AN OVERVIEW OF CONFINED MASONRY STRUCTURES AS SEISMIC RESISTANT STRUCTURE

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Abstract: **Seismic force is a major concern for the engineers nowadays specially in countries like India where occurrence of earthquakes are frequent nowadays. In order to make a structure seismic resistant, engineers opt for ductile design, ductile detailing, shear wall construction, etc. which ultimately sometimes increase the cost for small and medium height structures. Confined Masonry are those structures which are mainly build with walls but are confined with beams and columns which are poured after the walls are built. For Medium and Low height structures, this Confined Masonry structures gives a good performance against seismic forces and hence can be used as a Seismic Resistant Structures economically. This paper mainly deals with the Overview of Confined Masonry Structures, their differences with RC structures and some basic guidelines for construction of Confined Masonry Structures which are collected from various research papers and books. It also highlights various analysis techniques of Confined Masonry Structure and its elements from various research works**

Keywords*:* Confined masonry, Brick panel, Shear capacity, Construction Deficiencies, Earthquake-Resistance.

I. INTRODUCTION

From long time back, seismic force have been a major point of concern for engineers. As time passed more and more new technologies and systems developed and nowadays almost all structures are made seismic resistant structures. But sometimes special seismic resistant structures can increase the cost for small and medium rise building and also lack of expert skilled labors creates more problems. Hence in many cases people go for Unreinforced and Masonry structures for low rise building neglecting the earthquake effect which afterwards results in loss of property and life. As a result the concept of Confined Masonry arrived which consists of masonry walls confined by horizontal and vertical RC tie-columns and tie-beams that enclose the masonry wall panels on all sides. Application of confined masonry does not require advanced construction skills and so it can be used as an alternative to both unreinforced masonry and RC frame construction (T.M. Hart, et.al[1])

Fig. No. 1 Finished confined masonry structure (Ref. Zulqarnain A. S. et. al[2])

Some of the key features of the structural components of a confined masonry building as given in the Seismic Design Guide for Low Rise Confined Masonry Buildings by **Meli R.et. al[3]** are:

- <u>Masonry walls</u> transmit the gravity load from the slab(s) above down to the foundation (along with the RC tie-columns).
- <u>Confining elements</u> (RC tie-columns and RC tie-beams) are effective in improving stability and integrity of masonry walls for in-plane and out-of-plane earthquake effects. These elements prevent brittle seismic response of masonry walls and protect them from complete disintegration even in major earthquakes. Confining elements, particularly tie-columns, contribute to the overall building stability for gravity loads.
- <u>Floor and roof slabs</u> transmit both gravity and lateral loads to the walls. In an earthquake, floor and roof slabs behave like horizontal beams and are called diaphragms. The roof slabs are typically made of reinforced concrete.
- <u>Plinth band</u> transmits the load from the walls down to the foundation. It also protects the ground floor walls from excessive settlement in soft soil conditions and the moisture penetration into the building.
- <u>Foundation</u> transmits the loads from the structure to the ground.

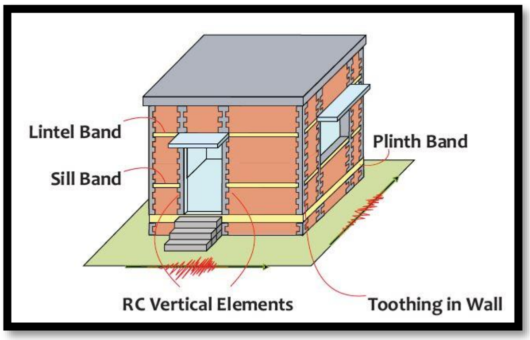

Fig. No.2 Structural Components of Confined Masonry Building (Ref. Build a Safe House with Confined Masonry[4])

Some of the prominent features of the confined masonry constructions are given below **Build a Safe House with Confined Masonry[4]** by Gujrat Sate Disaster Management Authority:

- Use of a regular grid of walls in both directions with RC vertical members at all wall junctions and in straight walls of longer lengths, and RC vertical elements (toothed into the masonry wall segments) and RC horizontal bands (resting on the masonry walls of the whole house). These items together confine the wall segments and prevent them from dilating along the length direction of the wall and from falling out-of-plane along the thickness direction of the wall.
- Sequence of first making the masonry walls and then pouring in-situ the RC vertical elements and horizontal bands. This choice of construction sequence is responsible for enhancing the integrity of the masonry units and mortar in Confined Masonry, which in turn makes Confined Masonry Construction superior to regular RC frame buildings with plain masonry walls as infill materials.

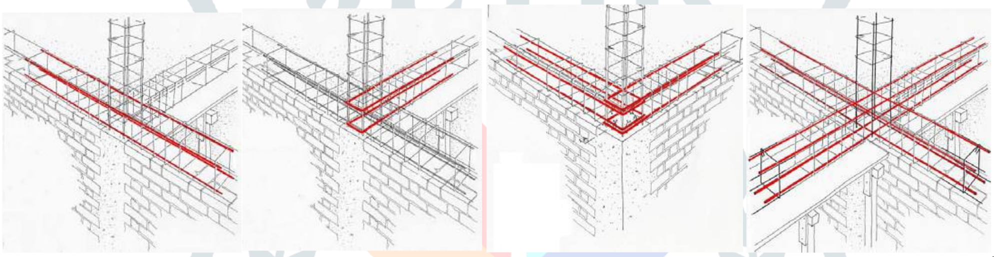

Fig No.3 Connect bond beams to columns with straight rebars and pins (Ref. Confined Masonry[5])

Various countries across the globe have already opted this concept as an alternative technology for constructing seismic resistant structures. **Constantinescu S.[6]** have done a research work on the ductile behavior of a confined masonry building in Bucharest, Romania which is considered as one of the seismic areas of Romania. Author considered a 3D model of the building, analyzed and showed how the ductile behavior is achieved and how the connecting beams first reaches its failure limit when the structure enters plastic state. **Lihong X. et. al[7]** studied the survey report conducted during the Wenchuan Earthquake which had proved that the Confined Masonry Building well designed and constructed performed well even in severely affected areas. Author had performed the nonlinear time history analysis, nonlinear static analysis and Pushover analysis for the Combined Masonry Structure and then compared the output results. **Tomaievic M. et. al[8]** studied the seismic behavior of Confined Masonry Building with two building models conforming to Euro Code, and placed on a shaking table for considering the effect of ground motion**.** **Rodriguez M.[9]** made a study on various Confined Masonry works of Mexico, Chile, etc. with their performance against earthquakes. Author also mentioned that in Mexico houses up to seven stories are built with this concept. . **Dr. Rai D.C.[10]** have made a review study of various design codes used for construction of masonry buildings across the globe. **Rajeshkumar A mali et.al[11]** considered a sample confined masonry building in his paper and made a simplified approach for the design of wall panel. **Kumar M. et.al[12]** studied the seismic behavior of a confined masonry building model. **V. Sigmund et.al[13]** made a research paper on the proper connection of the confining elements of confined masonry as per the Euro code and also studied the influence of different types of connection details between the masonry panel and reinforced tie-columns on the resistance and displacement capacity of confined masonry walls.

II. COMPARISON BETWEEN RC FRAME AND CONFINED MASONRY STRUCTURES

RC frame structure are the most common type of structures found whereas Confined Masonry Structure is totally a new concept. The appearance of a finished Confined Masonry and RC structures looks similar but their main differences are related to the construction sequence, as well as their behavior under seismic conditions like in case of confined masonry construction, confining elements are not designed as a moment resisting frame so detailing of reinforcement is simple **Brzevit S.[14]**. The most important difference between the confined masonry walls and infill walls is that infill walls are not load-bearing walls, while the walls in a confined masonry building are load bearing in nature **Brzevit S.[14]**. Hence proper and clear difference have to be made between RC frame and Confined Masonry Structures. Following table gives an idea about the differences between the both.

Table No.-1 Comparison between Masonry and RC frame construction (Ref. Kushal J. Desai et. al[15] and Zulqarnain A. S. et. al[2])

Parameter	Confined masonry construction	RC frame construction
Gravity and lateral load resisting system	Masonry walls are the main elements to resist gravity and lateral loads.	RC frames resist lateral load and gravity and lateral loads with larger beams, columns, and their connections. Masonry infills are not load-bearing walls.

Foundation construction	Strip footing below the wall and the RC plinth band	Isolated footing below each column.
Superstructure construction sequence	1. First masonry walls are constructed. 2. Parallel, tie-columns are cast in place. 3. Finally, tie-beams are constructed on top of the walls, in parallel to floor/roof slab construction.	1. First construction of frame is carried out. 2. Masonry walls are constructed at a later stage and are not bonded to the frame members; these are non-structural, that is, non-load bearing walls.
Time period	Confined masonry building takes less time for completion.	RC frame construction building takes more time for completion.
Economical	Confined masonry is more economical than RC structure.	RC frame construction building is less economical than confined masonry structures.
Architectural Design	Confined masonry building architectural design is simpler than RC frame construction buildings.	RC frame construction building architectural design is less simple than Confined masonry buildings.
Easier Construction	Confined masonry buildings are easier to construct as compare to RC frame construction.	RC frame Construction is difficult to construct as compare to Confined masonry buildings.

Fig. No.3 Examples of RC frame construction in Cambodia (left) and confined masonry construction in Mexico (Ref. Brzevit S.[14])

Fig. No. 4 Masonry building technologies: Confined masonry construction in Chile (S. Brzev, left), and Reinforced masonry construction in Canada (B. McEwen, Right) (Ref. Meli R. et. al[3])

III. HISTORY AND APPLICATIONS OF CONFINED MASONRY STRUCTURES WORLD WIDE

Concept of this Confined Masonry was first introduced in Italy as an alternative of unreinforced brick masonry structures which were destroyed in the 1908 Messina Earthquake Dr. Singhal V.16 and Brzevit S.14 . The next known practice of confined masonry construction was started in Chile in the 1930's after the 1928 Talca earthquake (Magnitude 8.0) that affected a significant number of unreinforced masonry buildings. Over the last 30 years, confined masonry construction has been practiced in Mediterranean Europe (Italy, Slovenia, Serbia), Latin America (Mexico, Chile, Peru, Argentina, and other countries), the Middle East (Iran), south Asia (Indonesia), and the Far East (China) Several examples of confined masonry construction around the world, from Argentina, Chile, Iran, Peru, Serbia and Slovenia, are featured in the World Housing Encyclopedia (EERI/IAEE, 2000) Svetlana Brzevit S.14. This concept now have become popular in Chile, Mexico and in various countries of South and Central America, Asia, East Europe, etc. (Dr. Singhal V.)16. In Mexico, even upto seven stories building are also getting constructed with this confined masonryconceptRodriguez.M[9].

Asian Countries like India, Pakistan and Indonesia have also just started construction in this concept. In March 2005, detailed subsector study of Confined Masonry Housings was started in Aceh, Indonesia **Appendex-2[17] .** In India the first major known big construction using Confined Masonry Concept is at the Campus on Sabarmati at IIT Gandhinagar. The student hostel, faculty and staff residences at IIT Gandhinagar were built with confined masonry concept. **Campus on Sabarmati[18] .**

Fig. No.5 Architectural rendering of faculty and staff residences (Vastu-Shilpa Consultants, 2014) (Ref: Campus on Sabarmati[18])

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IV. VARIOUS ANALYSIS AND RESEARCH WORKS OF CONFINED MASONRY STRUCTURES

There are various research works on different methodologies and analysis of Confined Masonry Structures across the globe. Some of the key research works of various researchers are provided in this paper in brief,. **Bourzam A. et. al[19]** made an analytical proposal to predict the lateral shear capacity of the confined masonry walls which fails by diagonal splitting. Author also investigated some of the empirical formulae obtained in the literature regarding the stiffness degradation. **Ahmed A.et. al[20]** made a full scale model of a room of size an area 3048 × 3658mm and height of 3353mm using confined brick masonry and was tested under quasistatic loading system. Author noted the Crack pattern at the end of each loading cycle and then the response of the model was interpreted through a hysteresis curve, which was then idealized by a bilinear curve. Author in the research paper also made a comparative study with the similar model made up of unreinforced brick masonry. **Ahmad N et. al**[21] have made a study on the performance of the low-rise confined masonry structures against earthquake induced site amplified strong ground motions using a probabilistic-based approach. **Arle pratibha. R et. al[22]** used ETabs software for the analysis of confined masonry and RCC frame structures and made a comparison between the two on the basis of max storey drift, max storey displacement, max storey shear, etc. **Ramesh.A.M[23]** presented a paper on the effect **of** confinement over unconfined masonry building by analyzing different 5nos of using Tremuri software which provides precise evaluation on Masonry structures and their degree of seismic vulnerability. **A. F. Lang et. al**[24] made a detailed assessment of the analysis techniques of confined masonry structures and summarizes the various analysis methods available to the researchers. Author also focused on the equivalent strut method and refined numerical micro modeling approach. **Singhal V. et. al[25]** made an experimental study confined masonry walls to investigate the role of toothing details at the wall-to-tie interface and effect of presence of openings under bidirectional loading

J. Varela-Rivera et. al[26] considered three full scale confined walls and made an experimental study on the out-of-plane seismic behaviors of those walls under concentrated reverse cyclic loads. The geometry and reinforcement details for those walls were as per the Mexico City Masonry Technical norms. **B. Shakarami et. al[27]** have done a research work with advanced numerical simulations in LS-DYNA to study the behavior of confined masonry walls with different aspect and reinforcement ratio subjected to the in-plane horizontal loads. Author also made the numerical investigation of confined masonry wall system based on concrete blocks and solid clay bricks masonry units, to be used in low to medium rise residential buildings in seismic areas and drawn certain conclusions based on the research result. **Mosaad El-Diasity et. al[28]** made an experimental study with the results of in-plane cyclic loading tests conducted on confined masonry walls with various features like solid walls, perforated walls with window and door openings, which are retrofitted using low-cost ferrocement and GFRP systems and drawn some conclusions. The wall model was subjected to a vertical load and lateral reversed cyclic loading with a displacement controlled loading protocol up to failure.

Chinchu.K.S et. al[29] did an analysis of Confined and Unconfined structure with Tremuri software which follows finite element analysis. This paper mainly focused on the effect of confining element with the variation in reinforcement diameter. Author finally concluded that the load carrying capacity will get increased with increase in area of steel but after attaining a particular load, further increase in area of steel will not affect the load carrying capacity of the structure. **Naseer A.[30]** in his thesis work framed building models of single and double storied with confined masonry conforming to Eurocode 8. The model had undergone test in compression, diagonal compression and cyclic test. Author also studied the failure modes and finally concluded with the result as to how much ground acceleration the model would take without distinct failure. **Khan S. et. al[31]** considered two masonry specimens of Plane and Confined Masonry and have tested with Portable Structural Testing Equipment and the test were carried out to obtain results of diagonal compression strength, shear strength and tensile strength between the specimens**.**

V. GUIDELINES FOR CONSTRUCTION OF CONFINED MASONRY STRUCTURES

Confined Masonry constructions have become very popular in various parts of the world. But in India, still now this technology is new. Not many constructions have been done in India using this concept. There are no proper BIS codal guidance in this regards also but certainly there are some guidelines for construction of Confined Masonry structures all around the world which can be also followed in India too. Some of the reference of guidelines have been listed below:

1. IITK-GSDMA Guidelines For Structural Use Of Reinforced Masonry[30]
2. Seismic Design Guide For Low-Rise Confined Masonry Buildings[3]
3. Build A Safe House With Confined Masonry[4]
4. Confined Masonry[5]
5. Confined Masonry For One And Two Storey Buildings In Low Tech Environments[32]

Construction Guide For Low Rise Confined Masonry Buildinngs[33]

Fig No.6 Constructions of Confined Masonry Buildings (Ref. Campus on Sabarmati[18])

VI. CONCLUSIONS

From this paper it is concluded that for construction of low and medium height structures, concept of confined masonry is a good choice as earthquake resistant structure. Countries like India, Bangladesh, Pakistan, etc. where masonry structures are very common in rural and village areas can implement this concept more and more. India has recently gone through various earthquakes which have created certain amount of structural damage. For large and high rise structures different structural and design alterations can be made to resist against the earthquakes like ductile design, shear wall construction, avoiding cantilever parts, strong column building , trying to reduce the dead load of the structure as low as possible, trying to maintain uniform moment of inertia all through the structures and all other seismic recommendations. But problem rises for medium or low height structures especially for building apartments, residential complexes and flats where cost is a key factor particularly after the covid pandemic situation and also in local rural, towns and village areas where money along with skilled and expert personals for seismic resistant structures are constraints. Hence implementation of this new concept right from the rural areas will be an effective alternative choice against the earthquakes and will also help to reduce the damage percentage caused due to earthquake.

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