and strong building system that has shown good seismic performance in several destructive earthquakes. It combines the advantages of unreinforced masonry and reinforced concrete structures without the complexity of the latter. The term "confined masonry" refers to masonry construction reinforced with additional steel, timber, or concrete elements. Thus, CM is a better alternative for sustainable housing schemes in seismic-prone regions of India.

The key features of structural components of a confined masonry building are discussed below [15]

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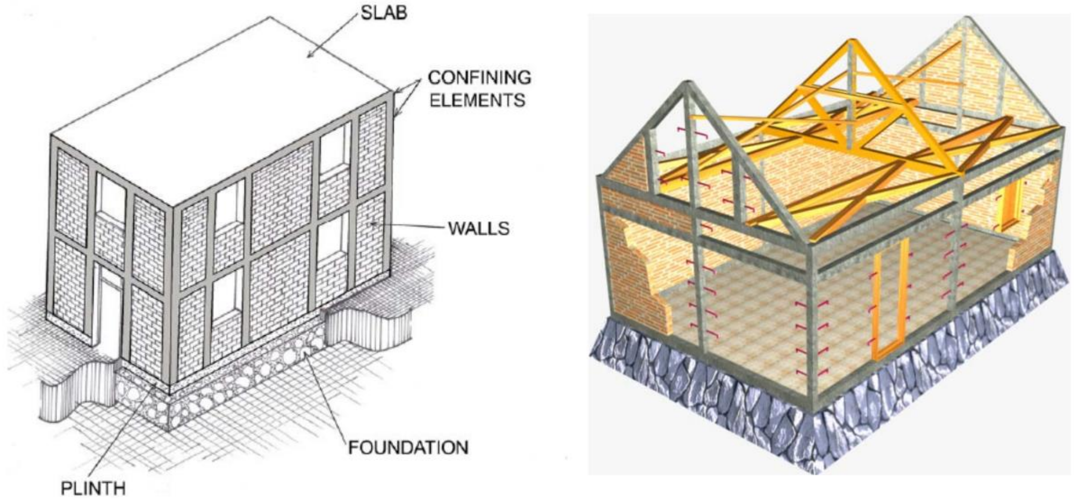
- Masonry walls carry the weight of the building down to the ground, along with reinforced concrete columns. Confined masonry construction is a way of building walls using bricks or blocks that can resist earthquakes. These walls act as braces to withstand horizontal earthquake forces. The walls must be reinforced with steel beams and columns to be effective and should not have significant openings to keep the building safe during an earthquake.
- Confining elements like RC tie-columns and tie-beams improve the stability and integrity of masonry walls during earthquakes. They prevent the walls from completely disintegrating and contribute to the overall stability of the building.
- The floor and roof slabs carry both gravity and lateral loads to the walls. During earthquakes, they act as diaphragms. Reinforced concrete is commonly used for roof slabs as shown in Figure 1-a, but lightweight materials like timber or light gauge steel can also be used as shown in Figure 1-b.
- Plinth band transmits the load from the walls down to the foundation and prevents too much settling and water damage.



a) b)

Figure 1.1 Typical confined masonry building: a) flat RC roof and b) pitched timber roof. [15]

- Foundation transmits the loads from the structure to the ground.

II.LITERATURE REVIEW

Borah et al (2022) [13] studied that tie columns can have a significant influence on the seismic behavior of confined masonry walls. They tried to develop a systematic approach for estimating the design shear forces for tie columns. A finite element study was therefore carried out to understand the load distribution between different members of CM walls under the combined action of gravity and lateral loads. They have been marked that the tie columns may be subjected to a significant amount of shear forces, and they have been designed columns for about 15% to 50% of the total design lateral shear of a CM wall, depending upon the masonry strength, thickness & aspect ratio.

Arturo et al (2009) [3] have done many experiments on different models for combined and confined masonry walls, including their cyclic testing according to the Mexican guidelines (NTCM-2004). The major difference in the cyclic behavior of the combined and confined masonry walls jointed with engineered and nonengineered mortar is related to the resisting shear mechanism that leads to failure. In the end, they said that the following variables are important to assess in experimental works: (a) the impact of other wall combinations, (b) the impact of the applied axial load, (c) the impact of other mortar mixes allowed by seismic codes and, (d) the impact of using concrete blocks of better quality, with similar mechanical properties to the ones of clay bricks.

Borah et al. (2019) [9] studied that low-rise CM structure exhibits better in-plane and out-of-plane resistance in comparison with URM (Unreinforced Masonry) and infilled RC (Reinforced Concrete) frame structures under any seismic event. and URM provides very less lateral strength in comparison with CM and a proper RC frame building with

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infill walls requires technical skills and finances. This paper compares the seismic performance of URM, infilled RC frame, and CM buildings through literature review and past seismic events.

Tomazevic et al. (1997) [1] studied and proved experimentally the mechanism of seismic behavior of confined masonry wall panels with a H/L ratio equal to 1.5 by testing several confined masonry walls under seismic loading conditions. Based on the observed behavior and analysis of test results, a model for the prediction of lateral resistance vs displacement envelope curve, idealized by a trilinear relationship, defined with elastic limit, maximum resistance, and ultimate state of the wall, has been proposed which has good correlation.

Sorina (2017) [8]**,** studied the confined masonry (CM) structure using push analysis using ETABS w.r.t Eurocodes. She has been seen that the CM structure was stiff. So that she has been analyzed the CM separately and saw that the plastic hinges in tie beams developed and the masonry has been crushed in that area. This analysis examines masonry behavior, internal forces, and bearing capacity, with the confining elements entering the plastic state as reinforcement bars reach the yield limit, but further study is needed to understand the masonry cracking and maximum deformation. The analysis includes a 3D model to show the behavior of the entire structure, followed by separate models to examine the ductility behavior of each wall.

Hart et al. (2014) [6]**,** studied the confined masonry (CM) structure. They have been provided design guidelines for non-engineered CM buildings in regions of moderate to high seismic hazard. In this document, the author has tried to draw from existing construction guidelines to create a more universal guideline that will include recommendations for site selection, wall layout and configuration, materials, workmanship, foundation placement, masonry construction, concrete placement, floor and roof construction, and quality control.

T. Mahdi et al. (2003) [4] conducted experimental tests to study the seismic behavior of confined walls made of a single wythe of masonry units, using clay and concrete tie beams and tie columns in The BHRC laboratory. In the literature, significant cracks in masonry walls are typically associated with the end of the elastic range and a change in initial stiffness. However, as demonstrated in this paper, confined masonry walls can remain active beyond the elastic limit and sometimes develop a mechanism involving ductile inelastic response. This highlights the importance of considering the full range of behavior in the design of confined masonry structures. Four full-scale wall specimens were constructed and subjected to cyclic loadings parallel to the wall axis. The specimens were evaluated for displacement, force, deformation capacity, energy dissipation, stiffness and strength degradation, maximum shear strength, cracking pattern, failure mechanism, and overall structural performance.

Ajay et al. (2013) [5] studied different factors that can affect the performance of confined masonry during earthquakes and suggests ways to overcome these factors. Past earthquakes and tests have shown that confined masonry is stronger and more ductile than unreinforced masonry. However, the performance of confined masonry depends on various factors like materials, structural configuration, reinforcement detailing, and more. To improve the seismic performance of confined masonry, approaches like horizontal reinforcement, ductile detailing of tie-columns, and dowels at interfaces can be used. More research is needed to better understand the behavior of confined masonry in different situations and to develop cost-effective design rules for future construction.

Kushal et al. (2017) [7] studied the conventional method of masonry construction and designed a sample building of confined masonry technique with the same construction material. The study has considered the analysis, design & comparison of a confined masonry wall with an unreinforced masonry wall. This study provides guidelines for load-bearing confined masonry structures. The study focussed on determining the more economic construction between the unreinforced and confined masonry. It can be concluded from the given study and analysis that confined masonry performs better under seismic load when compared to conventional masonry construction.

The summary of the literature review showed the analysis, design & comparison of confined masonry walls with unreinforced masonry walls. The confined masonry is the most suitable building system for low to medium-rise construction. The past earthquakes, including major ones and laboratory tests on CM walls, establish the effectiveness in terms of strength and ductility of confined masonry systems over unreinforced masonry. For brevity, it is assumed that masonry walls resist all possible loads imparted on CM buildings and understand the behavior of tie members as well as

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in-plane & out-of-plan wall panels also. A trilinear model for predicting the lateral resistance-displacement curve of a wall has been proposed in the paper based on observed behavior and test analysis. The model defines the elastic limit, maximum resistance, and ultimate state of the wall.

This paper presents the outlines of the development and key recommendations of design and construction guidelines for confined masonry buildings in regions of moderate to high seismic hazards. The paper will study the nonlinear behavior of the building, to show how the desired ductile behavior has been achieved. The plastic hinges formation and the redistribution of the stresses in the structure when the plastic state is reached will be shown. In this confined masonry wall system, the tie beams and tie columns are used to make the system function together, and the walls must resist both vertical and lateral loads. However, the conventional earthquake-resistant design relies on the ductility of the elements to enable redistribution and reduction of internal actions and dissipation of earthquake energy, which is why the RC tie-columns in the unreinforced masonry walls are essential.

III.CONCLUSION

The studies on seismic analysis and design of confined masonry the following conclusion are made:

- The confined masonry performs better under seismic load when compared to conventional masonry construction.
- The trilinear model developed for the lateral resistance-displacement curve shows a good correlation with experimental values for confined masonry walls with 1.5 and 1.0 h/l ratios, suggesting the effectiveness of a rational method for modeling the seismic behavior of such walls.
- Most of the time, confined masonry panels exhibit a seismic response dominated by shear forces.
- Connections between walls and tie beams or between walls and tie columns must be made compulsory.
- To provide a ductile behavior for the confined system, closely spaced transverse reinforcement at the beam-column intersection region is recommended. Such reinforcement is useful for concrete confinement, resistance to shear, restraint of longitudinal reinforcement buckling, and improved anchorage.
- Under-reinforced concrete members, as seen in this paper, often lack the flexibility needed to withstand lateral forces from masonry. To prevent shear failure, additional measures must be taken.
- For concrete elements that are not sufficiently reinforced, the bending mechanism is not as important as the shear mechanism, which becomes the basis for models at small levels of deformation.
- The confined masonry building behaves rigidly without showing an actual hysteresis curve due to the building's height, but the plastic mechanism forms as expected with plastic hinges developing first in the tie beams and then at the base of slender columns.
- The masonry walls experience stresses beyond their design strengths but does not collapse before the formation of plastic hinges, with almost the same rigidity maintained until they give in.
- The tie columns should be designed for about 15% to 50% of the total design lateral shear of a CM wall, depending upon the masonry strength, thickness, and aspect ratio.

Confined masonry is better at resisting earthquakes than traditional masonry construction. A trilinear model for lateral resistance-displacement curve correlates well with experimental values for confined masonry walls with 1.5 and 1.0 h/l ratios, suggesting an effective method for modeling seismic behavior. Confined masonry panels typically have a seismic response dominated by shear forces. Connections between walls and tie beams/columns are necessary, and closely spaced transverse reinforcement at beam-column intersections is recommended for ductile behavior. Under-reinforced concrete members require additional measures to prevent shear failure, and the shear mechanism becomes the basis for models at small deformation levels.

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