Performance of RC Structure with and without Infill Wall Subjected to Seismic Load

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Abstract- *A large number of buildings in globe are constructed with Masonry Infill for functional and architectural reasons. Masonry Infill Walls plays considerable role in performance of structure subjected to Seismic Load. However, behaviour of Masonry Infill is difficult to predict because of significant variations in material properties and because of failure modes that are brittle in nature. As a result Masonry Infill walls are often treated as non-structural member in structure and its contribution is not considered in analysis and design of structure. However, experiences shows that Masonry Infill may have significant positive or negative effects on the behaviour of buildings and therefore should be addressed appropriately. This report compares the effect of lateral load on a 30 storey building model without Infill Wall and with different combinations of Infill using structural design software ETABS having same area but different plans.*

Keywords- Masonry Infill (MI) Wall, Reinforced Concrete (RC) frame, Storey Shear, Storey Drift, Storey Displacement

I. INTRODUCTION

Most of the reinforced concrete frame structures are infilled with masonry walls for the purpose of separation or/and privacy. In conventional practice it is considered that infill wall doesn't take any load so for analysis and design of structure the role of infill wall is neglected and self-weight of infill is considered for design of other structural members. But it has been observed that frames with MI walls have a very high initial lateral stiffness and low de-formability. Because of infilling frames with masonry walls the lateral-load transfer mechanism of the structure changes from predominant frame action to predominant truss action, which leads to increase in axial forces and reduction in bending moments in the frame members.

Various modelling methods are available to stimulate the infill wall in RC frame and by using these modelling methods the analysis can be done. Various researchers studied and analysed infill wall RC frames and the need of inclusion of these non-structural elements on the structural seismic assessment and design process is recognized. This report describes and compares the results of the models of the typical 30 storey building subjected to earthquake load in ETABS Software.

Infill wall

It is a panel constructed from masonry usually built in between columns and beams of structural frame of building. Masonry walls are made up of clay units, aggregate concrete units and autoclaved aerated concrete units. In most design practices infill walls are constructed as non-structural element. But in some high and moderate seismic zones it is taken into consideration (Eurocode 8, 1994; NBC 201, 1994)

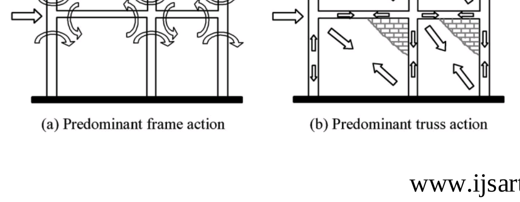
Masonry infill wall panels increase strength, stiffness, overall ductility and energy dissipation of the building. More importantly, they help in drastically reducing the deformation and ductility demand on RC frame members. Some ill effects are also seen such as short column effect, torsion effect and soft storey effect.

Types of Infill Wall

A. Based on material
1. Masonry Infill Walls
2. Light Steel Frames Infill Walls
3. Concrete Infill Walls
4. Timber Framed Infill Walls

B. Based on provisions
1. Bare Frame
2. Full Infill
3. Infill with Opening
4. Partial infill frame

Effect of Lateral Load on MC-RC Frame



(a) Predominant frame action (b) Predominant truss action

When lateral load comes on bare frame as shown in fig. a load is transferred by predominant frame action i.e. moments developed at column and beam junction. Whereas after introduction of infill wall the predominant frame action changes to predominant truss action. Because, compression strut is formed along one diagonal and tension comes along other diagonal. The bending moment is reduced and axial forces are increased in the members.

As masonry infill walls are laterally more stiffer than RC frames and therefore

Failure in Infilled Frames

A. Shear Friction Failure
B. Diagonal Tension Failure
C. Compressive Failure

A. Shear Friction Failure:

The shear forces in the columns may exceed the maximum along the contact length, near the loaded corner. Sliding along mortar joints expedite the shear failure of the column due to develop a short column effect.

B. Diagonal Tension Failure

Large shear forces and bending moment in the loaded corner and along the contact length in the zones near loaded corner can develop wide diagonal cracks running across the from the interior to exterior corner.

C. Compressive Failure:

Failure due to axial load: Gravity loads and the truss mechanism produce axial compressive forces in the columns. Buckling of the longitudinal reinforcement may occur due to severe cyclic loading and resulting in a compressive failure. However, this failure mode is not very common because of high compressive strength of the columns.

Modelling Of Infill Frames

Several analytical models have been proposed by researchers to understand the behavior of infill panels. These models are mainly classified into two groups i.e. micro and macro.

Micro Modelling:

In micro modelling infill walls are represented by using finite element method. The finite element method is the most popular analysis method for complex structural engineering problem. Several difficulties shown from the simulation, including modeling the connection of frame and infill. The connection strength and friction of frame and infill. Gives detailed results but its use is limited as it takes greater effort in computation for analysis and modeling as the elements constructed for building are not isotropic.

Macro Modelling:

In macro modelling infill walls are represented by equivalent struts. Analysis and modeling of infill wall gets easy in frame structure with equivalent strut method with considerably lesser efforts in computation.

a) Single Equivalent Strut Model
b) Double Equivalent Strut Model
c) Triple Equivalent Strut Model

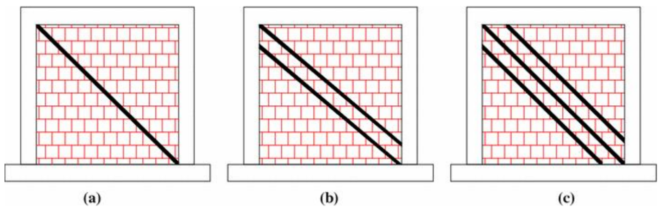


Fig.2 Types of Macro Modelling

Single Equivalent Strut Model

It is the mostly used model for analysis of RC MI frame. Various researchers has derived the formulae for calculating the effective width of infill wall.

FEMA (1998) proposed that the equivalent strut is represented by the actual infill thickness that is in contact with the frame (t_{inf}) and the diagonal length (d_{inf}) and an equivalent width, W, is given by:

$$W_{eff} = 0.175 \times (\lambda_h \times H)^{-0.4} \sqrt{H^2 + L^2}$$

$$\lambda_h = \sqrt[4]{\frac{E_{inf}\, t\, Sin\, 2\theta}{4\, E_c\, I_c H_{inf}}}$$

II. EXPERIMENTAL STUDY

Building data and material properties considered for the present study can be summerised as follows:

A typical square and rectangle buildings of G+30 floors are modelled in ETABS considering ground acceleration and relevant data as per the guidelines of Indian Standards for considered location (Mumbai). The square building has 6-6 bays in both directions (bays are of 5 m each). The buildings models are studied for various cases like bare frame, fully infilled, soft storey on ground floor and soft storey upto G+2 floors. R.C.C building models having relative storey height 3.5 m. The building site is considered under seismic zone III (Mumbai) and Medium type of soil is considered for analysis.

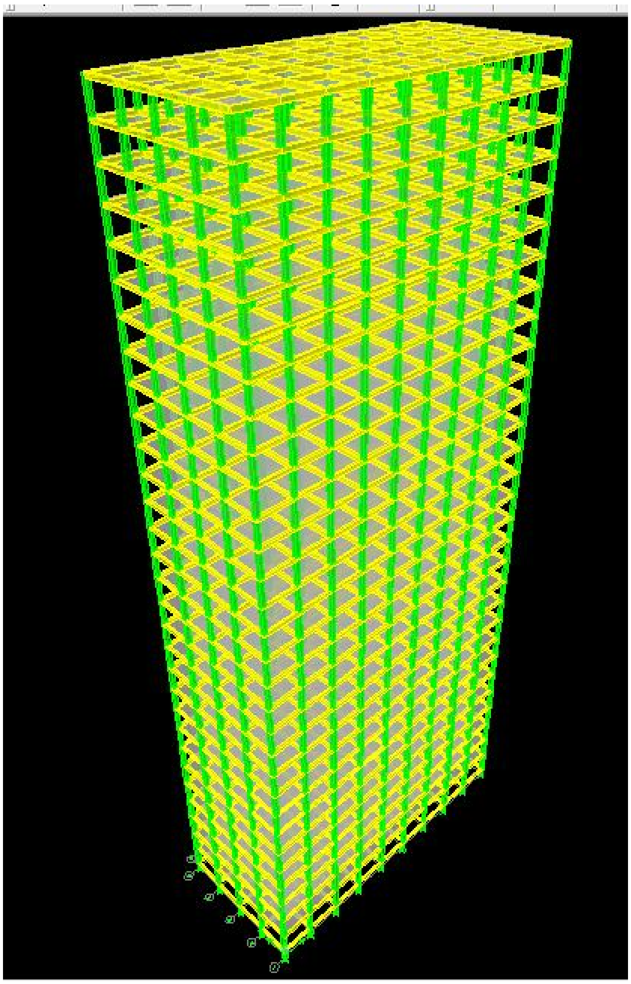


Fig.3 3D Rectangular Model

Concrete:

Table 1: Properties of Concrete

Sr. No.	Parameter	Value
1	Characteristic Compressive Strength (f_{ck})	25 MPa
2	Poisson's Ratio	0.3
3	Density	25 kN/m³
4	Modulus of Elasticity (E)	25000 MPa

Steel:

Table 2: Properties of Steel

Sr. No.	Parameters	Value
1	Fe 500 grade steel	500 MPa
2	Modulus of Elasticity (E)	2×10^5 MPa
3	Poisson's Ratio	0.3

Masonry Infill:

Table 3: Properties of Masonry

Sr. No.	Parameters	Value
1	Clay Burnt Brick	Class A
2	Size of Brick	19 x 9 x 9 cm
3	Compressive Strength of Masonry (f_m)	10 MPa
4	Modulus of Elasticity of Masonry (E_m)	550 x f_m =5500 MPa
5	Poisson's Ratio for Masonry	0.15
6	Proportion of Cement and Sand in Mortar for Masonry	1:4
7	Unit Weight of Masonry	19 kN/m²

Frame Elements:

Table 4: Properties of Frame Elements

Sr. No	Parameters	Value
1	Thickness of R.C.C. Slab	0.15 m
2	Size of R.C.C. Beam	0.30 m x 0.50 m
3	Size of R.C.C. Column	0.50 m x 0.50 m
4	Width of Compressive Strut (w)	0.670 m

Width of Equivalent Strut:

$$w_{eff} = 0.175 \times (\lambda_h \times H)^{-0.4} \sqrt{H^2 + L^2}$$

$$\lambda_h = \sqrt[4]{\frac{E_{inf}\, t \,Sin\, 2\theta}{4\, E_C\, I_C H_{inf}}}$$

Length of strut Ls = $\sqrt{3.5^2 + 5^2} = 6.1032$

$\theta = \sin^{-1}(3.5/6.10) = 35°$

$I_c = (b \times d^2)/12$

$$E_c = 5000 \times \sqrt{f_{ck}}$$

E_c = 5000 × $\sqrt{25}$ = 25000 MPa

$$E_m = 550 \times f_m$$

E_m = 550 × 10 = 5500 MPa

t (thickness on infill panel) = 230 mm

h_m = (height of infill panel) = 3500 mm

$$\lambda_h = \sqrt[4]{\frac{5000 \times 230 \times Sin(2\times 35)}{4 \times 25000 \times 5.2083 \times 10^9 \times 3500}}$$

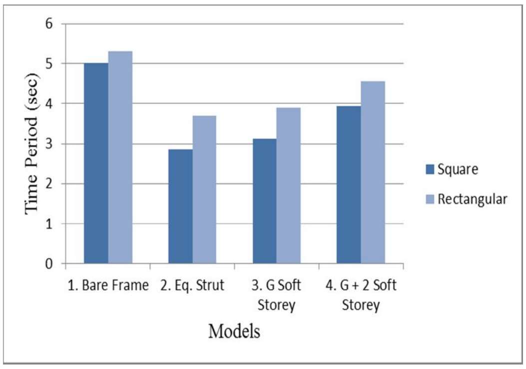
λ_h = 9.0065×10^{-4}

$$w_{eff} = 0.175 \times (\, 9.0065 \times 10 - 4 \times 3.5) - 0.4\sqrt{3.5^2 + 5^2}$$

w_{eff} = 674 mm (Approximately = 670 mm)

III. RESULTS

1. Time Period:

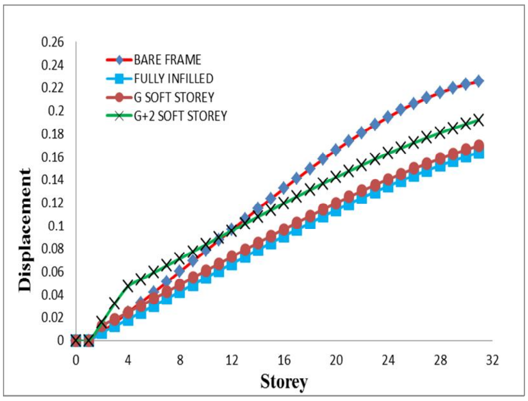


Graph 1: Time Period for Different Models

2. Storey Displacement:

A) Square Model

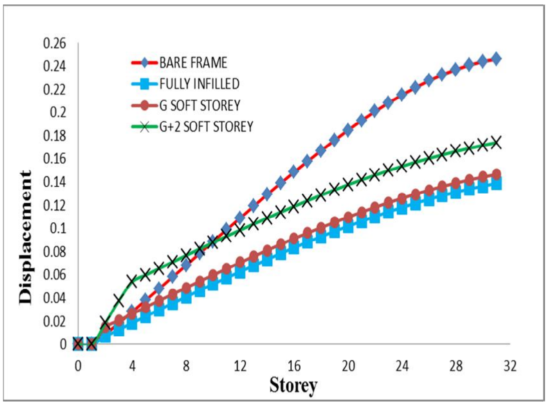
Period obtained from analysis of above shown models shows that the natural period considerably depends on the geometry of structure. Period of rectangular models is higher than the square model due to the decreased dimension of model along the direction of seismic force. The reduction in time period due to presence of infill wall (Equivalent strut) is considerably decreased in case of soft storey.



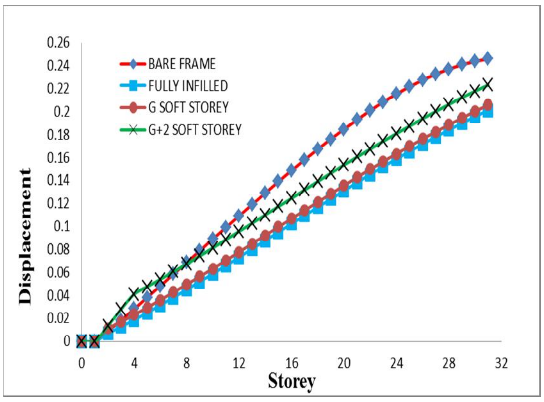
Graph 2: Max Storey Displacement - Square Model

Results obtained from square model clearly show that storey displacement recorded for the bare frame is maximum out of all other models described above. Common phenomenon observed from the model results, storey displacement is directly proportional to the height of structure.

B) Rectangular Model



Graph 3: Max Storey Displacement in Shorter Dimension - Rectangular Building

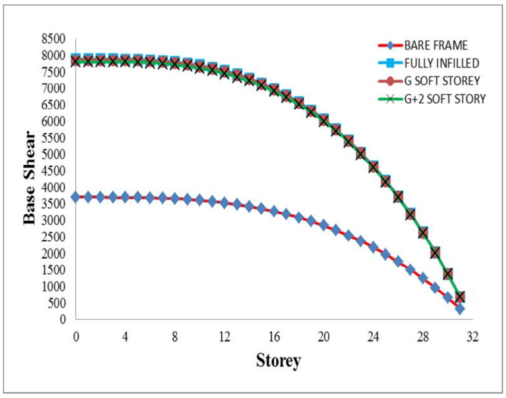


Graph 4: Max Storey Displacement in Longer Dimension - Rectangular Building

Results obtained from rectangular model clearly show that displacement depends on the available plan dimension of structure. Displacement in the shorter side is comparatively greater than the longer side. In both the cases (Square and Rectangular) due to introduction of soft storey, the displacement of structure is increased. From the results we can't say anything about the relation between square and rectangular plan area.

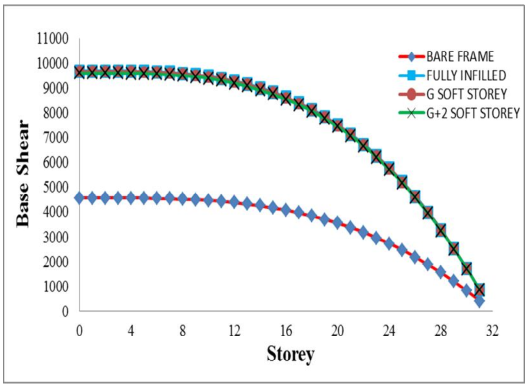
3. Storey Shear

A) Square Model



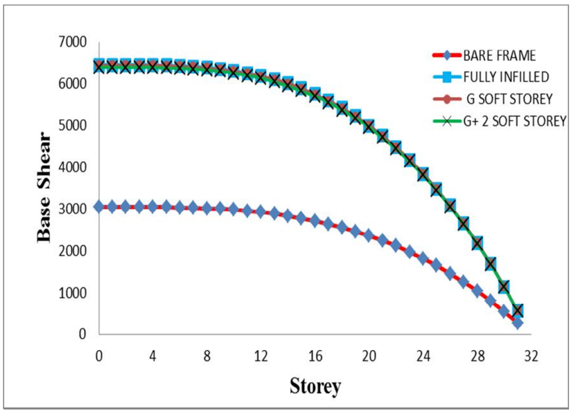
Graph 5: Storey Shear - Square Building

Base shear of square structure would be same in both the direction. Shear depends on variables at the site on seismic weight of structure and the total length of wall along the direction.



Graph 6: Storey Shear in Shorter Dimension - Rectangular Building

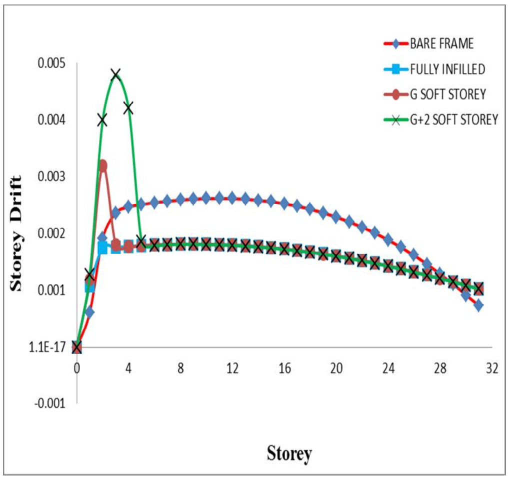
In infill model due to the additional weight of infill wall base shear is increased comparing with bare frame. Base shear developed in shorter side is much less than the longer side of same structure, as the deflection in shorter side is increased leading to more moment at the base.



Graph 7: Storey Shear in Longer Dimension - Rectangular Building

4. Storey Drift

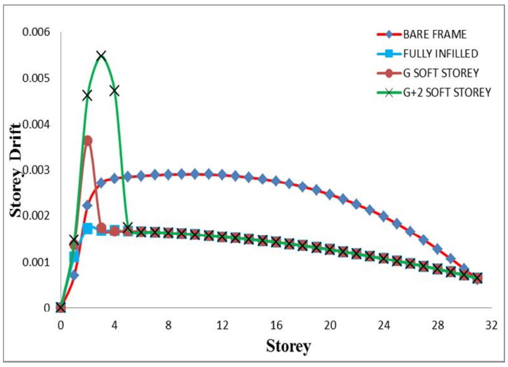
A) Square Model



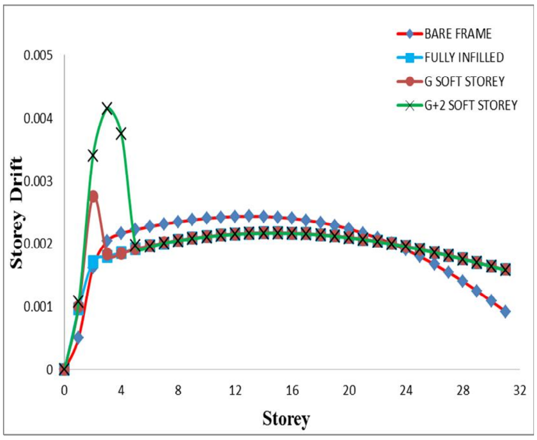
Graph 8: Storey Drift - Square Building

Drift is the ratio of storey displacement to consecutive floor to floor height of the storey. Drift is increased initially from the base and then gradual decrease is seen in the models under study. Due to presence of soft storey, the drift drastically increases.

B) Rectangular Model



Graph 9: Storey Drift in Shorter Dimension - Rectangular Building



Graph 10: Storey Drift in Longer Dimension - Rectangular Building

Drift in rectangular model is decreased in shorter side and increased in longer side comparing with square model. Maximum drift is developed at the middle of soft stories, it could be middle of single soft storey or of multiple soft stories.

IV. CONCLUSION & SCOPE

A) Conclusions

1. TIME PERIOD:

Geometry of structure influences time period of structure. Time period is greater in rectangular building as compare to square building having same plan area.
The time period decreased by 42% by addition of infill walls and it increases as number of soft stories increases.

2. MAX STOREY DISPLACEMENT:

The maximum storey displacement decreases by approximately 30% in fully infilled frame as compare to bare frame. The maximum storey displacement increases as number of soft storey increases as compare to fully infilled frame.

As the length of building dimension increases maximum storey displacement decreases.

3. BASE SHEAR:

Base shear increases by approximately 110% in fully infilled frame as compared to bare frame. Because the extra masonry load acts on fully infilled frame than bare frame.

4. STOREY DRIFT:

Drift distribution is sudden rise near ground and afterwards gradually decreasing towards the top of model which is been considerably reduced along the whole structure in the model with strut.

In G.F. soft storey, the storey drift increases by approximately 1.7 times than bare frame and 1.8 times than fully infilled frame.

In G+2 soft storey, the storey drift increases by approximately 2 times than bare frame and 2.7 times than fully infilled frame.

B) Future Scope

The high rise buildings are designed by considering infill wall as a structural member. And the relative effects on economy and safety of structure is found out by considering various cases of infill walls.

Also by considering different infill materials the most suitable infill type shall be found out so that economy and safety of structure are simultaneously optimized.

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