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Confined Masonry-Analysis, Design and Comparison

Kushal J. Desai[1], Prof. S. B. Patel[2], Prof. V. V. Agrawal[3]

[1,2,3]Department of Structural Engineering
Birla Vishvakarma Mahavidyalaya
Vallabh Vidyanagar, Gujarat, India.
kushalpatel2007@gmail.com, sbpatel@bvmengineering.ac.in, vvagrawal@bvmengineering.ac.in

***Abstract* - Considering the present scenario, it is observed that the response of the unreinforced masonry building during the earthquake conditions have resulted into significant damages in buildings and subsequent life loss. The conventional method of masonry construction adopted so far utilizes the same construction material as in confined masonry, however the construction technique differs for both. This study has considered the analysis, design and comparison of confined masonry wall with unreinforced masonry wall. The differences in the method of construction and the performance of both, under the seismic conditions has been considered through the study on a sample building. A user friendly tool in the form of Microsoft excel worksheet is to be generated to design a confined masonry wall. The study is aimed at determining the more economic construction between the unreinforced and confined masonry.**

Keywords – confined masonry, reinforced masonry, masonry wall.

1. Introduction

A. Significance of Masonry Systems

Masonry is one of the most important construction material in the history of mankind. Masonry has been used in a wide variety of forms as a basic construction material. Brick masonry is an assemblage of brick units bonded together with mortar. A great number of well-preserved old masonry buildings still exist indicating that masonry is resistant to loads and environmental impacts to a large extent if properly constructed.

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Main advantage of masonry building is their high compressive strength. They are heat and fire resistant and will last for over 100 years. The performance of masonry structures in the past few earthquakes reveal that they are not much efficient in taking earthquake loads without damage. These observations reveal the vulnerability of unreinforced masonry towards earthquake and the need of confinement.

B. Limitations of Unreinforced Masonry

Investigation of deformation capacity of masonry structures should start by studying the in plane behaviour of masonry walls and their constitutive elements-piers and spandrels. Deformation capacity of masonry walls are mainly identified with the deformation capacity of piers.

In case of low vertical load, seismic loads cause shearing of walls into two parts. The mechanism is called sliding shear failure. Diagonal shear failure occurs when principle tensile stress exceeds the in plane tensile strength of masonry. Flexural failure takes place in case of high moment or shear ratio.

C. Confined Masonry

Confined masonry construction consists of masonry walls and horizontal and vertical reinforced concrete (RC) confining elements built on all four sides of a masonry wall panel. Vertical elements, called tie-columns, which is similar to columns in RC frame except that they have small cross-sectional dimension. These RC members are constructed after the completion of masonry wall. Tie-beams are similar to beams in RC frame construction with the difference that they are not supposed to function as conventional beams as confined masonry walls are load-bearing. Terms like vertical ties and horizontal ties, are sometimes used instead of tie columns and tie-beams.

D. Comparison of RC frame construction and confined masonry

The appearance of a finished a RC frame construction with masonry in fills and confined masonry construction may look alike to layman, however these construction systems are very different. The main differences are related to the construction procedure, and also their behaviour under seismic conditions. These differences are shown in Figure 1.1 below and are summarized in Table 1.1

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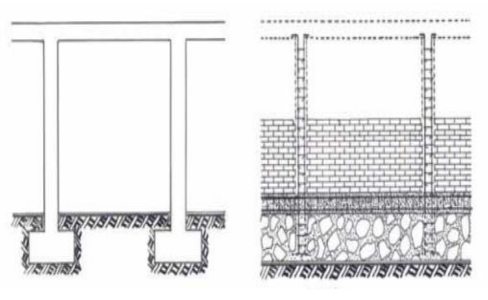

Fig. 1 Confined Masonry (right) And RC Frame Construction (left)

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.

Table 1: Comparison between Frame Construction and Confined Masonry

E. Aim:

- To carry out the analysis, design and comparison of a confined masonry wall building.

F. Objectives:

- To perform a case study on building of IIT, Gandhinagar and model and design of similar building.
- The result can be used to design walls of buildings in major earthquake zones, which can thereby reduce the loss of life and property during higher magnitude earthquakes.
- To study the performance of confined masonry wall under lateral and dead loads; and to determine the failure criteria in the form of cracks or other deformation.
- To prepare a user friendly tool in the form of an excel worksheet, that can aid designing of the masonry wall, which shall be a versatile sheet upto 9 openings in a wall; so that they can be used for all walls of the building.

G. Research Problem:

- Majority of the buildings today are build up by conventional method of construction; wherein initially a concrete framework is build up, which is followed up by the masonry construction. However the integrated performance of such conventional constructions is observed to be inferior during major lateral loads; especially during earthquakes.

- As a result of this, enhancement of a new technology, i.e the confined masonry construction technology is to be studied as a solution to the problem.

I. Numerical calculation of masonry wall

The figure 2, shows that elevation and figure 3 shows the plan of a typical wall with 3 openings (2 doors, 1 window) with reinforcement / column provided at 2 ends of the walls and near the jambs of all openings. Note that the masonry is utilized for compression and steel for tension only.

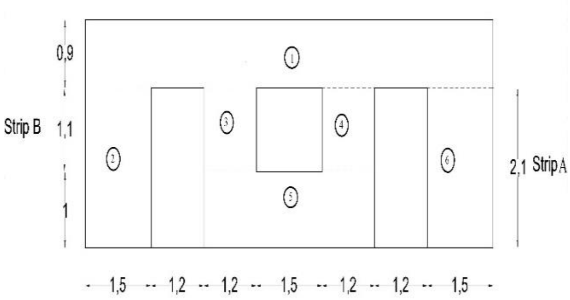

Fig. 2 Sample wall elevation

A. Rigidity of wall

$\Delta_{WALL} = \Delta_{SOLID\ WALL} - \Delta_{STRIP\ A} + \Delta_{2,3,4,5,6}$

$\Delta_{2,3,4,5,6(f)} = \frac{1}{R2,3,4,5,6(f)}$

$R_{2,3,4,5,6(f)} = R_{2(f)} + R_{3,4,5(f)} + R_{6(f)}$

$R_{3,4,5(f)} = \frac{1}{\Delta 3,4,5(f)}$

$\Delta_{3,4,5(f)} = \Delta_{SOLID\ 3,4,5(f)} - \Delta_{STRIP\ B} + \Delta_{3,4(f)}$

$\Delta_{3,4(f)} = \frac{1}{R3(f)+R4(f)}$

$\Delta_{SOLID} = \frac{1}{Et}\left[\left(\frac{H}{D}\right)^3 + 3\left(\frac{H}{D}\right)\right]$

For $\frac{H}{D} = \frac{3}{9.3} = 0.323$

$\Delta_{SOLID} = \frac{1.00}{Et}$

$\Delta_{STRIP\ A} = \frac{1}{Et}\left[\left(\frac{H}{D}\right)^3 + 3\left(\frac{H}{D}\right)\right]$

For $\frac{H}{D} = \frac{2.1}{9.3} = 0.226$

$\Delta_{STRIP\ A} = \frac{0.689}{Et}$

$R_{3(f)} = R_{4(f)} = \frac{Et}{\left[\left(\frac{H}{D}\right)^3 + 3\left(\frac{H}{D}\right)\right]}$

For $\frac{H}{D} = \frac{2.1}{9.3} = 0.226$

$R_{3(f)} = R_{4(f)} = \frac{Et}{3.52}$

$\Delta_{3,4(f)} = \frac{1}{R3(f)+R4(f)}$

$= \frac{1.76}{Et}$

$\Delta_{3,4,5(f)} = \frac{1}{Et}\left[\left(\frac{H}{D}\right)^3 + 3\left(\frac{H}{D}\right)\right]$

For $\frac{H}{D} = \frac{2.1}{3.9} = 0.54$

$\Delta_{3,4,5(f)} = \frac{1.77}{Et}$

$\Delta_{STRIP\ B} = \frac{1}{Et}\left[\left(\frac{H}{D}\right)^3 + 3\left(\frac{H}{D}\right)\right]$

For $\frac{H}{D} = \frac{1.2}{3.9} = 0.31$

$\Delta_{STRIP\ B} = \frac{0.96}{Et}$

$\Delta_{3,4,5(f)} = \frac{1.77}{Et} - \frac{0.96}{Et} + \frac{1.76}{Et}$

$= \frac{2.57}{Et}$

$R_{3,4,5(f)} = \frac{1}{\Delta 3,4,5(f)}$

$= 0.389\ Et$

$R_{2(f)} = R_{6(f)} = \frac{Et}{\left[\left(\frac{H}{D}\right)^3 + 3\left(\frac{H}{D}\right)\right]}$

For, $\frac{H}{D} = \frac{1.2}{1.5} = 1.4$

$R_{2(f)} = R_{6(f)} = 0.144\ Et$

$R_{2,3,4,5,6(f)} = R_{2(f)} + R_{3,4,5(f)} + R_{6(f)}$

$= 0.144\ Et + 0.389\ Et + 0.144\ Et$

$= 0.677\ Et$

$\Delta_{2,3,4,5,6(f)} = \frac{1}{R2,3,4,5,6(f)}$

$= \frac{1.477}{Et}$

$\Delta_{WALL} = \frac{1.00}{Et} - \frac{0.689}{Et} + \frac{1.477}{Et}$

$= \frac{1.477}{Et}$

B. Compression and tension in wall

$X_1 = \left(\frac{9.185-kd}{kd}\right) f_m$ $Y_1 = \left(\frac{kd-1.5}{kd}\right) f_m$

$X_2 = \left(\frac{7.685-kd}{kd}\right) f_m$ $Y_2 = \left(\frac{kd-2.7}{kd}\right) f_m$

$X_3 = \left(\frac{6.485-kd}{kd}\right) f_m$ $Y_3 = \left(\frac{kd-3.9}{kd}\right) f_m$

$X_4 = \left(\frac{5.285-kd}{kd}\right) f_m$

$C_1 = \left[\frac{\left(\frac{kd-1.5}{kd}\right) f_m + f_m}{2}\right] \times 1.5 \times t$

$= \left(\frac{0.64kd-0.45}{kd}\right) f_m$

$$C_2 = \left[\frac{\left(\frac{kd-3.9}{kd}\right)f_m + \left(\frac{kd-2.7}{kd}\right)f_m}{2}\right] \times 1.2 \times t$$

$$= \left(\frac{0.86kd-3.29}{kd}\right) f_m$$

$$C = C_1 + C_2$$

$$= \left(\frac{0.86kd-3.29}{kd}\right) f_m$$

$$T_1 = As \times n \left(\frac{9.185-kd}{kd}\right) f_m$$

Use 2 – 16 TOR

$As = 0.4 \times 10^{-3}\ m^2$

$$= 0.4 \times 10^{-3} \times 237.04 \times \left(\frac{9.185-kd}{kd}\right) f_m$$

$$= 0.095 \times \left(\frac{9.185-kd}{kd}\right) f_m$$

$$= \left(\frac{0.87 - 0.095kd}{kd}\right) f_m$$

$$T_2 = As \times n \left(\frac{7.685-kd}{kd}\right) f_m$$

Use 2 – 16 TOR

$As = 0.4 \times 10^{-3}\ m^2$

$$= 0.4 \times 10^{-3} \times 237.04 \times \left(\frac{7.685-kd}{kd}\right) f_m$$

$$= 0.095 \times \left(\frac{7.685-kd}{kd}\right) f_m$$

$$= \left(\frac{0.73-0.095kd}{kd}\right) f_m$$

$$T_3 = As \times n \left(\frac{6.485-kd}{kd}\right) f_m$$

Use 2 – 16 TOR

$As = 0.4 \times 10^{-3}\ m^2$

$$= 0.4 \times 10^{-3} \times 237.04 \times \left(\frac{6.485-kd}{kd}\right) f_m$$

$$= 0.095 \times \left(\frac{6.485-kd}{kd}\right) f_m$$

$$= \left(\frac{1.74-0.095kd}{kd}\right) f_m$$

T_4 = As × n $\left(\frac{5.285-\text{kd}}{\text{kd}}\right)$ f_m

Use 2 – 16 TOR

As = 0.4 × 10^{-3} m^2

= 0.4 × 10^{-3} × 237.04 × $\left(\frac{5.285-\text{kd}}{\text{kd}}\right)$ f_m

= 0.095 × $\left(\frac{5.285-\text{kd}}{\text{kd}}\right)$ f_m

= $\left(\frac{1.74-0.095\text{kd}}{\text{kd}}\right)$ f_m

T = T1+T2+T3+T4

= $\left(\frac{2.718 - 0.38\text{kd}}{\text{kd}}\right)$ f_m

P = C – T

600 = $\left(\frac{0.86\text{kd}-3.29}{\text{kd}}\right) f_m - \left(\frac{2.718 - 0.38\text{kd}}{\text{kd}}\right) f_m$

kd = 4.78 m

From kd, C1 = 614.09 kN

C2 = 193.18 kN

T1 = 97.88 kN

T2 = 64.935 kN

T3 = 38.10 kN

T4 = 11.273 kN

C. Moment of resistance

$$M1 = C1\left(\frac{L}{2} - X1\right) + C2\left(\frac{L}{2} - 2.7 - X2\right)$$
$$+T1\left(\frac{L}{2} - 0.115\right) + T2\left(\frac{L}{2} - 0.385\right)$$
$$+T3\left(\frac{L}{2} - 2.815\right) + T4\left(\frac{L}{2} - 3.785\right)$$

Where, X1, X2 C.G. of C1, C2 respectively

M1 = 2983.41 kN.m

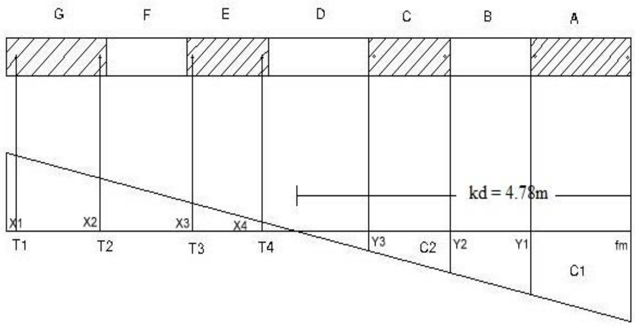

Fig. 3 Stress diagram

II. Conclusion

The calculated value of moment of resistance of 2983.41 kN.m can now be manipulated by change in the area of steel at various location and achieved to be more than actual moment carried by the particular wall as per seismic and reinforcement distribution calculation.

This study has considered the analysis, design and comparison of confined masonry wall with unreinforced masonry wall. The differences in the method of construction and the performance of both, under the seismic conditions has been considered through the study on a sample building.

This study provides guideline for load bearing confined masonry structure. The study focussed on determining the more economic construction between the unreinforced and confined masonry.

It can be concluded from given study and analysis that confined masonry performs better under seismic load when compared to conventional masonry construction.

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