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A STUDY ON INFLUENCE OF MASONRY INFILLS AND SHEAR WALL ON THE SEISMIC PERFORMANCE OF R.C FRAMED BUILDING

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ABSTRACT

The study offerings the practice for seismic performance estimation of asymmetric reinforced concrete frame buildings through ground soft storey built on a perception of the capacity spectrum method. Previous recent seismic tremors in many parts of India and globe have discovered the issue concerning the weakness of present structures. The present structures, which were designed and constructed based on earlier code requirements, do not content requirement of current seismic code and design practice. “ETABS” is used as a structural analysis tool for analyzing building models . Mainly which effect the mass, strength, stiffness and deformability of the structure & other important components which influence the above properties of the structures includes in analytical model of the building. To study the effect of infill and concrete core wall & shear wall at different positions during earthquake, seismic analysis using both linear static, linear dynamic (response spectrum method) as well as non-linear static procedure (pushover) has been performed. It is an attempt to study the performance of multistoried reinforced concrete building frame due to influence/provision of masonry infill’s and shear wall, five (5) building models (11 storey each) with identical building plan and asymmetry in elevation were study and analyzed. By performing Equivalent static, response spectrum method the deflections at each storey level has been compared as well as to determine capacity, demand and performance level of the considered building models the pushover method is adopted.

KEYWORDS: Shear Wall, Masonry Infill, ETABS v 9.7, Seismic Analysis, R.C Framed Building, Push Over Analysis.

INTRODUCTION

In general, the term infill frame is used to denote a composite structure formed by the combination of a moment resisting plane frame and infill walls. It can be comprehended that if the impact of infill is considered in the analysis and design of frame, the subsequent structures may be altogether diverse. In this manner, a study is attempted which will include the limited component analysis of the conduct of reinforced concrete (RC) frame with brick masonry infill. Again when a sudden change in stiffness happens along the building stature, the story at which this uncommon change of stiffness happens is known as a soft storey. A soft story is the one in which the lateral stiffness is under 70% of that in the story above or under 80% of the normal stiffness of the three stories above. Social and functional needs like vehicle parking, shops, reception etc. are compelling to provide soft storey in high-rise building. In the present study, seismic execution of 3D building frame with transitionally infill frames and shear wall at different positions was considered. Performance of R.C. frame was evaluated with ground soft storey and asymmetric in elevation of building with distinctive arrangement. The primary objective of the study is to examine the behavior of multistory, multi-bay with ground soft storey R C frames with and without infill’s, also with shear wall at various positions, and to evaluate their functioning levels when subjected to seismic loading. In this thesis, hypothetical multistoried R C buildings with ground soft storey (i.e., eleven storied with and without infill) found in zone IV of hard soil site has been analyzed and designed for load combinations given in code. pushover analysis is used for evaluation purpose.

Scope Of The Study: The present study is an attempt in the state of art of seismic evaluation of multistoried RC buildings. The focus of attention is to find the performance level of the building with the help of capacity and demand of the building for designed earthquake using nonlinear static pushover analysis, at the end suitable configuration of building to be used is suggested.

Building and Loading

1. The study is completed by considering a reinforced concrete frame office building resting on isolated footing.
2. Considering parabolic load pattern seismic force is applied.

Modeling and Analysis Method

1. 3 Dimensional modeling for investigations utilizing ETABS
2. The building is analyzed by Equivalent static, Response Spectrum as well as Pushover analysis.
3. The building models are impelled along positive orthogonal directions.

REVIEW

- A project on to study the "[**Effect of concrete core wall**" by (**Kabeyasawa, 1993; Eberhard and Sozen 1993**)][1] had carried out a study on a tall building with concrete core wall subjected to different levels of earth quake ground motions of magnitude7, resulting in the mean core wall moments over height. According to this analytical result, the wall develops its plastic moment strength at the base, as intended in design, and wall base moment remains close to the plastic moment capacity as the intensity of ground motion increases. Wall moment above the base; however, continue to increase with increasing ground motion intensity even though the base has reached its plastic moment capacity. This is because lateral deformations in various "modes" and associated internal forces continue to increase as shaking intensity increases.Design studies of tall concrete core wall buildings suggest that this behavior can lead to formation of secondary wall plastic hinges near mid height only by analyzing the building for the target hazard level.
- A study on cyclic tests on **["RC frames with masonry infill's"** (**Murthy and Jain, 2000**)][(2)] was carried out with an objective to compare the performance of infill masonry frames with that of bare frames subjected to reverse cyclic displacement controlled loading. They concluded that the average initial stiffness of an infill RC frame is about 4.3 times than that of a bare frame where the masonry is unreinforced, and about 4.0 times that of bare frame when the masonry is reinforced. From strength point of view they showed that the unreinforced masonry infill frames had about 70% greater strength than bare frames; the value was about 50% higher in the case of RC infill frames. They also concluded that the yield displacement of infill frames is much smaller than that of the bare frame, and hence showed that the infill frames have considerably greater ductility.
- A project on study the [**"Effect of infill patterns and soft storey"** by (**Jaswant N. Arlekar, Sudhir K. Jain and C.V.R. Murty)]**[(3)] of Department of Civil Engineering, I.I.T.Kanpur for these study they had taken about Nine different models of the building are studied . Linear elastic analysis is performed for the nine models of the building using ETABS analysis package .They studied various parameters like storey stiffness, natural period, lateral displacements ,bending moments and shear force in columns. And they came to following conclusion .RC frame buildings with open first storey are known to perform poorly during in strong earthquake shaking. The drift and the strength demands in the first storey columns are very large for buildings with soft ground storey. It is not very easy to provide such capacities in the columns of the first storey. Thus, it is clear that such buildings will exhibit poor performance during a strong shaking. This hazardous feature of Indian RC frame buildings needs to be recognized immediately and necessary measures taken to improve the performance of the buildings.The open first storey is an important functional requirement of almost all the urban multi-storey buildings, and hence, cannot be eliminated. Alternative measures need to be adopted for this specific situation. The under-lying principle of any solution to this problem is in (a) increasing the stiffness's of the first storey such that the first storey is at least 50% as stiff as the second storey, i.e., soft first storey are to be avoided, and (b) providing adequate lateral strength in the first storey.
- A project on [**"Seismic assessment of RC Framed buildings with brick masonry infill's"** by (**Mulgund G.V)]**[**(4)**] , in this study, five different models of an eight storey building symmetrical in the plan are considered. Usually in a building 40% to 60% presence of Masonry infill's (MI) are effective as the remaining portion of the Masonry infill's (MI) are meant for functional purpose such as doors and windows openings (Pauley and Priestley, 1992). In this study the buildings are modeled using 40 % Masonry infill's (MI) but arranging them in different manner, after performing pushover analysis it was seen that the performance of fully masonry infill panels was significantly superior to that of bare frame and soft storey frames. The present study also demonstrates use of nonlinear displacement based analysis methods for predicting performance based seismic evaluation. It has been found that the IS code provisions do not provide any guidelines for the analysis and design of RC frames with infill panels. It has been found that calculation of earthquake forces by treating RC

frames as ordinary frames without regards to infill leads to underestimation of base shear. The configuration of infill in the parking frame changes the behavior of the frame therefore it is essential for the structural systems selected, to be thoroughly investigated and well understood for catering to soft ground floor.

- **[Krawinkler Helmut and Seneviratna G. D. P. K.** [14]][5] Have described the basic concepts on which the pushover analysis can be based, assess the accuracy of pushover predictions, identify conditions under which the pushover will provide adequate information and identify cases in which the pushover predictions will be inadequate or even misleading. They concluded that pushover analysis provide good estimates of global, as well as local inelastic, deformation demands and also expose design weakness that may remain hidden in an elastic analysis. Both enlightened the basic concepts on which the pushover analysis can be based, assess the accuracy of pushover predictions, identify conditions under which the pushover will provide adequate information and identify cases in which the pushover predictions will be inadequate or even misleading. They concluded that pushover predictions will be inadequate or even misleading. They concluded that pushover analysis provide good estimates of global, as well as local inelastic, deformation demands and also expose design weakness that may remain hidden in an elastic analysis. ATC-40 volume-1[6] presents nonlinear static analytical procedures for evaluating the performance of existing buildings. This document emphasizes the use of non-linear static procedures in general and focuses on the Capacity Spectrum method which uses the intersection of the capacity (pushover) curve and a reduced response spectrum to estimate maximum displacement. The document also states that the Capacity Spectrum method is a very useful tool in the evaluation and retrofit design of existing concrete buildings.

MATERIALS AND METHODS

NONLINEAR STATIC PUSHOVER ANALYSIS

Pushover Analysis: The pushover analysis can be considered as a progression of incremental static analyses completed to analyze the non-linear behavior of structure, including the deformation and damage design. This method having two sections. Initial, an objective displacement for the structure is established. Pushover analysis, also known as collapse analysis, is a nonlinear static monotonic lateral force–displacement analysis in which the mathematical model of the multi degree- of-freedom structure is subjected to a distribution of incrementally increasing lateral forces until the stability limit of the structure is reached.

Infill effect: The vicinity of the infill wall builds the lateral stiffness impressively. Because of the adjustment in stiffness and mass of the basic framework, the dynamic attributes change too. Infill walls importantly affect the resistance and stiffness of structures. Be that as it may, the impact of the infill walls on the building reaction under seismic stacking is exceptionally mind boggling and math serious. It is normal that this auxiliary framework will keep on being utilized as a part of numerous nations in light of the fact that the brick work infill boards are frequently practical and suitable for temperature and sound protection purposes. Consequently, encourage examination of the genuine conduct of these frames is justified, with an objective towards adding to a displacement-based way to deal with their outline.

Shear wall: Shear wall is the primary vertical basic components with a double part of opposing both the gravity and lateral loads. Wall thickness alters from 150 mm to 500 mm, contingent upon the quantity of stories, building age, and thermal insulation prerequisites. As a rule, these walls are nonstop all through the building tallness a shear wall may be tall shear wall or low shear wall also known as squat walls characterized by relatively small height-to-length ratio.

EXPLANATION OF THE SAMPLE BUILDING

Model 1: The building is modeled as simple frame. In the first storey there should be no walls. However masses of the walls (230mm thick) are comprised at the upper stories. Also imposed live load and floor finish is considered.

Model 2: In this building has one full brick infill masonry walls (230mm thick) in the upper storeys & no walls in first storey. Stiffness and mass of the walls are considered in all stories. Also imposed live load and floor finish is considered.

Model 3: In this building one full brick infill masonry walls (230mm) thick in the above stories and also a structural concrete shear wall (200mm) thick is kept in both longitudinal and transverse direction at the exterior panel, also imposed live load and floor finish is considered.

Model 4: Building has no walls in the first storey and full brick infill masonry walls (230mm thick) in above stories. The building is enhanced by a structural concrete core wall of thickness (200mm) at Centre, the mass and stiffness of walls is considered. Also imposed live load and floor finish is considered.

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Model 5: In this building one full brick infill masonry walls (230mm) thick in the above storey and also a structural concrete shear wall (200mm) thick is kept in both longittudinal and transverse direction at all exterior corners & no wall should be considered in first storey. Floor finish is also considered.

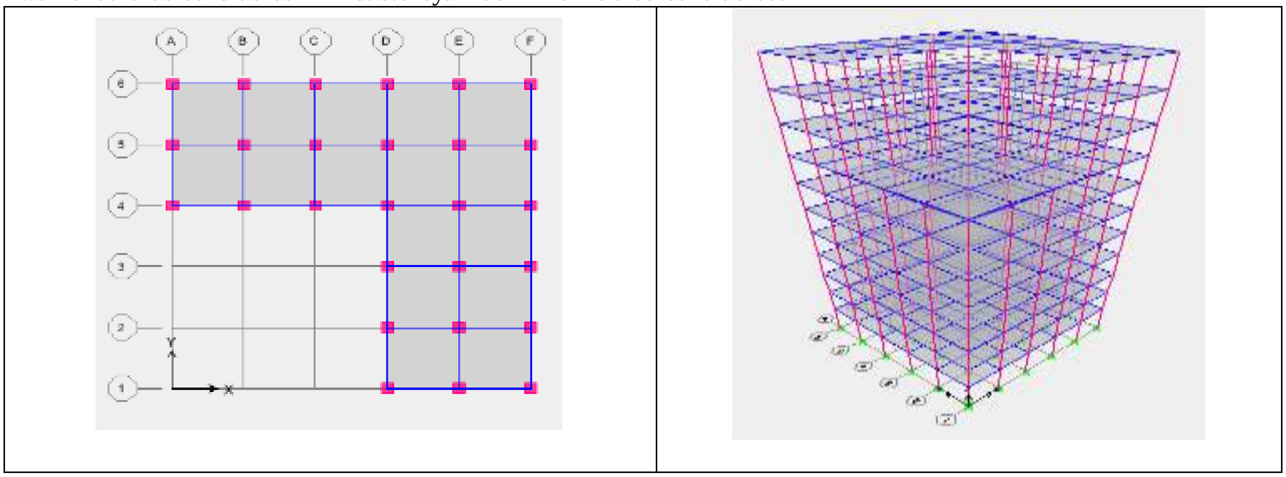

Figure-1.1 Plan Layout and 3D view of Asymmetric building Model-1

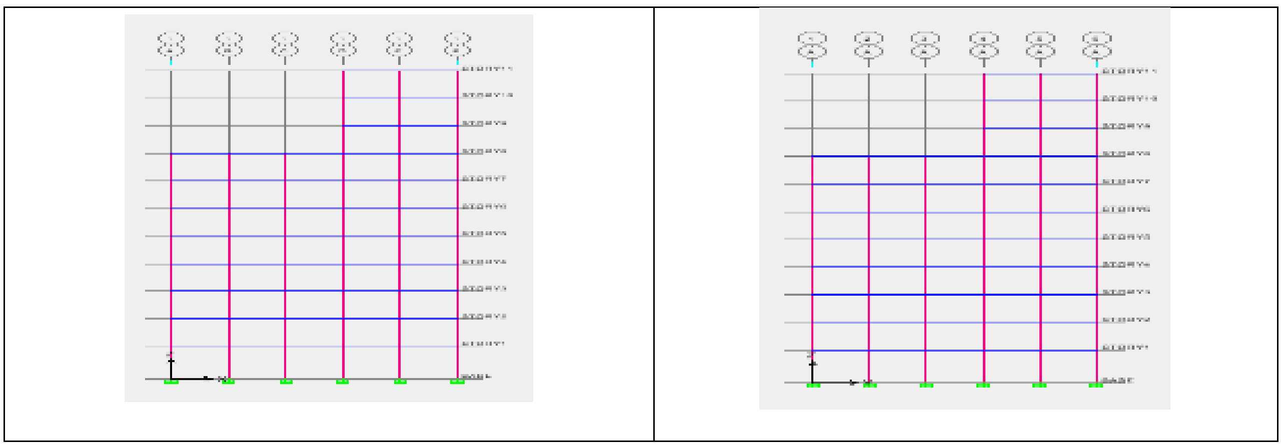

Figure-1.2 Elevation of Asymmetric building Model-1 along longitudinal and transverse direction

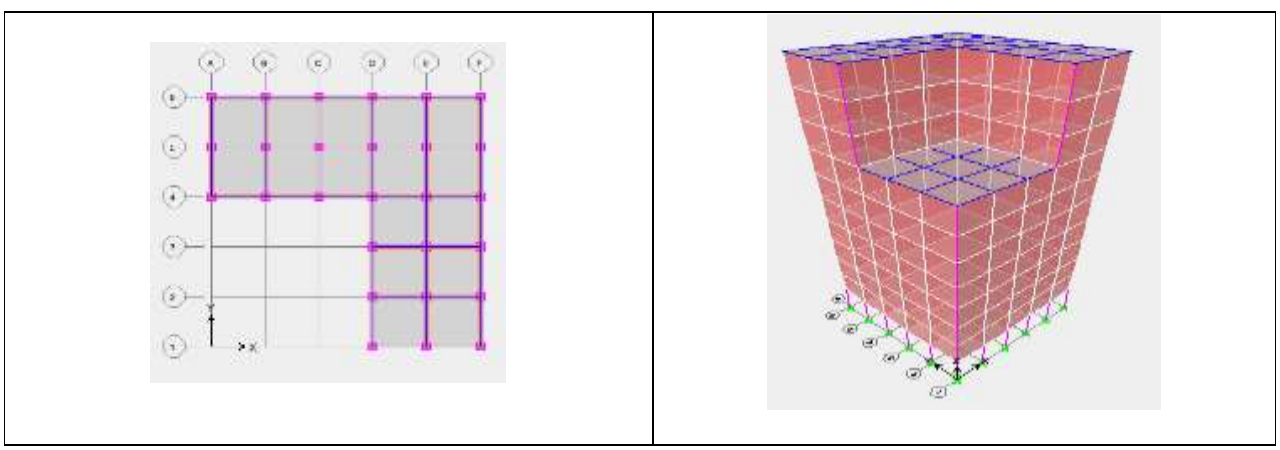

Figure-1.3 Plan Layout and 3D view Asymmetric building of Model-2

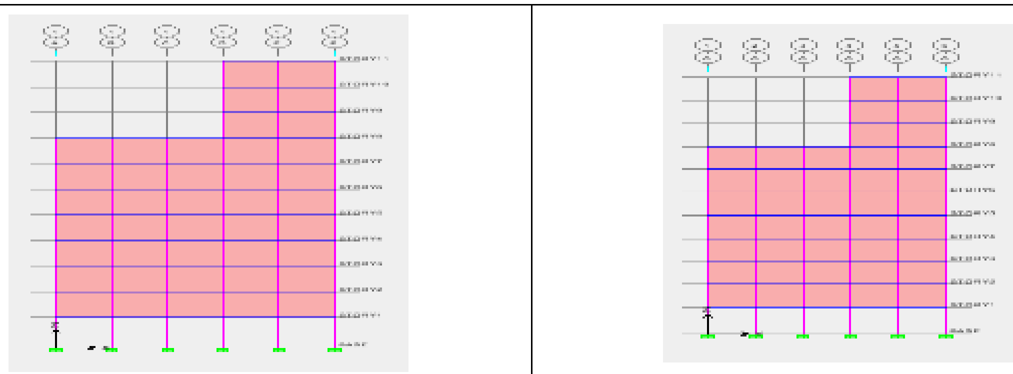

Figure-1.4 Elevation of Asymmetric building of Model-2 along longitudinal and transverse direction

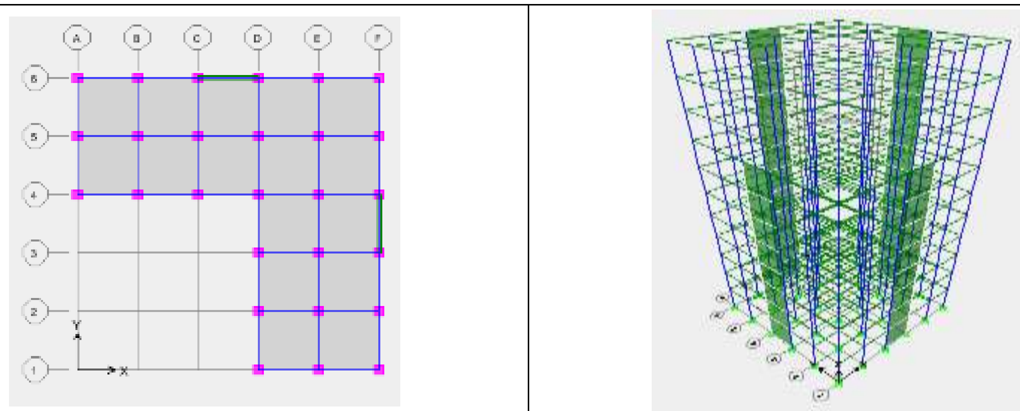

Figure-1.5 Plan Layout and 3D view of Asymmetric building Model-3

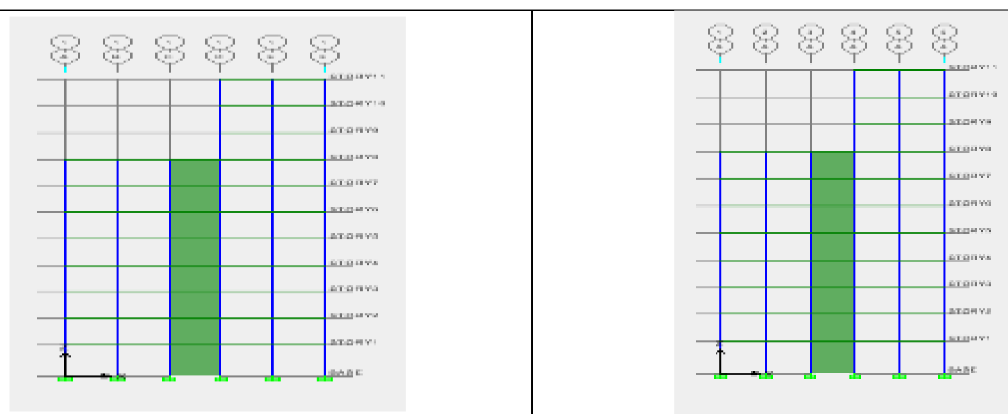

Figure-1.6 Elevation of Asymmetric building Model-3 along longitudinal and transverse direction

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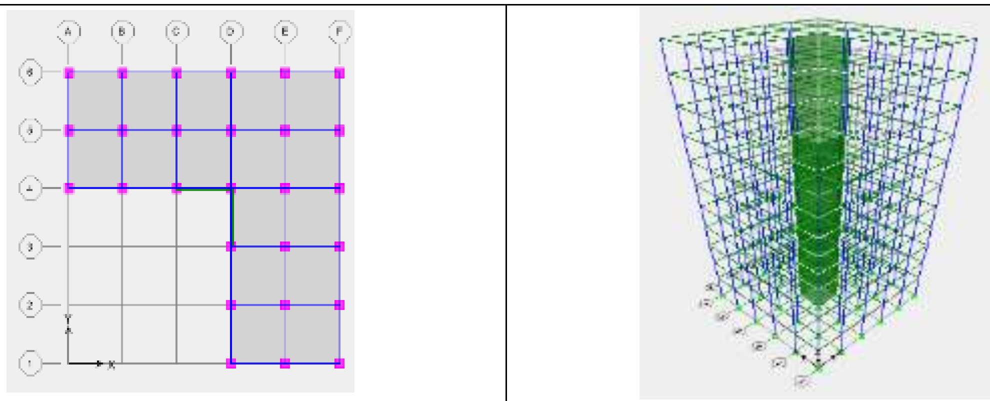

Figure-1.7 Plan Layout and 3D view of Asymmetric building Model-4

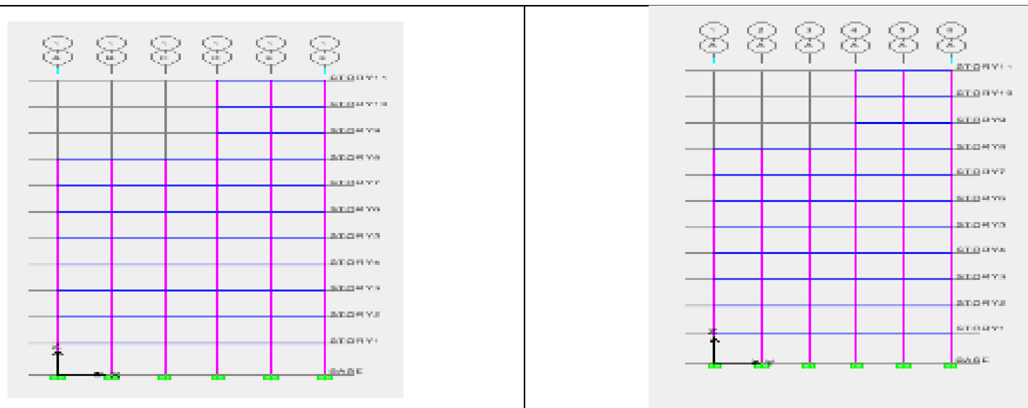

Figure-1.8 Elevation of Asymmetric building Model-4 along longitudinal and transverse direction

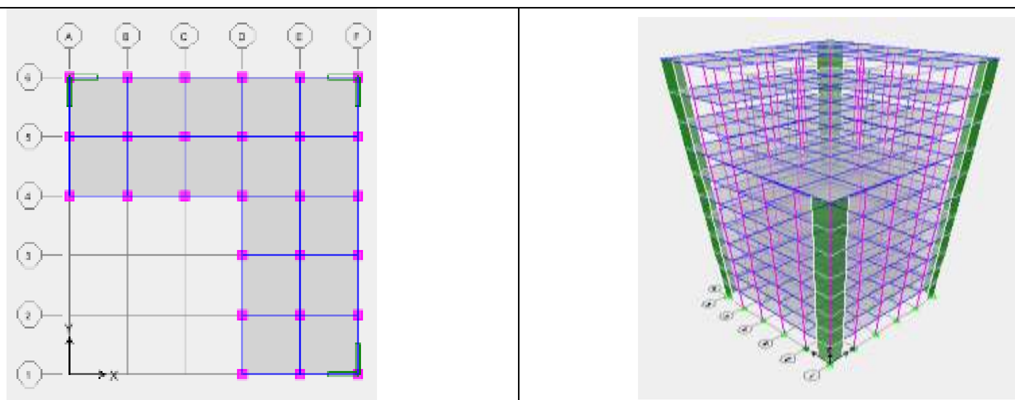

Figure-1.9 Plan Layout and 3D view of Asymmetric building Model-5

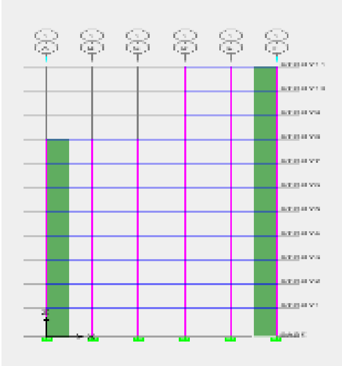
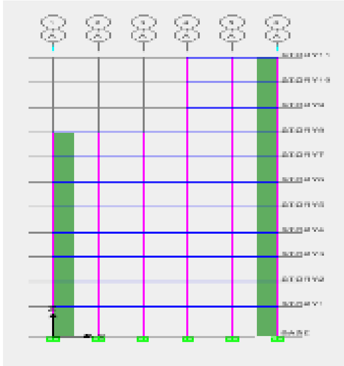

Figure-1.10 Elevation of Asymmetric building model-5 along longitudinal and transverse direction

DESIGN DATA:

Material Properties:

Modulus of elasticity of (M20) concrete, E = 22.360×10^6 KN/m²
Modulus of elasticity of (M25) concrete, E = 25×10^6 KN/m²
Density of RC = 25KN/m³
Modulus of elasticity of brick masonry = 3500x10³KN/m²
Density of brick masonry = 20KN/m³
Assumed Dead load intensities:
Floor finishes = 1KN/m²
Roof finishes = 1KN/m²

Live load intensities:

Imposed loads = 3.5KN/ m²

Member properties:

Slab thickness = 0.120m
Column size = (0.5m x 0.5m)
Beam size = (0.23m x 0.3m)
Wall thickness = 0.23m
Thickness of concrete wall = 0.20m
Earthquake Live Load on Slab as per clause7.3.1 and 7.3.2 of IS 1893 (Part-I)- 2002 is considered as:
Roof (clause 7.3.2) = 0
Floor (clause 7.3.1) = 0.5x3.5=1.75KN/m²
IS: 1893-2002 Equivalent Static method

Design Spectrum

Zone –IV
Zone factor, Z (Table2) – 0.24
Importance factor, I (Table 6) – 1.0
Response reduction factor, R (Table 7) – 5.00

Vertical Distribution of Lateral Load, $f_i = V_B \frac{w_i h_i^2}{\sum_{j=1}^{n} w_j h_j 2}$

CALCULATIONS

Natural periods and average response acceleration coefficients:

For **model 1**

Fundamental Natural period in longitudinal and transverse direction, $Ta=0.075*33.5^{0.75}=1.0444$ sec
For rocky or hard soil sites, $S_a/g = 1.00/T$
Spectral acceleration, $S_a/g= 1/1.044 = 0.957$m/sec^2
Fundamental Natural period, longitudinal and transverse direction,
For **model2, model3, model4, model5.**
Fundamental Natural period, in both directions,

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$T_a = \frac{0.09 \times 33.5}{\sqrt{15}} = 0.7785$ sec

For rocky or hard soil sites $S_a/g = 1.00/T$

Spectral acceleration, Sa/g = 1/0.7785 = 1.28m/sec^2

Design horizontal seismic coefficient, $A_h = \frac{Z}{2} x \frac{I}{R} x \frac{Sa}{g}$

RESULTS AND DISCUSSION

Model-1: First hinge is formed at STOREY 2 in both longitudinal and transverse direction. Roof displacement at first hinge is 30.194mm along both longitudinal and transverse direction. Hinge status remains within B-IO at first hinge.

Model-2: First hinge is formed at BASE in both longitudinal and transverse direction. Roof displacement at first hinge is 11.935mm along both longitudinal and transverse direction. The hinge status remains within B-IO at first hinge.

Model-3: First hinge is formed at BASE in both longitudinal and transverse direction. Roof displacement at first hinge is 15.268mm along both longitudinal direction 15.271mm along transverse direction. The hinge status remains within B-IO at first hinge.

Model-4: First hinge is formed at BASE in both longitudinal and transverse direction. Roof displacement at first hinge is 15.041mm along longitudinal direction and 15.040mm along transverse direction. The hinge status remains within B-IO at first hinge.

Model-5: First hinge is formed at BASE in both longitudinal and transverse direction. Roof displacement at first hinge is 14.233mm along both longitudinal and transverse directions. The hinge status remains within B-IO at first hinge.

LATERAL DISPLACEMENTS

The maximum displacements at each floor level with respect to ground are presented in Table-1 for equivalent static response spectrum and pushover analysis. For better comparability the displacement for each model along the two directions of ground motion are plotted in graphs as shown in figure-2.1 to 2.6. In the three dimensional model, however, there are six degrees of freedom with the two translational degree of freedom along X, Y-axes and rotation degree of freedom about Z (vertical)-axis playing significant role in the deformation of the structure. Apart from the translation motion in a particular direction, there is always an additional displacement due to the rotation of floor. Due to this the maximum displacement at floor levels obtained by three-dimensional analysis are always greater than the corresponding values obtained by one-dimensional analysis. Moreover, the floor rotation is maximum at the top floor, gradually reducing down the height of the building to an almost negligible rotation at the lowest basement floor.

Table 1: Lateral Displacements (mm) along Longitudinal and Transverse direction for Asymmetric building model-1

Storey No.	Asymmetric Building					
	Equivalent Static Method		Response Spectrum Method		Pushover Analysis Method	
	U_X	U_Y	U_X	U_Y	U_X	U_Y
11	20.63	34.75	14.71	18.84	26.46	29.75
10	19.85	33.70	14.26	18.38	25.84	29.17
09	18.67	31.93	13.55	17.61	24.87	28.20
08	17.19	29.46	12.65	16.51	23.57	26.76
07	15.58	26.47	11.65	15.14	22.04	24.86
06	13.65	22.98	10.41	13.47	20.02	22.42
05	11.42	19.10	8.92	11.52	17.47	19.43
04	8.98	14.95	7.22	9.29	14.39	15.90
03	6.42	10.67	5.32	6.83	10.80	11.86
02	3.87	6.42	3.29	4.21	6.83	7.47
01	1.55	2.57	1.34	1.72	2.86	3.11

In **equivalent static analysis** it has been found that model -2, model-3, model-4 and model-5, has 71.06%, 79.25%, 80.85% and 79.30% respectively less displacement as compared to the model-1 in longitudinal direction and in transverse direction model-2, model-3, model-4 and model-5 has 76.49%, 85.44%, 82.88% & 84.57% respectively less displacement compared to model-1.

In **response spectrum analysis** it has been found that model -2, model-3, model-4 and model-5 has 74.64%, 83.89%, 81.17% and 83.21% respectively less displacement as compared to the model-1 in longitudinal direction and in transverse direction model-2, model-3, model-4 and model-5 has 75.48%, 86.46%, 85.03% & 85.24% respectively less displacement compared to model-1.

In **pushover analysis** it can be seen that model -2, model-3, model-4 and model-5 has 57.71%, 44.18%, 47.84% and 48.11% respectively less displacement as compared to the model-1 in longitudinal direction, and in transverse direction model-2, model-3, model-4 and model-5 has 59.86%, 48.81%, 48.77% and 51.50% respectively less displacement compared to model-1.

From above it is clear that presence of brick infill, core wall and shear wall reduces the lateral displacement considerable by all equivalent static, response
spectrum analysis and pushover analysis.

DISPLACEMENT GRAPHS

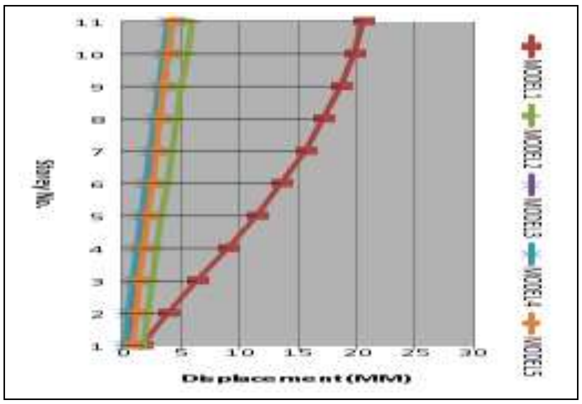

Figure-2.1: Storey-wise displacement for eleven story Asymmetric building models along X-direction (Analysis case: Equivalent static method-X)

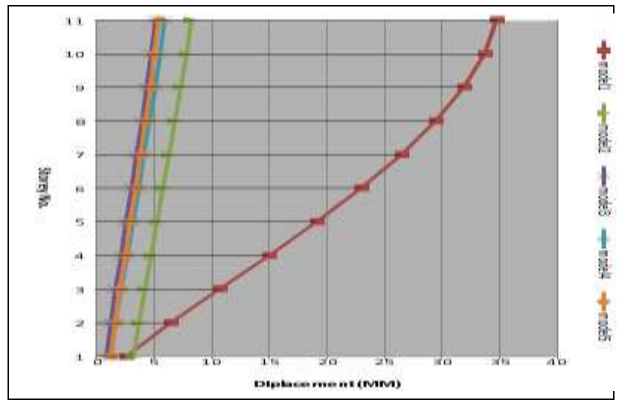

Figure-2.2: Storey-wise displacement for eleven story Asymmetric building models along Y-direction (Analysis case: Equivalent static method-Y)

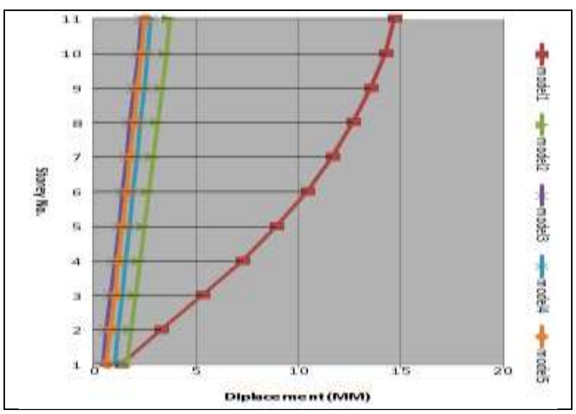

Figure-2.3: Storey-wise displacement for eleven story Asymmetric building models along X-direction (Analysis case: Response spectrum method-X)

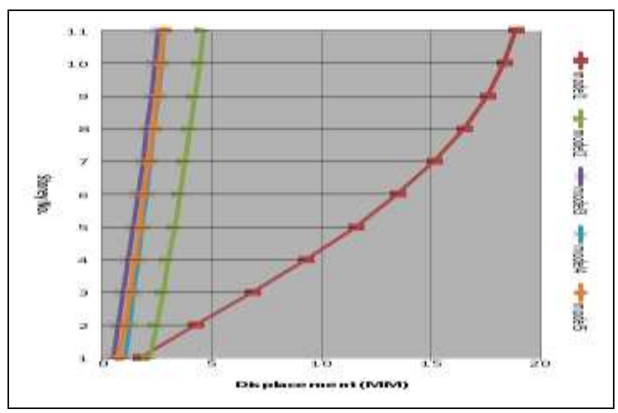

Figure-2.4: Storey-wise displacement for eleven story Asymmetric building models along Y-direction (Analysis case: Response spectrum method-Y)

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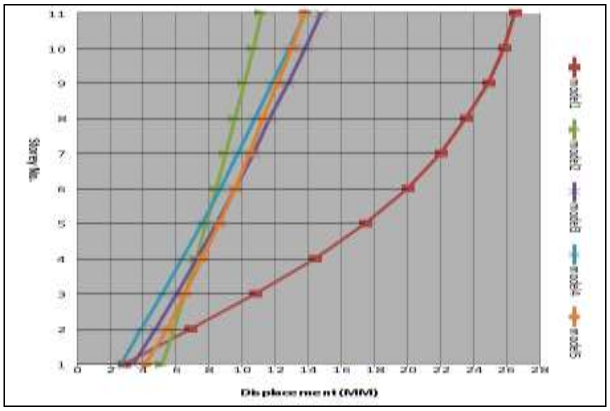

Figure-2.5: Storey-wise displacement for eleven story Asymmetric building models along X-direction (Analysis case: Pushover analysis method-X)

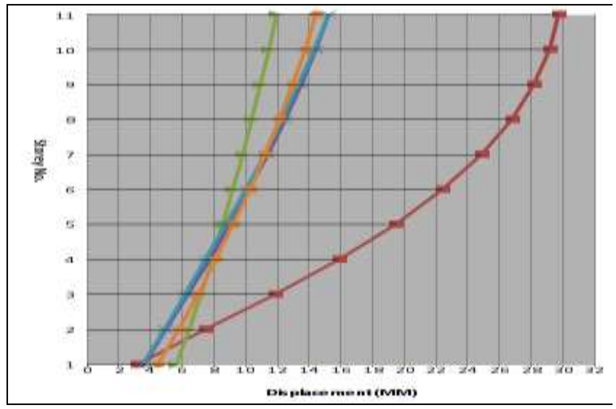

Figure-2.6: Storey-wise displacement for eleven story Asymmetric building models along Y-direction (Analysis case: Pushover analysis method-Y)

PERFORMANCE POINT

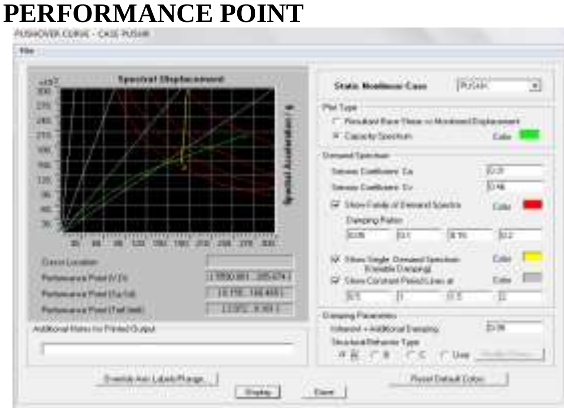

Figure-3.1: Performance point of Asymmetric building model-1 along Longitudinal Direction

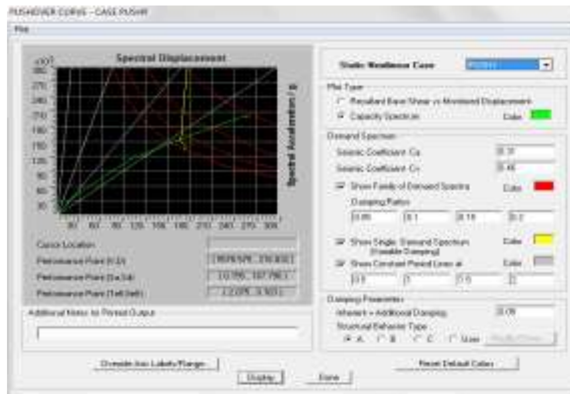

Figure-3.2: Performance point of Asymmetric building model-1 along transverse direction

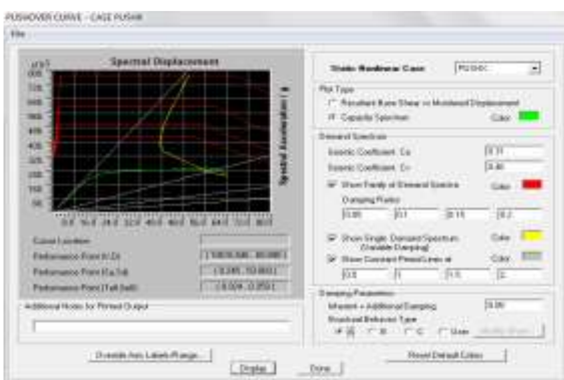

Figure-3.3: Performance point of Asymmetric building model-2 along longitudinal direction

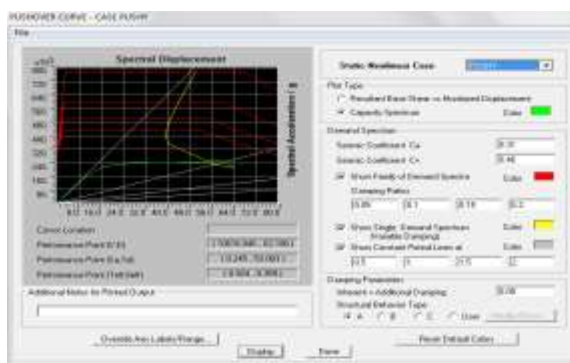

Figure-3.4: Performance point of Asymmetric building model-2 along transverse direction

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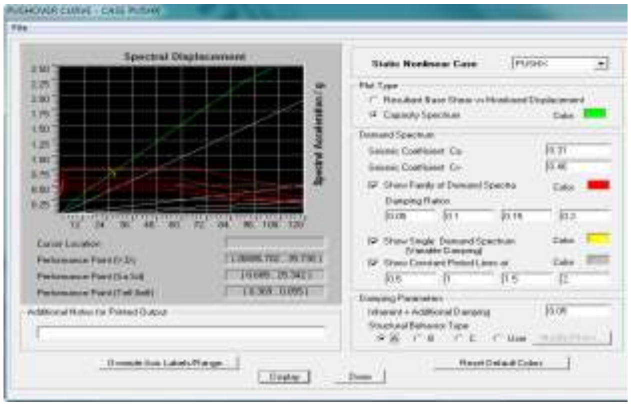

Figure-3.5: Performance point of Asymmetric building model-3 along longitudinal direction

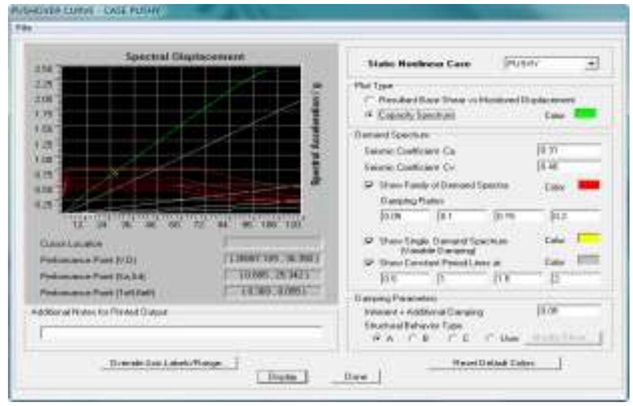

Figure-3.6: Performance point of Asymmetric building model-3 along transverse direction

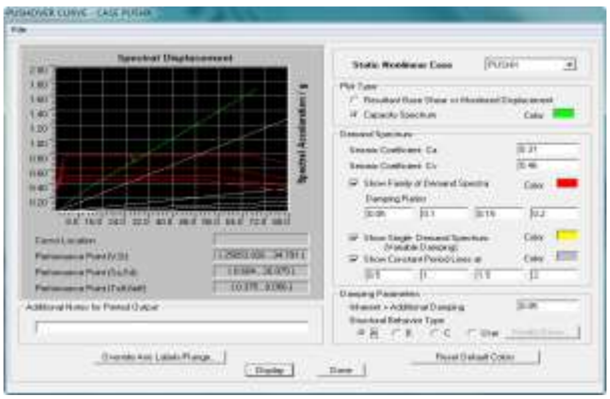

Figure-3.7: Performance point of Asymmetric building model-4 along longitudinal direction

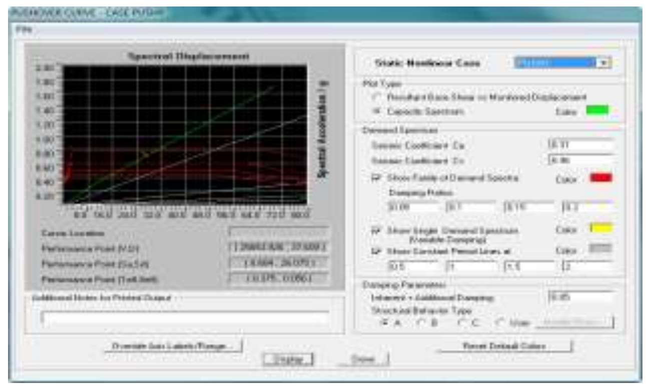

Figure-3.8: Performance point of Asymmetric building model-4 along transverse direction

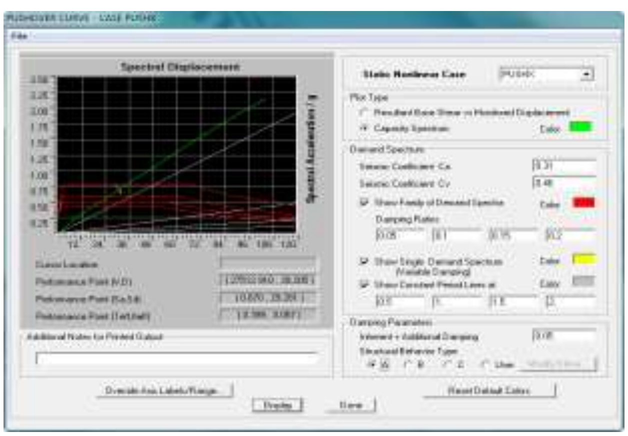

Figure-3.9: Performance point of Asymmetric building model-5 along longitudinal direction

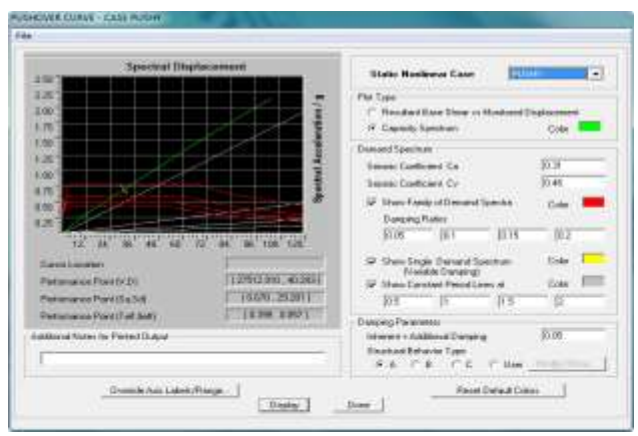

Figure-3.10: Performance point of Asymmetric building model-5 along transverse direction

Table 2: performance point parameter for building models along longitudinal direction.

Model	Asymmetric Building			
	Structural acceleration Sa (m/sec2)	Structural Displacement Sd (mm)	Base shear V (KN)	Roof Displacement D (mm)
1.	0.155	168.46	5590.80	205.67
2.	0.245	53.08	10616.85	60.89
3.	0.685	25.34	26886.70	35.74
4.	0.684	26.07	25653.93	35.79
5.	0.670	29.28	27512.91	39.20

ALONG LONGITUDINAL DIRECTION:

From the above table it can be noted that structural displacement (sd) and roof displacement (D) has smaller value for model-3 as compared to other models, it can also be seen that for the structural acceleration(Sa) is maximum for model-3 and base shear (V) is almost maximum for model-3 as compared to other models in longitudinal direction.

Table 3: performance point parameter for building models along transverse direction.

Model	Asymmetric Building			
	Structural acceleration Sa (m/sec2)	Structural Displacement Sd (mm)	Base shear V (KN)	Roof Displacement D (mm)
1.	0.155	167.80	5578.57	216.83
2.	0.245	53.08	10616.85	62.19
3.	0.685	25.34	26887.11	36.35
4.	0.684	26.07	25653.73	37.61
5.	0.670	29.28	27512.91	40.29

ALONG TRANSVERSE DIRECTION

From the above table we noticed, Compare to other model the value of roof displacement and structural displacement is very small for model . It can also be seen that for the structural acceleration(Sa) is maximum for model-3 and base shear (V) is almost extreme for model-3 as compared to other models in transverse direction.

CONCLUSION

1. Fundamental natural period decreases when effect of infill wall and concrete core wall is considered.
2. Storey drifts are found within the limit as specified by code (IS 1893-2002 Part-1) in both linear and dynamic and non-linear static analysis.
3. Base shear at first hinge is less and displacement at first hinge is more for asymmetric bare frame model and vice versa for other models.
4. The presence of masonry infill influences the overall behavior of structures when subjected to lateral forces. Joint displacements and storey drifts are considerably reduced while contribution of infill brick wall is taken into account.
5. The presence of concrete core wall at the center has not affected much on the overall behavior of the structure when subjected to lateral forces, as compared to other models.
6. When the effect of infill walls are not considered, the building performance level remains within yield point to immediate occupancy level and when effect of infill walls are considered, the building performance level goes down to 'D' level, however, for concrete core wall model it remains within "Life Safety" level.
7. Ductility ratio is maximum for bare frame structure and it get reduced when the effect of infill wall is considered. It indicates that these structures will show adequate warning before collapse.
8. Bare frame structures are having highest response reduction factor as compared to infill frame structures. It indicates that bare frame structures are capable of resisting the forces still after first hinge.
9. In case of core wall structure it can be seen that almost all hinges are formed in link beams. To function properly under severe earthquake loading, the core wall requires ductile link beams that can undergo large inelastic deformations.

10. In case of shear wall at exterior corners the structure is subjected to less displacement in almost all cases against the structure with core wall and shear wall at Centre , but the nonlinear hinge is found at very less displacement and base shear.
11. From the above study we conclude that model-3 i-e asymmetric R C frame building with shear wall at center of the exterior panel shows better performance among the others for the given seismic parameters.

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