Seismic Evaluation of Multistoried Building with Infill Masonry

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Abstract--- *In the recent past the Masonry Infills are commonly used in RC Multi Storey Buildings. Masonry Infill's are used as Equivalent Diagonal Strut. In the present study attempt has been made to study the effect of seismic loading in placing the Infill wall as Equivalent Diagonal Strut for the frame. In this study G+3,G+6,G+9 buildings with 4x4,5x5 and 6x6 Bays with Symmetrical Bay size and Unsymmetrical Bay size are been analyzed. All these models are been analyzed for 3 conditions: Bare Frame, Frame with Full Masonry Infill, and Frame with Soft Storey Infill. Linear Static Analysis is performed on these models to evaluate the seismic demand. The results are compared for Natural period, Storey Shear, Lateral Displacement and Storey Drift. Structural Analysis is carried out by using Extended Three Dimensional Analysis of Building Systems (ETABs) Version 9.6.0.*

Keywords--- *Seismic, Multistoried Building, Infill Masonry*

I. Introduction

MOST reinforced concrete (RC) frame buildings in developing countries are in filled with masonry Infill walls. The Seismic design of these Masonry Infill is handled in many different ways. They are:
Non Structural parts, Structural parts

A. Influence of Masonry Infill Walls

Infill is added to the building to increase stiffness. The transferring action is taken up by truss action.

The ductility of the infill depends on:

i. Infill properties
ii. Relative strengths of frame and infill.
iii. Ductile detailing of the frame when plastic hinging in the frame controls the failure.
iv. Infill distribution in building.

B. Objectives of Present Study

Based on the selected literature review the following objectives were set for the present study.

The Objectives of the study are

1) To analyse the building using Equivalent Static Method.
2) To determine the displacement of the building.
3) To analyse the building with equivalent diagonal strut for the whole frame
4) To analyse the building with equivalent diagonal strut for soft storey frame.
5) To analyse the building by varying the number of stories and by varying the number of bays.
6) To study the variation of lateral displacements at each storey and to determine the fundamental natural period, storey shear, base shear, storey drift of all the building models.

C. Scope of Present Study

1. Based on the project, the study was undertaken with a view to determine the extent of possible changes in the seismic behaviour of buildings with Masonry Infill.
2. The study has been carried out by introducing equivalent diagonal strut using equivalent static method.
3. To observe the seismic behaviour of RCC building in considered seismic zone as per IS 1893-2002(Part-1).
4. The study emphasis and discusses the effect of Infill as equivalent diagonal strut on the seismic performance of G+3,G+6,G+9 for varying number of Bay sized building models in terms of lateral displacement, storey drift, storey shear ,time period, base shear.
5. The entire process of modeling, analysis and design of all the primary elements for all the models are carried out by using ETABs Non- linear version software.

II. Methodology for Seismic Evaluation

A. Linear Static Analysis or Equivalent Static Analysis

The total design lateral force is calculated by design horizontal seismic coefficient and seismic weight of the structure. Design horizontal seismic coefficient depends on the zone factor, importance of the structure, response reduction factor and the fundamental period of the structure.(9)

Procedure for equivalent static analysis:

Determination of base shear (V_b) of the building.(9)

$$V_b = A_h x W$$

Where,

A_h= Coefficient

W= Weight.

A_h shall be determined by

$$A_h=(Z/2)x(I/R)x(S_a/g)$$

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DOI:10.9756/BIJMMI.8155

Where, Z= zone factor for the maximum earthquake considered, I = Importance factor R=Response reduction factor, Sa/g=Average response acceleration coefficient for rock or soil sites.

Seismic weight of building (W) is the sum of seismic weight of floors. The seismic weight at any floor level is equal to dead weight of the floor system plus weight of walls, column, plus appropriate amount of imposed load.

Lateral Distribution of Design Base Shear

The design base shear Vb, thus obtained is distributed along the height of the structure by,[(9)]

$$Q_i=V_b((wihi^2)/(\sum wihi^2))$$

Where,

Qi = design lateral force at floor i^{th} floor

Wi= Seismic weight of floor i^{th}floor

Hi= Height of floor measured from base

1. *Building Description*

III. Modelling of the Building

The entire analysis is been done for 3D Building models using ETABs Nonlinear Version Software. The results are tabulated in order to focus on the parameters such as Lateral Displacement, Storey Drift, Storey Shear, Base Shear, Time Period. The performance point and displacement is also been studied for different building models.

Types of building considered for the present study are:

- PART I: Regular buildings With Symmetrical bay Size for G+3,G+6.G+9 With Bays 4x4,5x5,6x6
- PART II: Irregular buildings With Symmetrical bay Size for G+3,G+6.G+9 With Bays 4x4,5x5,6x6
- PART III: Regular buildings With Unsymmetrical bay Size for G+3,G+6.G+9 With Bays 4x4,5x5,6x6
- PART IV: Irregular buildings With Unsymmetrical bay Size for G+3,G+6.G+9 With Bays 4x4,5x5,6x6

All these buildings are classified into IV Parts. And these are analysed for three conditions:

i. Bare Frame
ii. Frame with Full Masonry Infill
iii. Frame with Soft Storey Infill

Table 1: Building Description

Parameters	**G+3. 4x4,5x5, 6x6 Bay**	**G+6. 4x4,5x5,6x6 Bay**	**G+9. 4x4,5x5,6x6 Bay**
Seismic Zone	**III**	**III**	**III**
Seismic Zone Factor	**0.16**	**0.16**	**0.16**
Response Reduction Factor	**5**	**5**	**5**
Height of Building	12 m	21 m	30 m
Each Storey Height	3 m	3 m	3 m
Thickness of Infill Wall	.3 m	.3 m	.3 m
Thickness of Slab	.15 m	.15 m	.15 m
Beam Size	.3x.45 m^2	.3x.45 m^2	.3x.5 m^2
Column Size (Regular) (Irregular)	.35x.7 m^2 .35x.7 m^2	.4x..8m^2, .35x.7m^2	.4x.8 m^2 .4x.8 m^2
Live Load Intensities			
Roof	1.0 kN/m^2	1.0 kN/m^2	1.0 kN/m^2
Floor	3.0 kN/m^2	3.0 kN/m^2	3.0 kN/m^2
Dead Load Intensities			
Roof Finish	1.5 kN/m^2	1.5 kN/m^2	1.5 kN/m^2
Floor Finish	1.0 kN/m^2	1.0 kN/m^2	1.0 kN/m^2
Material Properties			
Concrete Properties	M 25 Grade of Concrete	M25 Grade of Concrete	M 25 Grade of Concrete
Steel Properties	Fe 415 Grade of Steel	Fe 415 Grade of Steel	Fe 415 Grade of Steel

2. Modelling

Building is modeled using Standard Package ETAB V9.6.0. Beams and Columns are modelled as two noded elements. Area elements like Slabs are been modelled and Equivalent Diagonal Strut is been modelled. After Modelling the properties are been assigned and load conditions are given, After assigning, the equivalent static analysis was carried out .Based on the results obtained after analysis the parameters like Lateral Displacement, Storey Drift, Storey Shear , Time Period, are been compared for each Model. Equivalent Diagonal Strut is been considered in the design. The width of the Strut is calculated by using Stafford Smith's Formula.(3)

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

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

$$w = \frac{1}{2} \sqrt{\alpha h^2 + \alpha l^2}$$

3. Types of Buildings

1. Regular buildings With Symmetrical bay Size for G+3,G+6.G+9 With Bays 4x4,5x5,6x6
   a) 4x4 bay with 6mx6m Spacing
   b) 5x5 bay with 4.8mx4.8m Spacing
   c) 6x6 bay with 4mx4m Spacing
2. Irregular buildings with Symmetrical bay size for G+3,G+6.G+9 with Bays 4x4, 5x5x, 6x6
   For the same bay sizes the plan irregularity has been done like L Shape buildings.
3. Regular buildings With Unsymmetrical bay Size for G+3,G+6.G+9 With Bays 4x4,5x5,6x6
   a) 4x4 bay with 4.5mx6m spacing
   b) 5x5 bay with 3.6x4.8m spacing
   c) 6x6 bay with 3mx4m Spacing
4. Irregular buildings With Unsymmetrical bay Size for G+3,G+6,G+9 With Bays 4x4,5x5,6x6

For the same bay sizes the plan irregularity has been done like L Shape buildings.

Different Building Models for which the Analysis is been done

Model I: Building is modeled as Bare Frame with 4x4,5x5,6x6 for G+3 Building.

Model II: Building is modeled as Full Masonry Infill with 4x4,5x5,6x6 for G+3 Building.

Model III: Building is modeled as Soft Storey Infill with 4x4,5x5,6x6 for G+3 Building.

Model IV: Building is modeled as Bare Frame with 4x4,5x5,6x6 for G+6 Building.

Model V: Building is modeled as Full Masonry Infill with 4x4,5x5,6x6 for G+6 Building.

Model VI: : Building is modeled as Soft Storey Infill with 4x4,5x5,6x6 for G+6 Building.

Model VII: Building is modeled as Bare Frame with 4x4,5x5,6x6 for G+9 Building.

Model VIII: Building is modeled as Full Masonry Infill with 4x4,5x5,6x6 for G+9 Building.

Model IX: Building is modeled as Soft Storey Infill with 4x4,5x5,6x6 for G+9 Building.

IV. RESULTS AND DISCUSSIONS

Lateral Displacement

For G+3 Storeyed Part I building models, there is a decrease in the lateral displacement of fully infilled frame building model with bare frame by 56% for 6x6 Bay and there is a decrease in soft storey building model when compared to bare frame by 40% for 6x6 bay. Similarly, for G+6 Storeyed Part I building models, there is a decrease of 50% for fully infilled building and 44% for soft storey Building. For G+9 Storeyed Part I Building models, there is a decrease of 55% for fully infilled building and 51% for soft storey building.

For G+3 Storeyed Part II building models, there is a decrease in the lateral displacement of fully infilled frame building model with the bare frame by 59% for 6x6 Bay. And there is decrease in soft storey building by 44% for 6x6 Bay. Similarly, for G+6 Storeyed Part II building models, there is a decrease of 38.35% for fully infilled as well as soft storey building. For G+9 Storeyed Part II Building models, there is a decrease of 36.6 % for fully infilled as well as soft storey building.

For G+3 Storeyed Part III building models, there is a decrease in the lateral displacement of fully infilled frame building model with the bare frame by 58% for 6x6 Bay. And there is decrease in soft storey building by 38% for 6x6 Bay. Similarly, for G+6 Storeyed Part III building models, there is a decrease of 47% for fully infilled building and 53% for soft storey building. For G+9 Storeyed Part III building models, there is a decrease of 48% for fully infilled building and 44% for soft storey building.

For G+3 Storeyed Part IV building models, there is a decrease in the lateral displacement of fully infilled frame building model with the bare frame by 57% for 6x6 Bay. And there is decrease in soft storey building by 36% for 6x6 Bay. Similarly, for G+6 Storeyed Part IV building models, there is a decreaseof 38% for fully infilled building and 35% for soft storey building. For G+9 Storeyed Part IV building models, there is a decrease of 37% for fully infilled building and 52% for soft storey building.

Storey Drift

For G+3 Storeyed Part I building models, there is a decrease in the storey drift of fully infilled frame building model with the bare frame by 2.18 times for 6x6 Bay and there is decrease in soft storey building model by 2.39 times for 6x6 Bay . Similarly, for G+6 Storeyed Part I building models, there is a decrease of 1.87 times for fully infilled building and by 1.41 times for soft storey building. For G+9 Storeyed Part I building models there is a decrease Of 1.5 times for 6x6 bay and 1.4 times for soft storey building.

For G+3 Storeyed Part II building models, there is a decrease in the storey drift of fully infilled frame building model with the bare frame by 1.80 times for 6x6 Bay and there is decrease in soft storey building model by 1.82 times for 6x6 Bay. Similarly, for G+6 Storeyed Part II building models, there is a decrease of 1.37 times for fully infilled building and by 1.46 times for soft storey building. For G+9 Storeyed Part II building models, there is a decrease of 1.32 times for fully infilled building and 1.36 times for soft storey building.

For G+3 Storeyed Part III building models there is a decrease in the storey drift of fully infilled frame building model with the bare frame by 2.33 times for 6x6 Bay and there is a decrease in soft storey building model by 2.45 times for 6x6 Bay. Similarly, for G+6 Storeyed Part III building models, there is a decrease of 1.56 times for fully infilled frame and by 1.84 times for soft storey building. For G+9 Storeyed Part III building models, there is a decrease of 1.38 times for fully infilled frame and 1.48 times for soft storey building.

For G+3 Storeyed Part IV building models there is a decrease in the storey drift of fully infilled frame building model with the bare frame by 1.74 times for 6x6 bay and there is a decrease in soft storey building model by 2.39 times for 6x6 Bay. Similarly, for G+6 Storeyed Part IV building models, there is a decrease of 1.11 times for fully infilled frame and by 1.27 times for soft storey building. For G+9 Storeyed Part IV building models, there is a decrease of 1.01 times for fully infilled frame and 0.6 times for soft storey building.

Storey Shear

For G+3 Storeyed Part I building models, there is an increase in the Base shear of fully infilled frame building model with the bare frame by 19% for 6x6 Bay and there is an increase in soft storey building by 2.39% for 6x6 Bay. Similarly, for G+6 Storeyed Part I building models, there is an increase of 38% for fully infilled building and 7% for soft storey building. For G+9 Storeyed building Part I models there is an increase of 38% for fully infilled building and 24% for soft storey building.

For G+3Storeyed Part II building models, there is an increase in the Base shear of fully infilled frame building model with the bare frame by 18% for 6x6 Bay and there is an increase in soft storey building by 16% for 6x6 Bay. Similarly, for G+6 Storeyed Part II building models, there is an increase of 37% for fully infilled building and 33% for soft storey building. For G+9 Storeyed building Part II models there is an increase of 36% for fully infilled building and 33% for soft storey building.

For G+3 Storeyed Part III building models, there is an increase in the Base shear of fully infilled frame building model with the bare frame by 13% for 6x6 Bay and there is an increase in soft storey building by 12% for 6x6 Bay.Similarly, for G+6 Storeyed Part III building models, there is an increase of 41% for fully infilled building and 36% for soft storey building. For G+9 Storeyed building Part III models there is an increase of 39% for fully infilled building and 37% for soft storey building model.

For G+3 Storeyed Part IV building models, there is an increase in the base shear of fully infilled frame building with the bare frame by 13% for 6x6 Bay and there is an increase in soft storey building by 46% for 6x6 Bay. Similarly, for G+6 Storeyed Part IV building models, there is an increase of 39% for fully infilled building and 34% for soft storey building. For G+9 Storeyed building Part IV models there is an increase of 36% for fully infilled building and 35% for soft storey building model.

Time Period

For G+3 Storeyed Part I building models, there is a decrease in the time period of fully infilled frame building model with the bare frame by 1.33 times for 6x6 bay and there is a decrease in soft storey building by 1.33 times for 6x6 Bay. Similarly, for G+6 Storeyed part I building models, there is a decrease of 1.64 times for fully Infilled building and 1.46 times for soft storey building. For G+ 9 storeyed building Part I model, there is a decrease of 1.59 times for fully infilled building and 1.46 times for soft storey building model.

For G+3 storeyed Part II building model, there is a decrease in the time period of fully infilled frame building model with the bare frame by 1.59 times for 6x6 bay and there is a decrease in soft storey building by 1.31 times for 6x6 Bay. Similarly, for G+6 storeyed Part II building models, there is a decrease of 1.56 for infilled building and 1.43 for soft storey building. For G+9 storeyed building Part II model there is a decrease of 1.47 for fully infilled building and 1.40 times for soft storey building model.

For G+3 storeyed Part III building model, there is a decrease in the time period of fully infilled frame building model with the bare frame by 1.57 times for 6x6 Bay and there is a decrease in soft storey building by 1.27 times for 6x6 Bay. Similarly, for G+6 storeyed Part III building models, there is a decrease of 1.57 times for infilled building and 1.37 times for soft storey building. For G+9 storeyed building Part III model there is a decrease of 1.44 times for fully infilled building and 1.36 times for soft storey building model.

For G+3 Storeyed Part IV building model, there is a decrease in the time period of fully infilled frame building model with the bare frame by 1.51 times for 6x6 Bay and there is a decrease in soft storey building by 0.8 times for 6x6 Bay. Similarly, for G+6 Storeyed Part IV building models, there is a decrease of 1.51 times for infilled building and 1.31 times for soft storey building. For G+9 storeyed building Part IV model there is a decrease of 1.45 times for fully infilled building and 1.25 times for soft storey building model.

V. CONCLUSION

1. Displacement decreases when Infill is considered as compared to bare frame.
2. For soft storey infill the displacement is more than the full infill but is less when compared to the bare frame.
3. Storey Drift decreases when full infill is considered as compared to the bare frame
4. For soft storey infill the Storey drift is more than the full infill but is less when compared to the bare frame.

5. Time Period reduces when full infill is considered as compared to bare frame.
6. Time period of soft storey infill is more when compared to full infill.

REFERENCES

[1] F.J. Crisafulli, A.J. Carr and R. Park, "Analytical modelling of infilled frame structures-a general review," Bulletin-New Zealand Society for Earthquake Engineering, Vol. 33, No. 1, Pp. 30-47, 2000.

[2] G. Amato, L. Cavaleri, M. Fossetti and M. Papia, "Infilled frames: influence of vertical loads on the equivalent diagonal strut model", Procedings of 14th WCEE, Beijing, China. CD-ROM, 2008.

[3] H.R. Tamboli, U.N. Karadi and H.R. Tamboli, "Seismic Analysis of RC Frame Structure with and without Masonry Infill Walls", Indian Journal Of Natural Sciences International Bimonthly, Vol. 3, No. 14, 2012, Pp. 1137-1148, 2012.

[4] H.B. Kaushik, D.C. Rai and S.K. Jain, "A rational approach to analytical modeling of masonry infills in reinforced concrete frame buildings", In Proceedings of the 14thWorld Conference on Earthquake Engineering, Beijing, China. 2008.

[5] V.R. Kodur, M.A Erki, and J.H. Quennevill, "Seismic Design and Analysis of Masonry Infilled Frames", Canadian Journal of Civil Engineering, Vol. 22, No. 3, Pp. 576-587, 1995.

[6] D.S. Hirde and M.D. Bhoite, "Effect of Modeling of Infill Walls On Performance of Multi Story Rc Building", International Journal of Civil Engineering & Technology (IJCIET), Vol. 4, No. 4, Pp. 243-250, 2013.

[7] D. Santhosh, "Pushover Analysis of RC Frame Structure using ETABs 9.7.1", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Vol. 2, No. 1, Pp. 08-16, 2014.

[8] P. Agarwal and M. Shrikhande, "Earthquake Design of Structures", Prentice Hall of India Private Limited. New Delhi, India, 2006.

[9] IS 1893 (Part 1), "Criteria for Earthquake Resistant Design of Structures", Bureau of Indian Standards, New Delhi, 2002.