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Seismic Vulnerability Assesment and Comparision of RC Buildings with and Without Infill Using Pushover Analysis

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Abstract: *Infill panels are widely used as interior partitions and external walls in buildings, but they are usually treated as non-structural elements and in a lot of cases their stiffness is not included in the reinforced concrete design. While performing the evaluation of existing reinforce concrete buildings, to know the actual behaviour of structure, effect of infill need to be incorporated in seismic evaluation. The masonry infill has been modelled as an equivalent diagonal strut, there are various formulae derived by research scholars and scientist for width of strut and modelling. In this study a 5-story R/C frame structure is considered to investigate the effect of masonry walls on high rise building. Pushover analysis has been carried out on bare frame and frame with infill using the software SAP2000. The results obtained from the non-linear are compared in terms of strength and stiffness with bare frame. It is observed that performance of the infilled frames is better in resisting the seismic loading by giving more stiffness to the frame compared to the bare frame. The vulnerability of the buildings is estimated in terms of vulnerability index to assess the performance of the building.*

1. INTRODUCTION

Earthquakes are one of the most devastating natural disasters. Most earthquakes occur without any prior warning and cause immeasurable damage and devastation. The risk posed by earthquakes on a particular community or building depends on the earthquake hazard at the site and the vulnerability of the built environment to earthquakes. In multi-storey building, the vertical loads, dead or alive, do not pose much of a problem, but the lateral loads due to wind or earthquake tremors are a matter of great concern and need special considerations in the design of buildings. These lateral forces can produce the critical stress in a structure, which can reach the stage of discomfort to the occupants.

Reinforced concrete (RC) frame buildings with masonry infill walls have been widely constructed for commercial, industrial and multi-family residential uses in seismic-prone regions worldwide. Masonry infill typically consists of brick masonry or concrete block walls, constructed between columns and beams of a RC frame. These panels are generally not considered in the design process and treated as non-structural components. In country like India, Brick masonry infill panels have been widely used as interior and exterior partition walls for aesthetic reasons and functional needs. Though the brick Masonry infill is considered to be a non-structural element, but it has its own strength and stiffness. Hence if the effect of brick masonry is considered in analysis and design, considerable increase in strength and stiffness of overall structure may be observed. Although the infill panels significantly enhance both the stiffness and strength of the frame, their contribution is often not taken into account because of the lack of knowledge of the composite behaviour of the frame and the infill.

The pushover analysis can be considered as a series of incremental static analyses carried out to examine the non-linear behaviour of structure, including the deformation and damage pattern. The procedure consists of two parts. First, a target displacement for the structure is established. The target displacement is an estimate of the seismic top displacement of the building, when it is exposed to the design earthquake excitation. Then, a pushover analysis is carried out on the structure until the displacement at the top of the building reaches the target displacement. The extent of damage experienced by the building at the target displacement is considered to be representative of the damage experienced by the building when subjected to design level ground shaking. A judgment is formed as to the acceptability of the structural behaviour for the design of the new building, or the level of damage of an existing building for evaluation purposes.

2. INFILLED FRAMES

A structure can transfer the forces to the ground developed by the lateral loads due to the wind and seismic loads, vertical loads due to gravity as well. The building frame is thus subjected to a combined action of vertical and horizontal loads. To resist these loads, normally the buildings are of reinforced concrete frame type with partition walls, of bricks or concrete blocks. The composite structure formed by the frame and the filling walls is termed as infilled frame.

2.1 Modelling of infill panel

A method based on equivalent diagonal strut approach for analysis and design of infilled frames subjected to in-plane forces was proposed in this paper. Fig. 1 shows the details of equivalent strut model

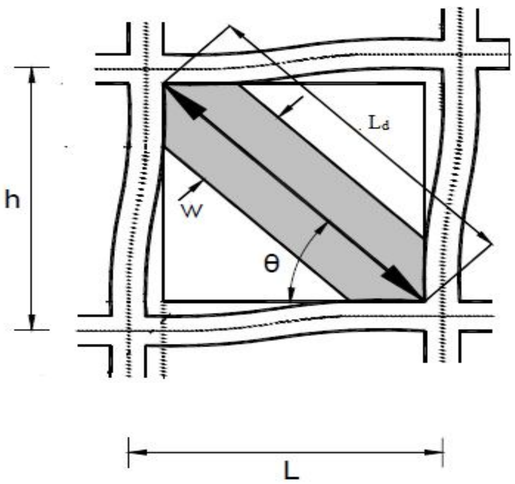


Fig 1 Equivalent Width of Strut

2.2 Width of the Diagonal Strut

A large number of researchers have studied the behaviour of infilled frames, starting with Mainstone (1974) to Durrani and Luo (1994), which were did modelling by replacing the infill wall by an equivalent pin-jointed diagonal strut.

a) **Mainstone**

$$W=0.175L_d(\lambda_h h)$$

Where,

$$\lambda_h = \sqrt[4]{\frac{E_z \cdot t \cdot \sin 2\theta}{4 \cdot E_b \cdot I_s \cdot H}}$$

b) **Hendry**

$$\alpha_h = \left(\frac{\pi}{2}\right)\sqrt[4]{\frac{4E_f I_c h}{E_m t \sin 2\theta}}$$

$$\alpha_L = \left(\frac{\pi}{2}\right)\sqrt[4]{\frac{4E_f I_b L}{E_m t \sin 2\theta}}$$

The effective width of diagonal strut is

$$w = \frac{1}{2}\sqrt{\alpha_h^2 + \alpha_L^2}$$

c) Liaw and kwan

$$w = \frac{0.95H\cos\theta}{\sqrt{\lambda_h H}}$$

d) Bertoldi

$$\frac{w}{L_d} = \frac{k_1}{\lambda_h \cdot H} + k_2$$

The values of the parameters *k1* and *k2* are presented in Table 1

	λ_h H <3.14	3.14<λ_h H <7.85	λ_h H >7.85
k_1	1.3	0.707	0.47
k_2	-0.178	0.01	0.04

e) Romania Code

According to the Romania Code, the diagonal strut width should be considered as *dz/10*

Where,

W = Equivalent Diagonal Width
L_d = Diagonal length of the strut
H = Height of Infill Panel
E_z = Modulus of elasticity of Masonry
t = Thickness of the infill
Θ = Slope angle of the panel's diagonal
E_b = Modulus of elasticity of concrete
I_s = Moment of inertia of column

3. PROBLEM FORMULATION

In the analysis work six models of R.C.C. High Rise building G+4 floors are made to know the realistic behaviour of building during earthquake. The length of the building is 24m and width is 24m.Having a four bays of 6m. Height of typical story is 3m. Building is located in second zone. Building is designed as per IS 456-2000 using ETABS software. Material concrete grade M25 is used, while steel Fe 500 are used. Modal damping 5% is considered. For the Non-linear analysis work SAP2000 software is used. The columns are assumed to be fixed at the ground level.

3.1 Schedules of R.C.C Structural members

Sizes of Beams 0.3x0.5 m,
Sizes of Columns 0.5x0.5 m (Gf and 1st floor)

Sizes of Columns 0.4x0.4 m (2nd , 3rd and 4th floor)

4. VULNERABILITY ANALYSIS

The vulnerability index is a measure of the damage in a building obtained from the pushover analysis. It is defined as a scaled linear combination (weighted average) of performance measures of the hinges in the components, and is calculated from the performance levels of the components at the performance point or at the point of termination of the pushover analysis. The vulnerability index of a building is assessed with the expression as follows

$$VI_{bldg} = \frac{1.5\,\Sigma_i^c N_c^i\, x_i + \Sigma_j^b N_b^j\, x_j}{\Sigma_c^i N + \Sigma_b^j N}$$

Where,

N_c^i and N_b^j are the numbers of hinges in columns and beams, respectively, for the i^{th} and j^{th} performance range. A weightage factor (x_i) is assigned for columns and (x_j) is assigned for beams to each performance range, the weightage factor is shown in Table.2

VI_{bldg} is a measure of the overall vulnerability of the building. A high value of VI_{bldg} reflects poor performance of the building.

SL. NO	Performance range	Weightage Factor(x_i)
1	<B	0
2	B-IO	0.125
3	IO-LS	0.375
4	LS-CP	0.625
5	CP-C	0.875
6	C-D,D-E,>E	1.00

Table 2 Weightage factors for Performance Range

SL. No.	Strut Width in m
Mainstone	0.768
Liaw an Kwan	1.47
Bertoldi	0.273
Hendry	1.125
Romania code	0.670

Table 3 Width of the Strut of RC Building

5. RESULTS AND DISCUSSION

5.1 Pushover curves for bare frame

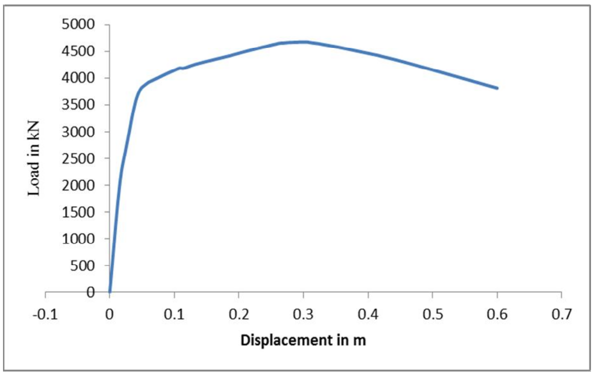


Fig I Capacity curve for the Bare Frame

5.2 Pushover curves for infill wall frames

a) Mainstone

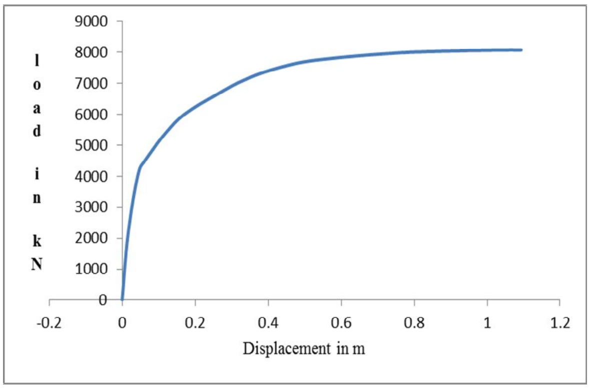


Fig II Capacity curve for infilled frame (Mainstone)

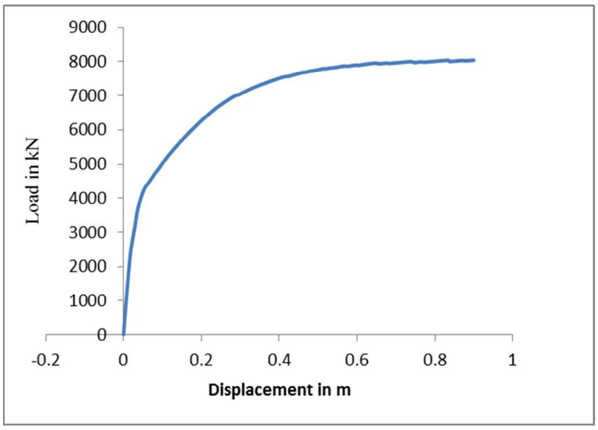


Fig III Capacity curve for infilled frame (Liaw and Kwan)

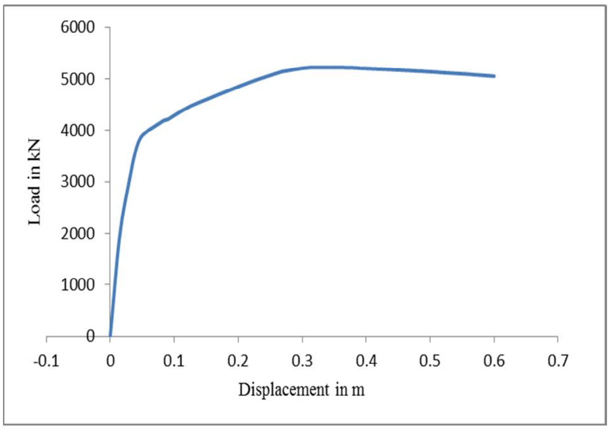


Fig VI Capacity curve for infilled frame (ROMANIA CODE)

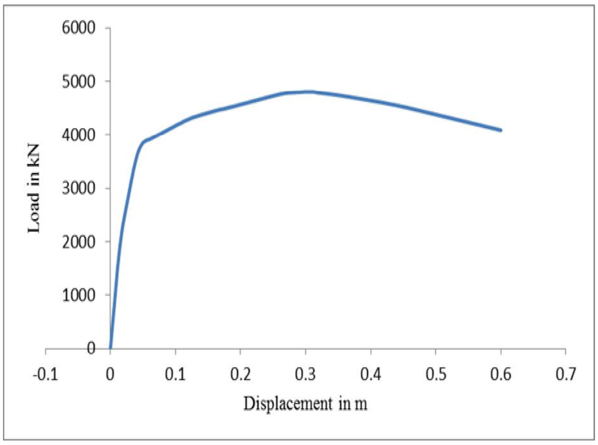


Fig IV Capacity curve for infilled frame (Bertoldi)

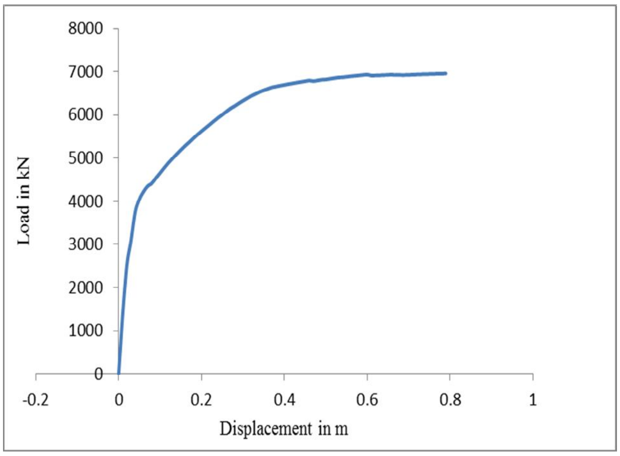
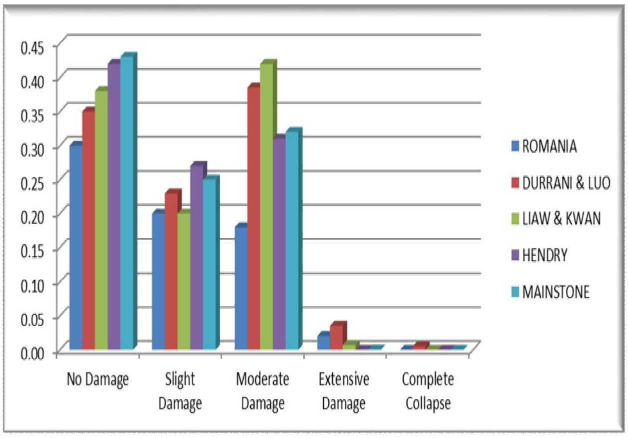


Fig V Capacity curve for infilled frame(Hendry)

6. Vulnerability index for different frames



6. CONCLUSION

G+4 bare frame model and G+4 infill wall frame models are analysed using SAP2000, and the following conclusions are drawn based on the present study.

1. Frame with Infill have more lateral load capacity compare to bare frame.
2. Since infill increases lateral resistance and initial stiffness of the frames they appear to have a significant effect on the reduction of the global lateral displacement.
3. Analysing the equations for the width of the diagonal strut on three different frames, it has been concluded that Romania code is the most suitable choice, due to its reliability and simplicity.
4. From the results it is shown that due to infill walls in building the base shear carrying capacity of the frame is increased.

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