A Study on Seismic Analysis of Masonry Infilled RC Frames with and without Opening

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Abstract— Reinforced concrete frames with masonry infill walls are termed as infilled frames. The provisions of the masonry infill wall increase the strength of the frame. But masonry infill walls are considered as non-structural elements and their bonding interaction is ignored in the design. However during strong lateral loads this infill walls contribute to the response of the structure and may induce a load resistance mechanism different from that predicted for bare frame structure. The objective of the work is to study the seismic performance of the infilled RC frames with and without opening using pushover analysis. The stiffness of the masonry infilled walls is included in the model by converting them into an equivalent diagonal strut (EDS) with references to FEMA-356. The seismic parameter like base shear, storey drift, storey displacement, hinge states are studied for different models and the conclusions are made. The RC frame is designed as per IS 456-2000 and the Static Non Linear Analysis is done using ETABS.

Key words: Equivalent Diagonal Strut, Equivalent Static Method, Pushover Analysis, ATC-40, ETAB

I. INTRODUCTION

In many parts of the world earthquake have concerned an issue regarding the safety of the structure. The currently employed elastic design and analysis methods cannot capture important phenomena that control the performance of the structure in severe earthquakes. The unreinforced masonry walls (URM) are frequently constructed in the buildings and used as a interior partitions and exterior walls. In the seismic assessment of the new building and the existing ones infills are considered as a non structural elements and designed as a bare frame by ignoring their structural interaction

Pushover methods are becoming practical tools of analysis and evaluation of buildings considering the performance-based seismic philosophy. One main step in these pushover methods of analysis for determining the seismic demands is the construction of pushover curve of the building by using an adequate lateral load pattern simulating the distribution of inertia forces developed through the building when subjected to an earthquake

In the present study the main purpose is to summarize the pushover analysis which can assess the accuracy of pushover predictions, to identify the conditions in which pushover will provide proper information and also most important to determine the contribution of openings in infilled masonry walls in a framed structure subjected to lateral loads.

II. RESEARCH OBJECTIVE

The principal objectives of the study are as follows:

1) To access the seismicity of the Reinforced Concrete Framed building.
2) To study the behaviour of the infilled wall frame by converting the stiffness of the masonry infill as a Diagonal Strut Method.
3) To study the influence of the equivalent diagonal strut on the models with and without opening.
4) To obtain the base shear and displacement relation for different strut models.
5) To find out the different seismic parameters such as storey drift, storey displacement, base shear, time period etc using the equivalent static analysis, and pushover analysis.

III. METHOD OF ANALYSIS

- Equivalent Static Analysis
- Pushover Analysis

1) The method of finding the design lateral force is known as Equivalent Static Method or seismic coefficient method. This method is found to be simple method as it requires less computational effort and is based on the formulae as per the code of practice. First the design base shear is computed for the whole given building and then the resulted base shear is distributed all along the height of the building. The lateral force at each floor level is distributed to individual lateral load resisting elements
2) Pushover analysis is a comprehensive type of seismic analysis where the structure is subjected to lateral load and gravity load through elastic and inelastic behaviour until an ultimate condition or collapse condition is reached. Lateral load is the representation of the base shear due to the induced earthquake force and is proportion to the mass along building height, mode shape and other structural means. The nonlinear approximation consists of vertical distribution of lateral loads to an existing structure or new designed structure which captures the material non linearity and increase in those loads continues until the peak response of the structure is obtained as shown in the below fig

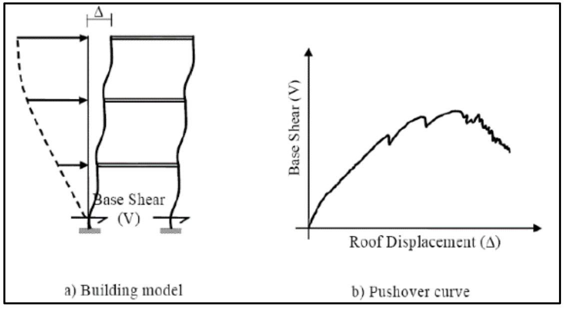

Fig. 1: Push over Analysis

IV. MODELLING AND ANALYSIS

The method used for modelling infill masonry is grouped as Macro element model .It is a simplified approach in which the entire masonry panel is replicated as single unit (Diagonal compression Strut) and only the global behaviour of the masonry is taken into account.

The expression for modelling masonry infill as a diagonal strut is computed from the FEMA 356 which is also suggested by the Mainstone

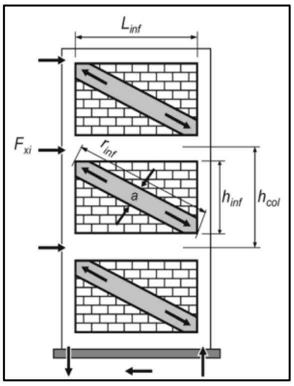

Fig. 2: Compression Strut Analogy – Concentric Struts

The width of the strut is given by

$$a = 0.175(\lambda_1 h_{col})^{-0.4} r_{inf}$$

$$\lambda_1 = \left[\frac{E_{me} t_{inf} \sin 2\theta}{4 E_{fe} I_{col} h_{inf}}\right]^{\frac{1}{4}}$$

Where a = Effective width of diagonal strut, mm
Λ_1 = Co-efficient used to determine equivalent width of infill strut.
h_{col} = Column height between centerlines of beams, mm.
r_{inf} = Diagonal length of infill panel, mm.
E_{me} = Expected modulus of elasticity of infill material, MPa
t_{inf} = Thickness of infill panel and equivalent strut, mm.
ϴ = Angle whose tangent is the infill height-to length aspect ratio.
E_{fe} = Expected modulus of elasticity of frame material, MPa
I_{col} = Moment of inertia of column, mm^4.

The plan layout of the reinforced concrete moment resisting frame building is shown in figure. The elevations of different building models are also shown. For the study, the plan layout is kept the same for all the models. Each building model is of seven storeys. The height of each storey is kept as 3.2m for all the different building models. The building is considered to be located in seismic zone III .In seismic weight

Calculations, 25% of floor live load is considered. The input data given for all the different building models is listed below.

The study was done by considering 5 models. The plan configuration for all the models is same as shown in the Fig below

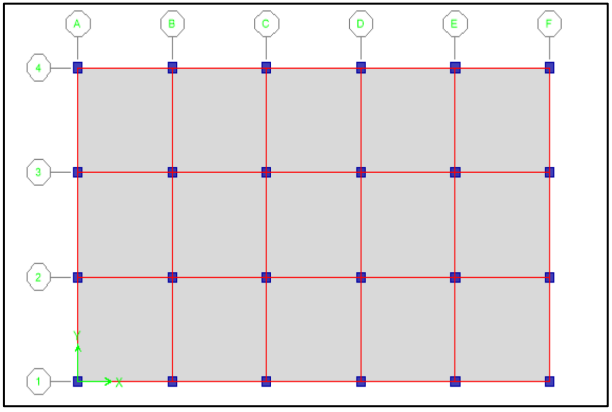

Fig. 3: Plan Layout

A. Building Configurations for the Models

No. Of Stories	G+5
Height Of Each Storey	3.2m
Grade Of Steel	Fe500
Grade Of Concrete	M25
Depth Of Slab	125mm
Size Of Columns	450x450mm
Size Of Beams	300x450mm

Table 1: Building Configuration

Live load	3 kN/m²
Floor finish	1.5 kN/m²
Parapet loading	5 kN/m²
Seismic loading	IS 1893
Soil type	II
Response reduction, R	5
Importance factor, I	1
Zone factor	0.16 (zone III)

Table 2: Loadings

The following are the distinct building models used in the study:

- Model 1: Building modelled as bare frame. However, masses of the 230mm thick walls are included in the model.
- Model 2: Building modelled as Diagonal strut frame with 0% opening.
- Model 3: Building modelled as Diagonal strut frame with 10% opening.
- Model 4: Building modelled as Diagonal strut frame with 20% opening.
- Model 5: Building modelled as Diagonal strut frame with 30% opening

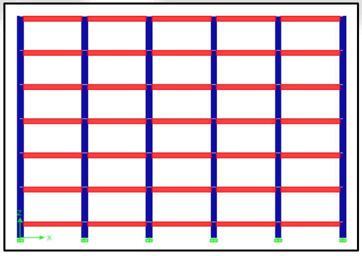

Fig. 4: Elevation of 7 storey building model 1

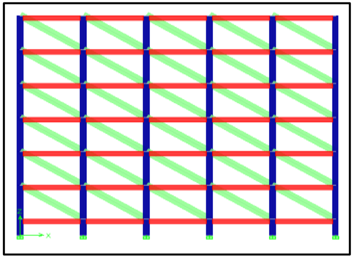

Fig. 5: Elevation of 7 storey building model 2

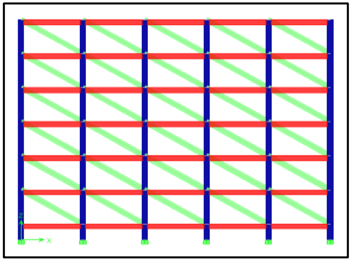

Fig. 6: Elevation of 7 storey building model 3

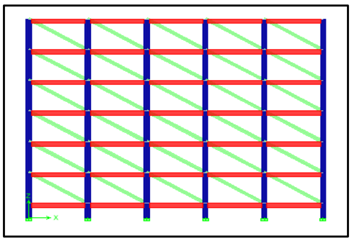

Fig. 7: Elevation of 7 storey building model 4

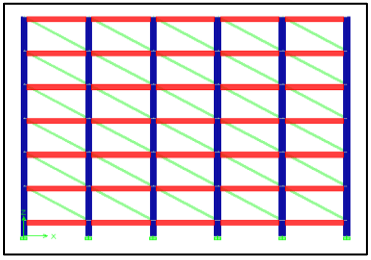

Fig. 8: Elevation of 7 storey building model 5

V. RESULTS AND DISCUSSIONS

The results of the five selected buildings models are presented and discussed in detail. The results are included for all different building models .The analysis of the different building models is performed by using ETABS analysis package. The results of natural period of vibration, base shear, lateral displacements, storey drifts, and overall performance of different building models are presented and compared. An effort has been made to study the effect of different percentage of opening of equivalent diagonal strut on seismic performance of reinforced concrete building in longitudinal & transverse direction respectively

A. Fundamental Natural Time Period

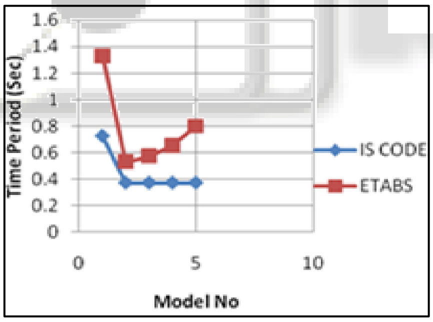

Fig. 9: Model Vs Time period for different building models along longitudinal direction**.**

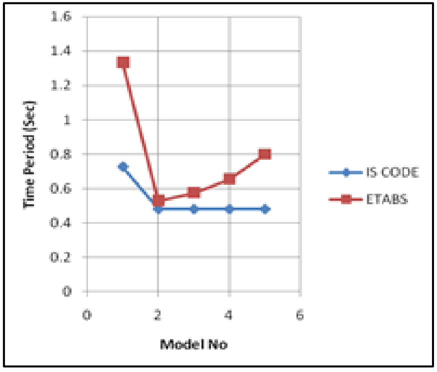

Fig. 10: Model Vs Time period for different building models along Transverse direction

The building and the ground have a "natural period of vibration" As seismic waves propagates among the ground, the ground additionally moves at its natural period When it is found that structure and the ground vibrate at the same rate, they are said to resonate.

It is observed that the fundamental time period for both longitudinal and transverse direction is same for the respective building model considered. When the building models being analyzed in ETABS, the natural time period is increased by 45.5% as compared with IS Code method for bare frame (model 1). When the effect of stiffness as masonry infill is incorporated in the building models, the time period has been reduced. Model 2 i.e. with 0% opening showing the least time period, compared to the other models but as the percentage of opening is increased the width of the strut get reduced from model 2 to model 5 the fundamental natural time period is consequently increased.

B. Storey Displacement

The maximum displacement at each floor level with respect to ground is obtained from equivalent static analysis and pushover analysis. For better compatibility the displacement for each model along the longitudinal and transverse direction of ground motion are plotted in figs below.

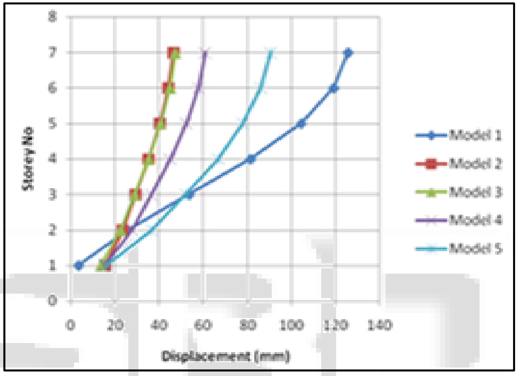

Fig. 11: Maximum storey displacement in existing models along longitudinal direction (Pushover)

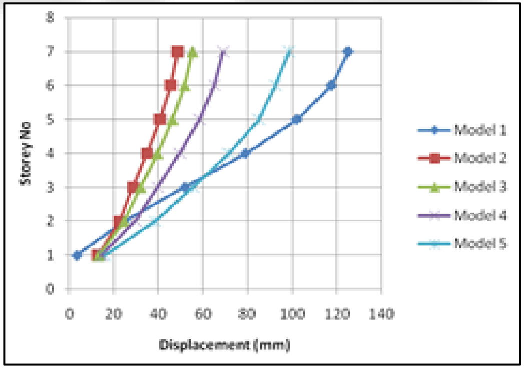

Fig. 12: Maximum storey displacement in existing models along transverse direction (Pushover)

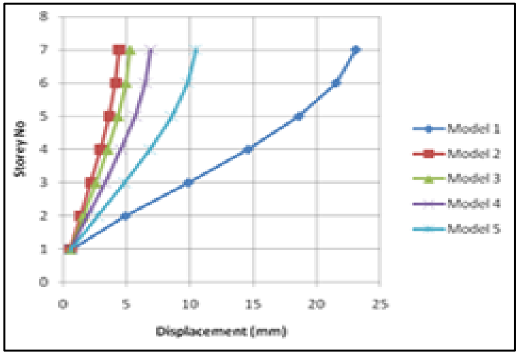

Fig. 13: Maximum storey displacement in existing models along longitudinal direction (ESA)

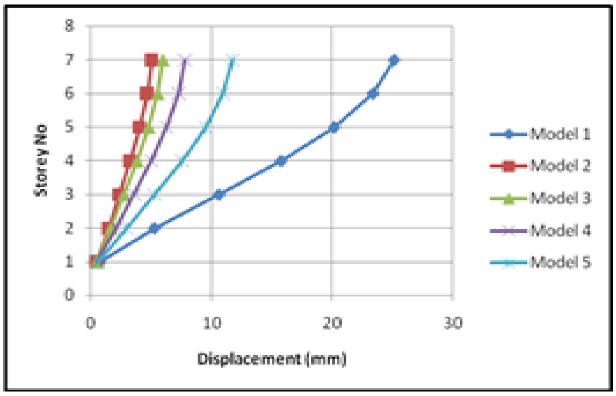

Fig. 14: Maximum storey displacement in existing models along transverse direction (ESA)

It is observed that the displacement value for bare frame is showing higher value along longitudinal direction and transverse direction when compared to other models in ESA as well as Pushover analysis.

From the charts it is seen that when the effect of masonry stiffness as diagonal strut is considered the storey displacement for different model get reduced and as the percentage of opening increases the corresponding storey displacement values increases. Hence for the model 2 with 0% opening the displacement is reduced to 62% when compared to the bare frame model.

C. Storey Drift

The permissible storey drift according to IS1893 (part1)-2002 is limited to 0.004 times the storey height, so that minimum damage would take place during earthquake.

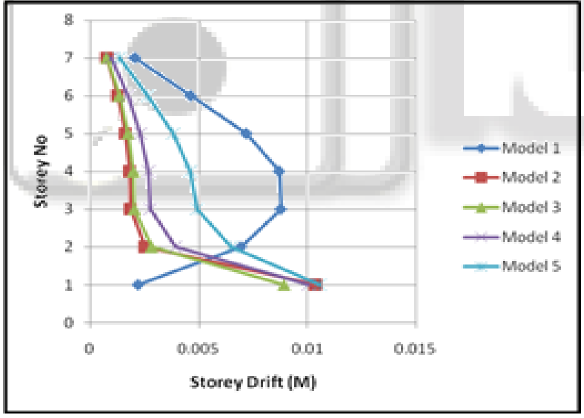

Fig. 15: Comparison of storey drift for different building models along longitudinal direction (Pushover)

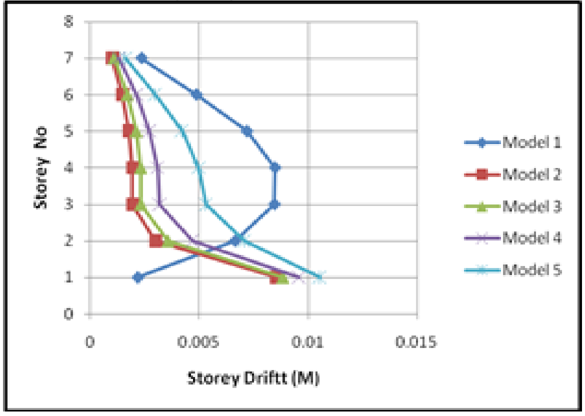

Fig. 16: Comparison of storey drift for different building models along transverse direction (Pushover)

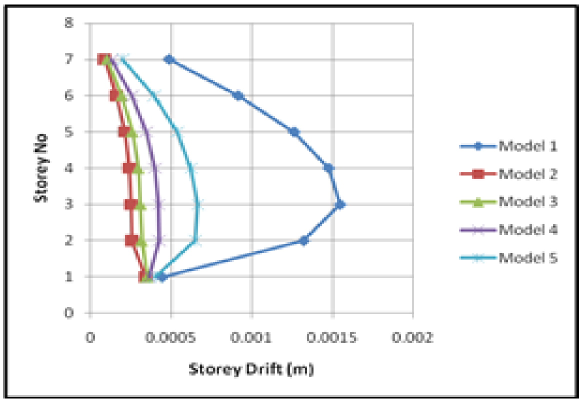

Fig. 17: Comparison of storey drift for different building models along longitudinal direction (ESA).

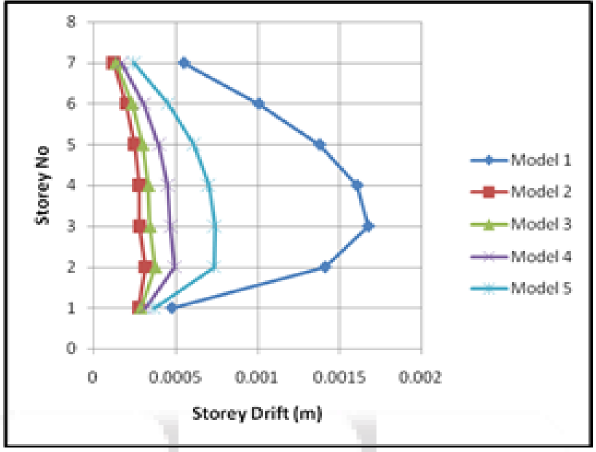

Fig. 18: Comparison of storey drift for different building models along transverse direction (ESA)

It is observed that the drift value gradually increases from storey 2 to storey 4 and then start decreasing from storey 5 in both the directions as shown in the above charts. The storey drift values obtained due to ETAB in both directions satisfy the permissible limit i.e 0.004*h= 0.004*3.2 =0.0128m= 12.8 mm Storey Drift values are found within the permissible limit specified by the IS CODE 1893-2002 Model 2 o% opening showing much strength and stiffness when subjected to seismic ground motion. But it can also be seen that as the opening increases the strength reduces and corresponding storey drift value increases in case of ESA and PA.

D. Base Shear (KN) and Displacement (m) at Performance Point.

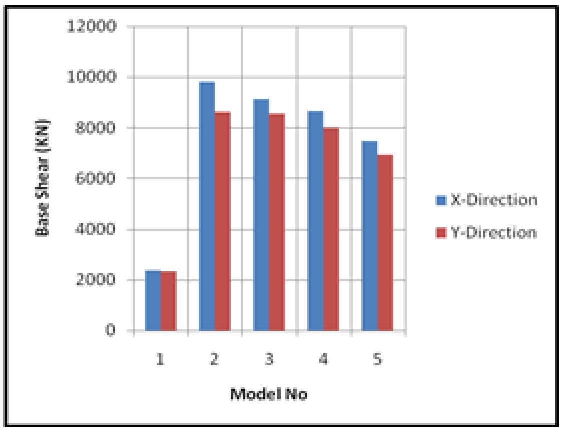

Fig. 19: Comparison of base Shear at Performance point for various models along longitudinal and transverse direction

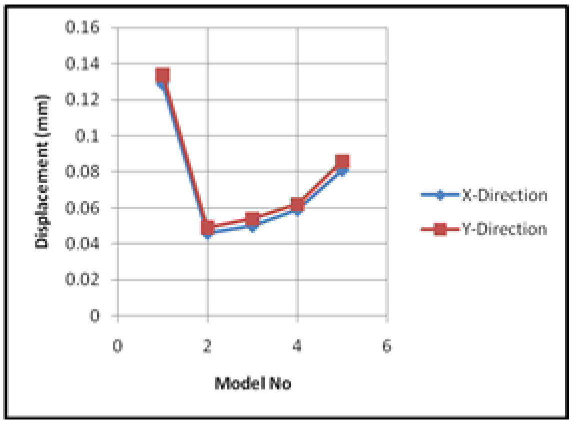

Fig. 20: Comparison of Displacement at Performance point for various models along longitudinal direction

It is observed that the base reaction at performance point in all seven storey building model that is base reaction is more in model II as compare to all other models, in both in X as well as Y-direction. Also it is observed that roof displacement is more for bare frame model compared to the other model.

E. Hinge Status at Performance Point

Models	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
1	564	66	164	74	0	0	0	0	868
2	761	32	43	26	0	0	6	0	868
3	762	24	50	30	0	2	0	0	868
4	683	105	36	40	0	4	0	0	868
5	621	177	18	49	0	3	0	0	868

Fig. 21: Hinge status of seven storey buildings in X (EQX) direction

Models	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
1	578	86	146	58	0	0	0	0	868
2	787	33	21	25	0	0	2	0	868
3	778	30	31	27	0	0	2	0	868
4	720	88	30	26	0	3	0	0	868
5	649	121	56	37	0	5	0	0	868

Fig. 22: Hinge status of seven storey buildings in Y (EQY) direction

The Fig above represent the hinges formed in the structure subjected to pushover analysis. The number of hinges in various regions is tabulated above. From the table it is observed that bare frame model consists more number of hinges in plastic state then compared to other building models in both directions. The number of hinges in elastic state in model II is greater than other building models along longitudinal direction as well as transverse direction. The structural behaviour changes with change in the percent of masonry opening, with equal to 30% opening or more the building behave as a bare frame model and reaches to collapse prevention when subjected to seismic load. More the number of hinges in elastic state, fever the number of hinges in plastic state is better performance of the structure

VI. CONCLUSIONS

1) Fundamental time period for different models increases with the increase in percent of opening.
2) Presence of masonry infill allows higher stiffness and base shear when compared to the bare frame model. And these go on reducing as the size of the opening presence in the frame increases.
3) The storey drift and storey displacement are influenced by the Equivalent Diagonal Strut when compared to the bare frame model.
4) With increase in the percent of opening storey drift and storey displacement values for different models increases.
5) Storey drifts values obtained are found within the permissible limit as specified by IS1893-2002.
6) The effect of the opening can be neglected if area of opening is <5% of area of infill. And effect of infill may be neglected if area of opening exceeds 30% of area of infill panel, as masonry infilled frame with 30% opening exhibits the bare frame behavior
7) Model II with o% opening is giving least roof displacement at performance point compared to the other models.
8) In seismic evaluation of building, at the capacity level bare frame model is reaching the collapse level, while the model II with o% opening is giving the result within the life safety region.
9) The building studied plastic hinges are more in bare frame model compared to the other building models
10) By performing pushover analysis, the weak links and failure location can fairly be identified.

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