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SEISMIC RESPONSE OF RC FRAMES CONSIDERING EFFECT OF INFILL WALLS

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ABSTRACT

Infill walls are considered as non structural member while designing reinforced concrete moment resisting frames due to its several undesirable effects under seismic loading. However, Infill walls contribute to lateral stiffness and seismic resistance to the buildings. This paper studies the effect of infill walls on a structure subjected to seismic loading. And also effect of central opening on the behaviour of infilled reinforced concrete frame is also studied. A 8 storey special moment resisting frame building is modelled in SAP 2000. A total 5 models are modelled varying the infill openings in the building. Infill wall is modelled as equivalent diagonal strut. Nonlinear static analysis i.e pushover analysis is performed to study the nonlinear seismic response of infilled frame buildings.

Keywords : equivalent diagonal strut, infill opening, pushover analysis, response reduction factor, SMRF.

I. INTRODUCTION

Masonry infill walls in reinforced concrete buildings cause several undesirable effects under seismic loading: short-column effect, soft-storey effect, torsion, and out-of-plane collapse. Hence, seismic codes tend to discourage such constructions in high seismic regions. However, in several moderate earthquakes, such buildings have shown excellent performance even though many such buildings were not designed and detailed for earthquake forces. Infill walls contribute to lateral stiffness and resistance of buildings they stuff. These variations of rigidity and strength are dependent on the mechanical properties of the material used for the infill and also on the interaction existing between infill and the frame.

Generally, infill walls are not considered in analysis and design of reinforced concrete frame buildings. They are assumed to not carry any vertical or lateral forces and also to do not transfer of forces between beams and columns that are generated in buildings during earthquake event, therefore known as non-structural elements. However, the brick infill walls in reinforced concrete moment resisting (Murty, et.al., 2012) buildings contribute significant

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strength and stiffness. It is noticed that the enhanced strength and stiffness of infill wall until they crack alters the course of nonlinear response and also seen that infill walls reduces the maximum displacement and member ductility demand significantly (Murty and Nagar, 1996). It is explained that brick infill is responsible in case of many low-rise RC frame buildings without formal engineering design withstood strong seismic events in the past (Jain, Singh, et.al., 1992). It is seen that the masonry infills contribute significant lateral stiffness, strength, overall ductility and energy dissipation capacity.

Masonry infill walls are stiffer in nature, thus attract most of the lateral seismic force on building, and therefore demand on the RC frame members gets reduces. It is indicated that under lateral loading the infill walls increases the stiffness by acting as a diagonal strut, resulting in a possible change of the seismic demand because of significant reduction in the natural period of the composite structure (Dakhakhni et al., 2003, and Asteries et al., 2011).

Apart from fully infilled walls, the infills also have openings to cater the functionality of buildings. Generally, the structural behavior of infill wall with opening is different from infilled walls without opening. Moreover, the failure mechanisms are also affected by size and placement of openings (tasnimi et. al., 2010).

II. BUILDING DETAILS AND MODELLING

A total 5 space frames are considered by varying infill and infill central opening. The detailed description of all selected frames is given in table 2.1. The storey height is kept 3.5m, where as the bay width in both longitudinal as well as transverse direction is kept 3m. The cross-section of beam is considered as 300mm x 500mm where as the cross-section for column is considered as 400mm x 400mm. The response reduction factors for SMRF is given as 5 as per IS 1893 (Part 1) : 2002. Plan for all models is kept same which is 18m x 12m with 6 bays in longitudinal direction and 4 bays in transverse direction. Fixed supports are considered for all the models in study. Material properties, geometric parameters and seismic design data assumed for the study is given in table 2.2. The infill walls are modelled as equivalent diagonal compression strut. The equivalent diagonal strut width is calculated by equation 1 (Mainstone, 1971).

$$w = 0.175(\lambda_1 h_{col})^{-0.4} L_{diag} \qquad (1)$$

where,

$$\lambda_1 = \left(\frac{E_m t_{inf} \sin 2\Theta}{4 E_{fe} I_{col} h_{inf}}\right)^{0.25}$$

E_m and E_f are moduli of ealasticity of infill and frame material respectively, t_{inf} is thickness of infill wall, h_{col} and I_{col} are the height and moment of inertia of column of surrounding frame, h_{inf} is height of infill wall and L_{diag} is length of diagonal strut.

To model central opening in infill wall, the width of diagonal strut is multiplied by reduction factor, R_F given in equation 2 (Al-chaar, 2002).

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$$R_F = 0.6(\frac{A_O}{A_p})^2 - 1.6\left(\frac{A_O}{A_p}\right) + 1 \quad (2)$$

Table 2.1 Details of models

Sr. No.	Frame Name	Type	% of opening
1	8S SMRF BF	Bare	Nill
2	8S SMRF IF	Infill	Nill
3	8S SMRF IF 15%	Infill	15%
4	8S SMRF IF 25%	Infill	25%
5	8S SMRF IF 50%	Infill	50%

Table 2.2 Geometric and material properties and Design seismic date

Sr. No.	Parameter	Value
1	Unit Weight of Concrete	25 Kn/m^3
2	Unit Weight of masonry wall	18 Kn/m^3
3	Characteristic strength of concrete	25 MPa
4	Characteristic strength of steel	415 MPa
5	Damping Ratio	5%
6	Slab Thickness	150 mm
7	Wall thickness	230 mm
8	Modulus of elasticity of infill wall	$550f'_m$
9	Seismic Zone	V
10	Zone Factor	0.36
11	Response Reduction Factor	5 SMRF
12	Importance Factor	1
13	Soil Type	Medium Soil

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III. RESULTS AND DISCUSSIONS

8 story building frames are firstly analysed by response spectrum method and for each analyzed frame, the design base shear (V_B) obtained from response spectrum analysis is compared with the base shear (V'_B) calculated using a fundamental time period T_a given in clause 7.6 IS 1893 : 2002 for corresponding building modelled and the values of base shear obtained by response spectrum are then corrected by modified scale factor with the help of correction factor V'_B/V_B and then designed as per IS 456 : 2000 and IS 1893 : 2000.

Nonlinear static analysis or pushover analysis is carried out on 8 story building where masonry infill act as equivalent strut. Figures 3.1 and 3.2 shows the pushover curves in *x* and *y* directions respectively varying percentage of central opening such as fully infilled i.e. 0%, 15%, 25%, 50% and Bare frame. Table 3.1 shows the modal parameters i.e. modal time period and direction of first 3 modes. Variation of stiffness due to variation in opening percentage is shown in Figure 3.3 It is clear from Figures 3.1, 3.2 and 3.3 Table 3.1 that as the opening percentage increases, strength and stiffness of building decreases. Also time period increases as the opening percentage increases in building frame hence lesser earthquake force.

Figure 3.4 and 3.5 presents the effect of opening percentage on storey displacements of the 8 storey building. It can clearly be seen that as the opening percentage increases, storey displacement also increases.

Table 3.2 and 3.3 shows the response reduction factors in *x* and *y* directions respectively. These response reduction factors are calculated using methodology given in FEMA p695.

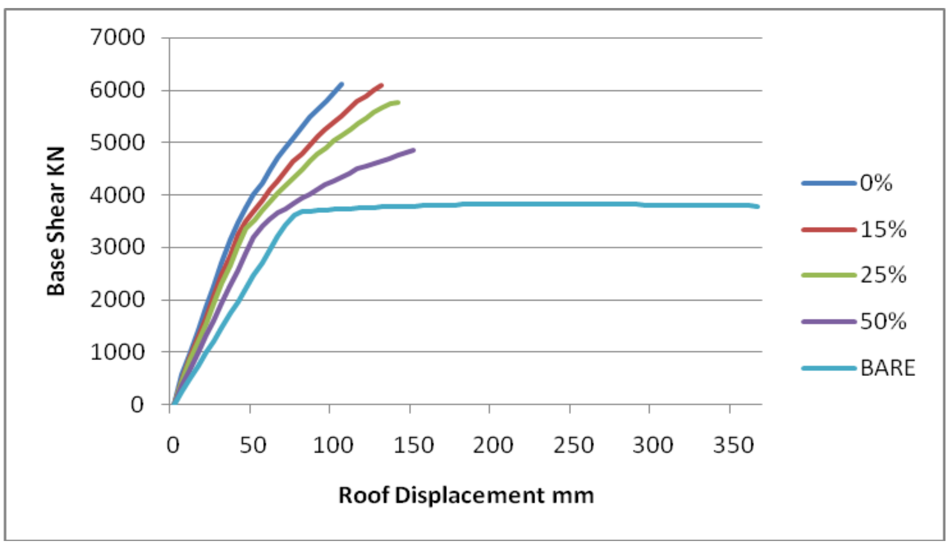

Fig. 3.1 Capacity Curve in X Direction

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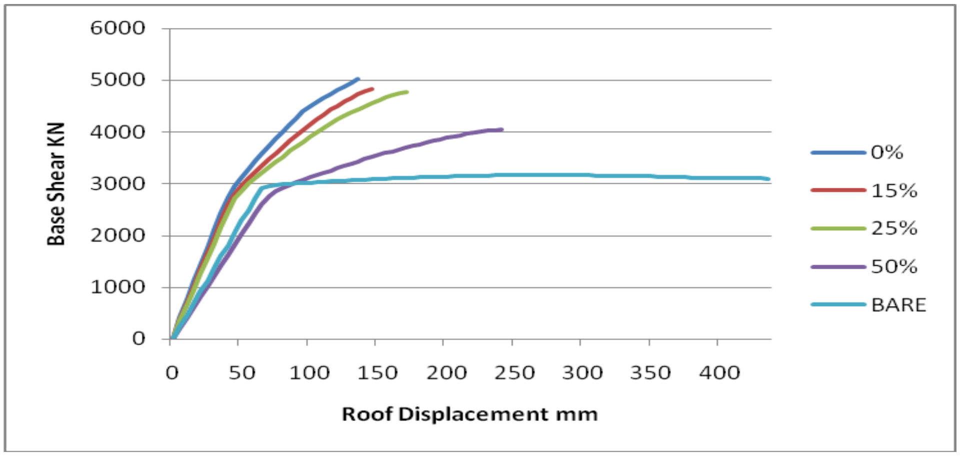

Fig. 3.2 Capacity Curve in Y Direction

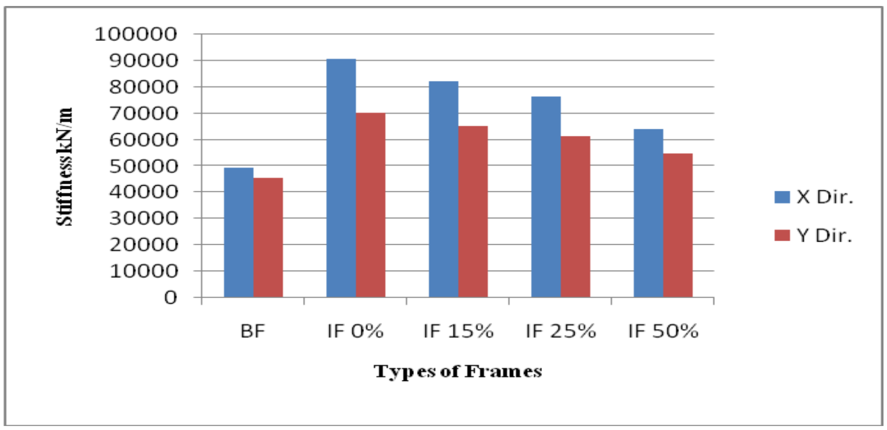

Fig. 3.3 Stiffness Variation due to infill openings

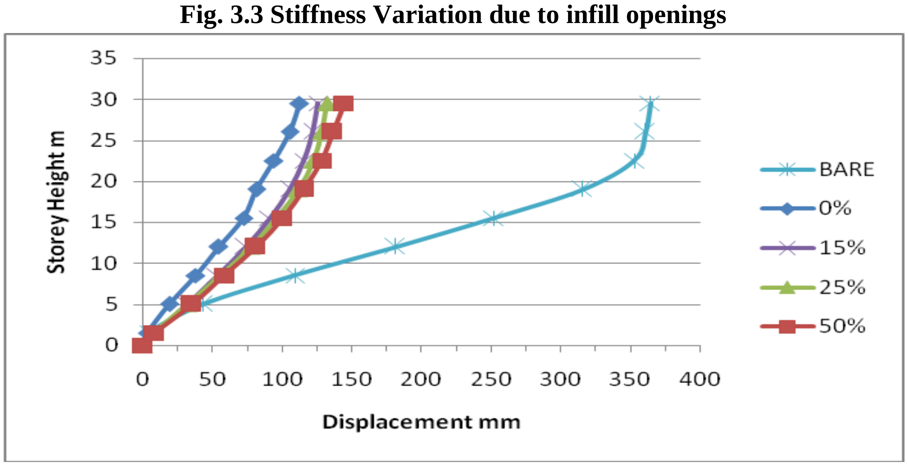

Fig. 3.4 Storey Displacement in *x* direction

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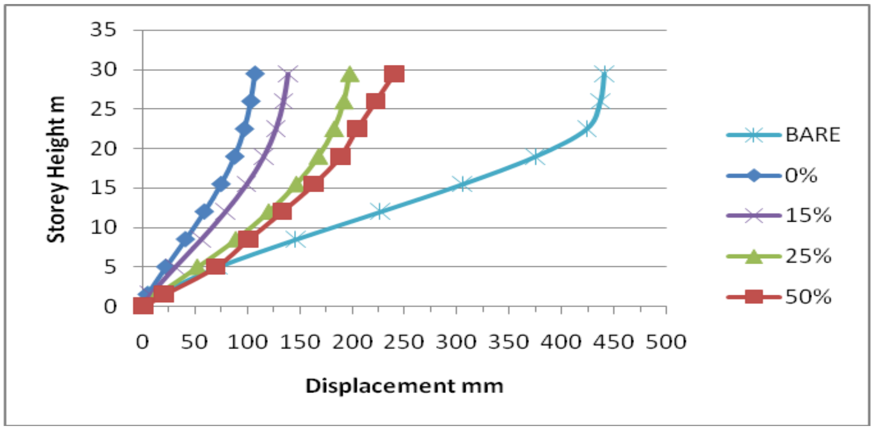

Fig. 3.5 Storey Displacement in *y* direction

Table 3.1 Modal Parameters of models

Sr. No.	Frame	Modal Time Period (Direction)
1	8S SMRF BF	1.18(Y), 1.14(X), 1.10(Torsion)
2	8S SMRF IF	0.93(Y), 0.82(X), 0.67(Torsion)
3	8S SMRF IF 15%	0.96(Y), 0.86(X), 0.71(Torsion)
4	8S SMRF IF 25%	0.99(Y), 0.89(X), 0.75(Torsion)
5	8S SMRF IF 50%	1.06(Y), 0.98(X), 0.86(Torsion)

Table 3.2 Response Reduction Factors in *x* direction

Frame	R, Calculated	R (IS 1893:2000)
8S SMRF BF	9.9	5
8S SMRF IF	5.7	5
8S SMRF IF 15%	6.2	5
8S SMRF IF 25%	5.5	5
8S SMRF IF 50%	4.9	5

Table 3.3 Response Reduction Factors in *y* direction

Frame	R, Calculated	R (IS 1893:2000)
8S SMRF BF	11.7	5
8S SMRF IF	6.9	5
8S SMRF IF 15%	5.4	5
8S SMRF IF 25%	6.0	5
8S SMRF IF 50%	7.5	5

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IV. CONCLUSIONS

The seismic response of 8 storey building with varying opening percentage and designed for special moment resisting frame is presented in this study. The seismic response of these buildings is noted by performing pushover analysis in SAP2000. From study of pushover curves and results presented, following conclusions are noted.

- Presence of infill drastically increases the stiffness in the building. Increase in opening percentage decreases the stiffness in the building.
- The 8 storey building with fully infilled frame attracts about 38% more base shear than bare frame in both *x* and *y* direction. Similarly, roof displacement of fully infilled 8 storey building is decreased by 64 to 69 % in both *x* and *y* directions.
- Presence of infill decreases time period by about 21.2%. Also, increase in opening percentages increases the time period.
- Response reduction factors calculated using FEMA p695 are greater than given in IS 1893 : 2000. Response reduction factor calculated for fully infilled 8 storey building is much less than that of bare frame building.

All the conclusions presented above are noticed for a single regular plan 8 storey building, the results for different building plan may be different than results presented in this study.

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