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Effect of Opening in Masonry Infill Wall on Seismic Response of L-shaped Unsymmetrical Reinforced Concrete Frame Building

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Abstract—*Reinforced concrete frame with masonry infill walls are generally used for the construction of multi-storey buildings. Door and window openings in masonry infill wall are provided for functional use. Masonry infill wall is not considered as structural element which contribute to mass of structure, whereas it's strength and stiffness is ignored in general design practice in IS:1893-2002, which may lead to an unsafe design. To include effect of in-plane stiffness of unreinforced masonry (URM) infill wall or panel, IS:1893-2016 suggests that it shall be modeled by using equivalent diagonal strut and reduction in strut width is not required for URM infill wall with openings. In this paper effect of opening in URM infill wall is considered by applying a width reduction factor for diagonal strut. Seismic Response of G+5 L- shaped RC frame building with different openings in URM infill wall located in seismic zone IV has been analyzed by linear dynamic Response Spectra Method using ETABS software. The parameters investigated are lateral stiffness, displacement, story drift, base shear, overturning moment. It is found that IS1893-2016 underestimates the effect of opening, as when opening in infill wall increase. the parameters evaluated in the paper show significant changes; Therefor necessitating need for in depth study in the topic.*

Keywords: *Equivalent diagonal strut, lateral stiffness, Masonry infill wall, Opening, Seismic Response.*

Introduction

Masonry infill plane frames are commonly used in RC frame structure, even in seismically active regions. Clay bricks or concrete blocks are used in the construction of panels to make panels sufficiently rigid. It was a general perception that the masonry walls provided in buildings played no role in the seismic performance of the building and treated as a non-structural element in old design codes. But contrary to this past studies has shown that these properties of the infill walls have a valuable influence on global response of the structure due to seismic loads. Every structural element present at any storey contributes to the lateral stiffness of that storey. Hence the combination of the lateral stiffness of individual structural elements of any storey will give stiffness of that storey. Moreover, MI panel has significant in-plane stiffness & strength and hence contribute to overall stiffness and strength of the building. If we consider effect of MI panel in the analysis and design of RC framed structures, the results may be substantially different. Moreover, if the masonry infill panels present in all storey of the structure then it contributes to energy dissipation capacity, decrease the lateral displacement and increase the resistance to lateral forces. The behavior of MI frame structures has been researched in past in attempts to develop an approach for the design of MI frame structures. Different Methods based upon analytical and experimental research are used to calculate In-plane stiffness & strength of MI panel. According to IS 1893:2016 unreinforced masonry infill panel shall be modeled as an Equivalent diagonal strut. Model suggested by IS code is based on following assumptions a) connection between the RC frame and strut is pin-jointed; b) if both the ratio of height to thickness & length to thickness of infill panel are less than 12 then thickness of strut is original thickness of panel and code is silent if the above requirement is not fulfilled. Equivalent diagonal strut width can be determined with help of IS 1893:2016 and FEMA-273. The above codes have a formula for calculation of width of masonry infill walls. Once the Equivalent Diagonal Strut width is determined, a simple frame analysis can be done to calculate the stiffness & strength of MI frames.

Door and window openings in masonry infill wall are provided for functional use. Infill with door and window openings in walls are less studied in comparison to experiments on solid masonry infill; even within available studies, limited parameters were considered. It is generally accepted that presence of openings decreases the lateral stiffness & strength of the infill frame system. Several analytical and experimental equations have been proposed to calculate for these reductions as affected by opening in infill frame. However, efficacy of these methods have not been thoroughly examined. Effect of position, size and percentage of opening has to be studied more precisely; as there is lot of difference in the results of previous researches on openings. Due to lack of reliable technical information, the current design code IS 1893:2016 does not consider effect of opening in masonry infill wall. But FEMA-273 has provision to consider effect of opening in infill frame wall by using a width reduction factor. Behavior of infill wall has been analyzed and studied by researchers manipulating with many parameters by changing the percentage of openings, size and location of openings, change in infill material and frame material analysis with different software accompanied by different methods of analysis. In this paper effect of opening in URM infill wall is considered by applying a width reduction factor for diagonal strut.

. In the present study, Seismic Response of G+5 L- shaped RC frame building with different openings in URM infill wall located in seismic zone IV has been analyzed by linear dynamic Response Spectra Method using ETABS v17 software.

Methodology

The simplest way to define the infill panel in a frame is the Equivalent diagonal strut. The principle behind the method is that the infill frame can be assumed as a brace frame and it functions similar to the diagonal strut. As per IS1893: 2016 (Part 1), in RC buildings with URM infill walls, consideration of in-plane strength and stiffness of URM infill walls is important in order to examine the variation of storey strength and stiffness. The estimation of in-plane stiffness and strength of the URM infill walls is calculated by considering the following provisions-

(i) The modulus of elasticity E_m(in MPa) of masonry infill wall shall be taken as:

$\mathbf{E_m} = 550\ f_m$

$\mathbf{f_m} = 0.433\ f_b^{0.64} f_{mm}^{0.36}$

where

f_b = compressive strength of brick in MPa: and

f_{mo}= compressive strength of mortar, in MPa

(ii) URM infill walls are modelled by using Equivalent diagonal strut as below-

a) The ends of the diagonal strut are considered to be pin – jointed to the RC frame.

b) For URM infill walls without any opening, strut width $w_{ds}$of equivalent diagonal strut is taken as**:**

$\mathbf{w_{ds} = 0.175\ \alpha_h^{-0.4} L_{ds}}$

where

$\boldsymbol{\alpha_h = h\ (E_m t \sin 2\theta / 4\ E_f I_c\ h)^{-0.25}}$

where E_m and E_f are the modulii of elasticity of the materials of the URM infill and RC MRF; I_c is the moment of inertia of the adjoining column; t is the thickness of the infill wall; and θ the angle of the diagonal strut with the horizontal.

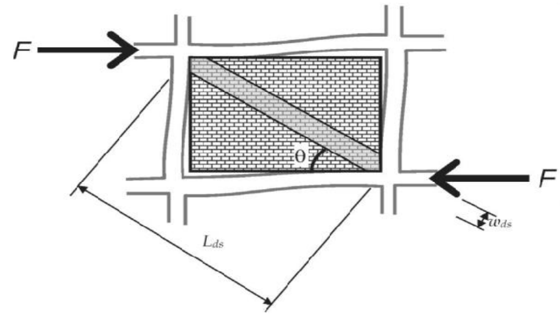

Figure 1: Equivalent diagonal strut model of URM infill wall.

Strut width reduction factor given by Al-Chaar:

$\mathbf{(R_1)_i = 0.6(A_{open}/A_{panel})^2 - 1.6(A_{open}/A_{panel}) + 1}$

Where:

A_{open} = area of opening,

A_{panel} = area of infil panel

Strut width with opening = $(R_1)_I * w_{ds}$

Value of Reduction factor = 0.7(20%)

0.46(40%)

0.26(60%)

Modelling

In this study, model of an sixstoreyL- shaped RC frame building with different openings in URM infill wall located in seismic zone IV has been analyzed by linear dynamic Response Spectra Method using shown in figure having storey height of 3 m with and without openingin infill panel as a structural member have been modelled and analyzed using ETABS v17 software. Properties of the material considered have been mentioned in table-1 and the dimensional properties have been mentioned in table-2. The figure of the various models considered are shown in the figures below.

Table 1: Material Properties

	Materials		
	Concrete	**Steel Reinforcement**	**Brick Masonry Infill**
Grade Strength (N/mm²)	**M25**	**Fe415**	**10.5**
Density(kN/m³)	**25**	**77**	**20**
Modulus of Elasticity(N/mm²)	**27386**	**200000**	**2457.04**
Poisson's ratio	**0.2**	**0.28**	**0.2**

Table 2: Dimensional Properties

Specification of Model Element	
Total Height	**18 m**
Column Size	**450x450 mm**
Beam Size	**375x450 mm**
Slab Thickness	**125 mm**
Masonry Wall Thickness	**230 mm** **11.73 kN/m DL**
Equivalent width of Strut	**748.5 mm** **5.83 m span length**
Strut width for different openings	**748.5mm for 0%** **527mm for 20%** **341mm for 40%** **192mm for 60%**

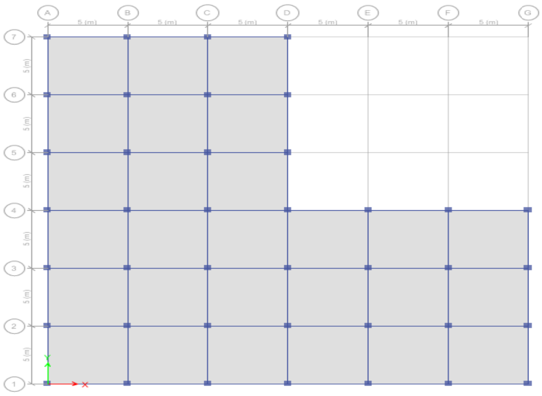

Fig: L shaped plan

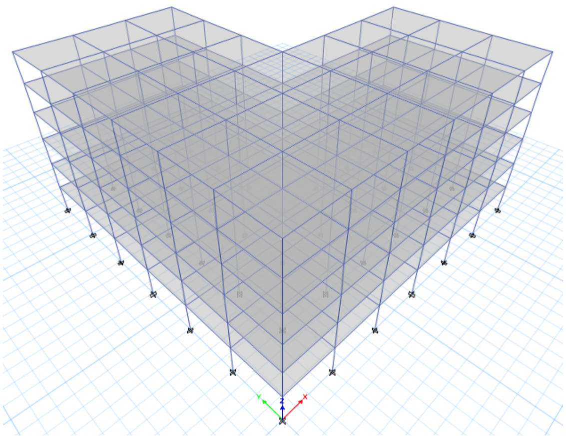

Fig: RC Bare frame

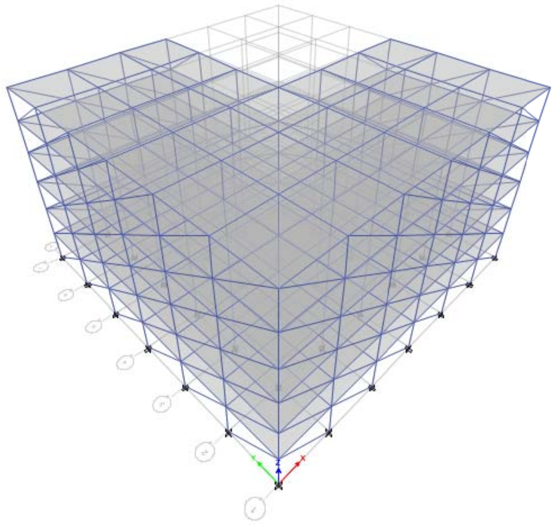

Fig: RC Frame with masonry infill

Analysis

Modelled frames have been assigned the general loading as per IS 875 (part1, part2) and seismic loading as per IS 1893(Part1):2016. The loading data and the seismic factors used for analysis are shown in table-3. Various models with different openings are analyzed using the linear dynamic response spectra method and their results are obtained using ETABSv17 software.

Calculation of width of Equivalent Diagonal Strut

compressive strength of brick = **10.5Mpa**

And mortar of grade H1(as per IS 1905:1987) having compressive strength=**10Mpa**

$f_m = 0.433 \times 10.5^{0.64} \times 10^{0.36} = \mathbf{4.4673\ Mpa}$

$E_m = 550 \times 4.4673 = \mathbf{2457.04\ Mpa}$

$\alpha_h = 2550\ [\{2457.04 \times 230 \times \sin(2\times3/5)/4 \times 27386 \times 3.417 \times 10^9 \times 2550\}^{1/4}] = \mathbf{2.167}$

Length of Equivalent diagonal strut = **5.83 m**

$W_{ds} = 0.175 \times 2.167^{-0.4} \times 5.83 = \mathbf{748.5\ mm}$

Ends of the equivalent diagonal strut are connected to RCC frame via pin connection.

Table 3: Loading data

Seismic data and loading	
Earthquake load	**As per IS 1893 (part1):2016**
Seismic zone	**IV**
Zone factor	**0.24**
Importance factor	**1.5**
Response reduction factor	**5**
Soil type	**Medium stiff soil**

Damping	**5%**
Live load	**3 KN/m^2**
SIDL	**floor finishing** **1.0 KN/m^2**
Partition wall thickness	**115 mm** **5.9 kN/m DL**

Results and Discussions

The analysis results for different opening percentage of unreinforced masonry infill walls have been compared below. In the figures shown, the change in the lateral displacement, storey drift and storey stiffnessafter the introduction of width reduction factor for Equivalent diagonal strut have been represented with the help of line graphs. In bare frame, mass of the masonry infill wall is considered and its strength is ignored. Due to symmetry about diagonal axis, results in both X and Y directions are same; That's why we have not mentioned direction in graphs.

Comparing results for various opening percentages

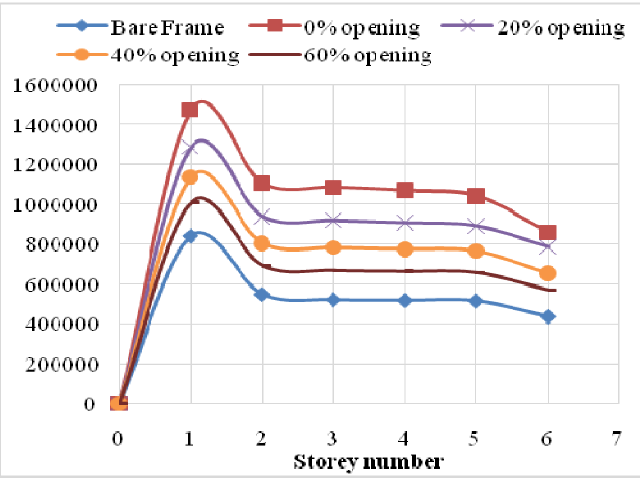

Fig 5: Comparison of Storey Stiffness (kN/m)

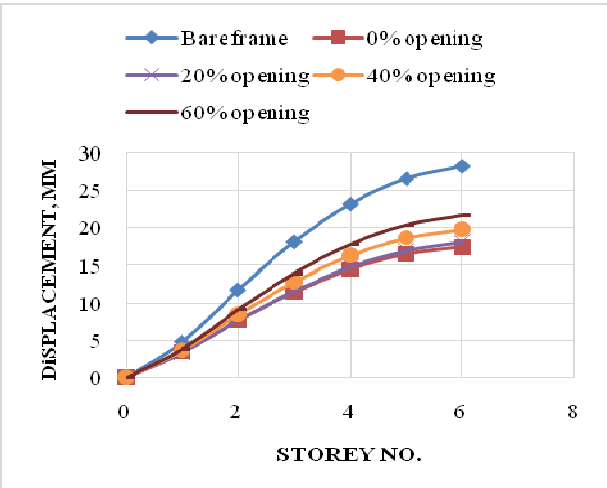

Fig 6 : Comparison of lateral displacement

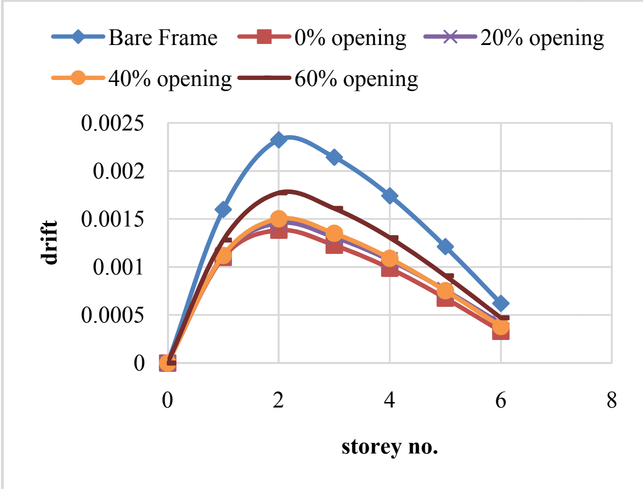

Fig 7: Comparison of StoreyDrift

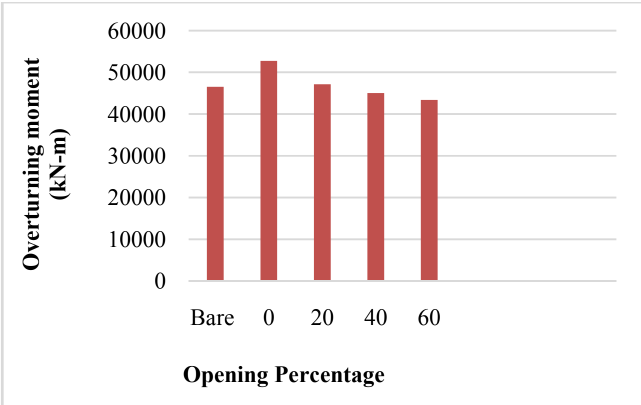

Fig 9: Comparison of Overturning moment(kN-m)

CONCLUSIONS

This study focusses on the structural response of masonry infilled RC structures analyzed using the linear dynamic response spectra analysis. From the results obtained, it is clearly seen that the inclusion of unreinforced masonry infill walls (URM) as a structural member in the analysis contributes heavily in resisting the in-plane lateral loads. The effects of increasing openings in walls of the considered model have been discussed in the following conclusions-

- As the opening percentage is increased, the storey displacement and the drift gradually increases.
- Due to the effect of URMinfill wall, the lateral stiffness at first floor of fully infilled frame (0% opening) is 1.75 times of bare frame.
- As the opening percentage increases, the value of lateral stiffness decreases by 12.6% for 20% opening, 22.5% for 40% opening and 31.5% for 60% opening with respect to fully infilled frame(0%).

- Storey drift values for all the configurations Is found to be less than the permissible value,i.e, less than 0.004 times the storey height as per IS 1893:2016(part 1).
- The overturning moment decreases as the opening percentage increases.
- Finally as per the observations of this paper, it is recommended to consider the effect of opening in the unreinforced masonry infill wall in the seismic analysis of the R.C.C framed building

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