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IMPORTANCE OF STOREY DRIFT RATIO,DUCTITY AND PERFORMANCE POINT LEVELS ON MULTI STORY BUILDING WITH AND WITH OUT INFILLLS

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ABSTRACT : *Multistory buildings with open (soft story) ground floor are inherently vulnerable to collapse due to seismic loads, their constructions is still widespread in develop nations. Social and functional need to provide car parking space at ground level far outweights the warning against such buildings from engineering community.*

In this study, 3D analytical model of multistory buildings have been generating for different buildings models and analyzing using structural analysis tool 'ETABS'. To study the effect of ground soft, infill, and models with ground soft during earthquake, seismic analysis both linear static, linear dynamic (response spectrum method) as well as nonlinear static(pushover) procedure have to be perform. The analytical model of building includes all important components that influence the mass, strength, stiffness of the structure. The deflections at each story have to be compare by performing equivalent static, response spectrum method as well as pushover have also be perform to determine capacity, demand and performance level of the considering models. Numerical results for the following seismic demands considering the inelastic behavior of the building, ductility coefficients of structure.

1.INTRODUCTION

The capacity of structural members to undergo inelastic deformations governs the structural behaviour and damageability of multi-storey buildings during earthquake ground motions. From this point of view, the evaluation and design of buildings should be based on the inelastic deformations demanded by earthquakes, besides the stresses induced by the equivalent static forces as specified in several seismic regulations and codes. Although, the current practice for earthquake-resistant design is mainly governed by the principles of force-based seismic design, there have been significant attempts to incorporate the concepts of deformation-based seismic design and evaluation into the earthquake engineering practice. In general, the study of the inelastic seismic responses of buildings is not only useful to improve the guidelines and code provisions for minimizing the potential damage of buildings, but also important to provide economical design by making use of the reserved strength of the building as it experiences inelastic deformations. Pushover methods are becoming practical tools of analysis and evaluation of buildings considering the performance-based seismic philosophy. pushover curve represents the lateral capacity of the building by plotting the nonlinear relation between the base shear and roof displacement of the building. The intersection of this pushover curve with the seismic demand curve determined by the design response spectrum represents the deformation state at which the performance of the building is evaluated.

2 . OBJECTIVES OF STUDY

1. To study the effect of infill walls and without infill walls on structure.
2. To study of natural frequency of the structure.
3. To study the performance level of the structure

3 DIFFERENT METHODS OF SEISMIC EVALUATION STUDIES

3.1 LINEAR STATIC ANALYSIS

In linear static procedures the building is modeled as an equivalent single-degreeof freedom (SDOF) system with a linear static stiffness and an equivalent viscous damping. The seismic input is modeled by an equivalent lateral force with the objective to produce the same stresses and strains as the earthquake it represents. Based on an estimate of the first fundamental frequency of the building using empirical relationships or Rayleigh's method

3.2 LINEAR DYNAMIC ANALYSIS

In a linear dynamic procedure the building is modelled as a multi-degree-of-freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix. The seismic input is modelled using either modal spectral analysis or time history analysis. Modal spectral analysis assumes that the dynamic response of a building can be found by considering the independent response of each natural mode of vibration using linear elastic response spectra. Only the modes contributing considerably to the response need to be considered. The modal responses are compared using schemes such as the square-root-sum-of-squares (SRSS). Time-history analysis involves a time step- by-step evaluation of building response, using recorded or synthetic earthquake records as a base motion input. In both cases the corresponding internal forces and displacements are determined using again linear elastic analyses.

3.3 NONLINEAR STATIC ANALYSIS

Pushover Analysis is a nonlinear static method of analysis. This analysis technique, also known as sequential yield analysis or simply "Pushover" analysis has gained significant popularity during past few years. It is one of the three analysis techniques recommended by FEMA 273/274 and a main component of Capacity Spectrum Analysis method (ATC-40).

Pushover analysis provide information on many response characteristics that cannot be obtained from an elastic static or elastic dynamic analysis. These are [30];

- Estimates of inter story drifts and its distribution along the height.
- Determination of force demands on brittle members, such as axial force demands on columns, moment demands on beam-column connections.
- Determination of deformation demands for ductile members.
- Identification of location of weak points in the structure (or potential failure modes).
- Consequences of strength deterioration of individual members on the behaviour of structural system.
- Identification of strength discontinuities in plan or elevation that will lead to changes in dynamic characteristics in the inelastic range.
- Verification of the completeness and adequacy of load path .

3.4 NON-LINEAR DYNAMIC ANALYSIS

In nonlinear dynamic procedure the building model is similar to the one used in non-linear static procedures incorporating directly the inelastic material response using in general finite elements. The main difference is that seismic input is modelled using a time history analysis, which involves time-step-by-time-step evaluation of the building response.

3.5 ADVANTAGES OF INELASTIC PROCEDURE OVER ELASTIC PROCEDURES.

Although an elastic analysis gives a good understanding of the elastic capacity of structures and indicates where first yielding will occur, it cannot predict failure mechanisms and account for redistribution of forces during progressive yielding. Inelastic analyses procedures help demonstrate how buildings really work by identifying modes of failure and the potential for progressive collapse. The use of inelastic procedures for design and evaluation is an attempt to help engineers better understand how structures will behave when subjected to major earthquakes, where it is assumed that the elastic capacity of the structure will be exceeded. This resolves some of the uncertainties associated with code and elastic procedures.

4. Analysis of MULTISTORIED BUILDINGS WITH GROUND SOFT STORY AND WITH INFILLS

4.1 DESCRIPTION OF THE SAMPLE BUILDING

The plan layout for all the building models are shown in figures

SYMMETRIC BUILDING MODELS:

Model 1: Twelve stoteyed Building with full infill masonry wall (230 mm thick) in all storeys.

Model 2: Twelve storeyed Building (ground soft story) no walls in the first storey and full brick infill masonry walls (230 mm thick) in the upper storeys.

Model 3: Nine stoteyed Building with full infill masonry wall (230 mm thick) in all storey

Model 4: Nine storeyed Building (ground soft story) no walls in the first storey and full brick infill masonry walls (230 mm thick) in the upper storeys.

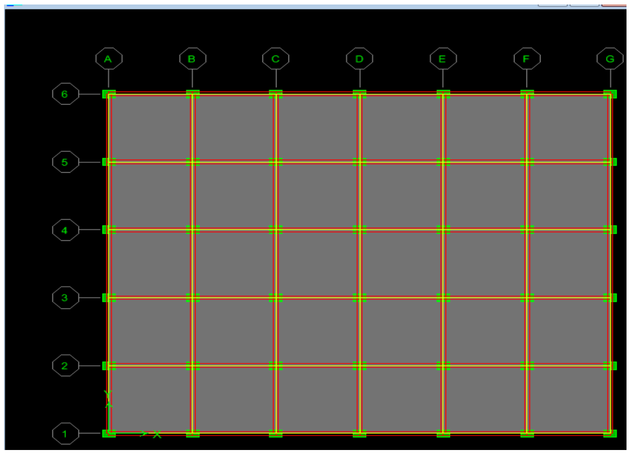


Figure:4.1 Plan Layout

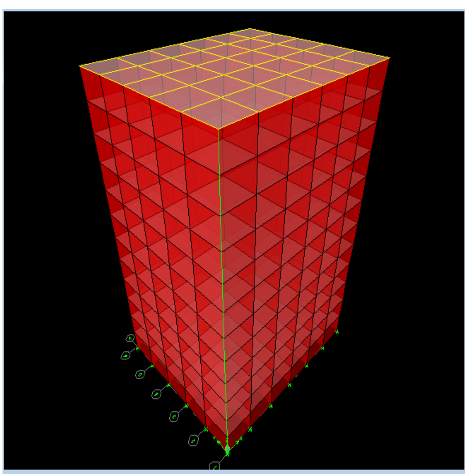


Fig:4.2 Elevation of twelve storeyed Building Model 1 (full infill)

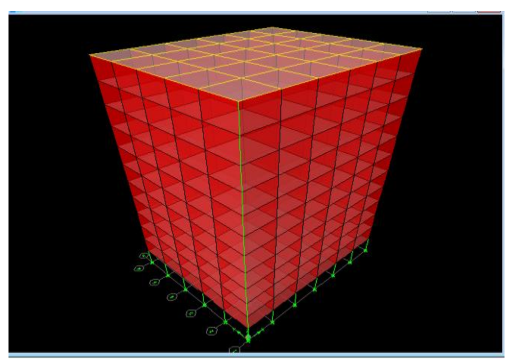


Fig:4.3 Elevation of twelve storeyed Building Model 2 (ground soft)

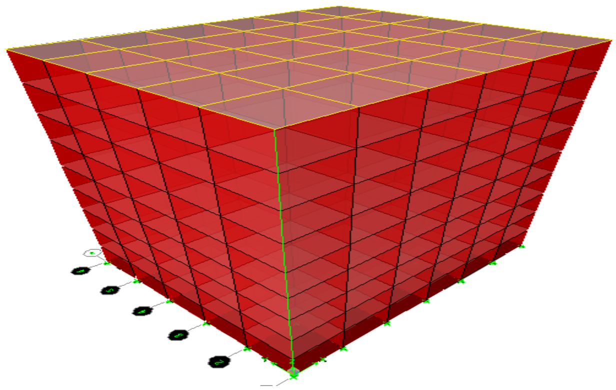


Fig:4.4 Elevation of nine storeyed Building

Model 3 (full infill)

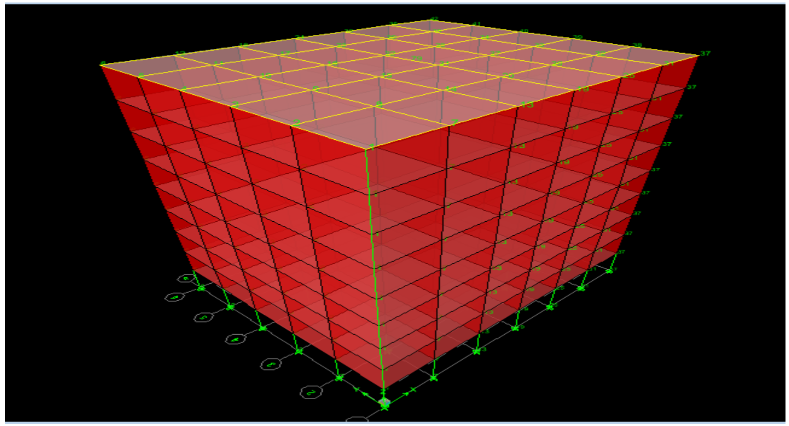


**Fig:4.5 Elevation of nine storeyed Building
Model 4 (ground soft)**

4.2 Design Data:

Material Properties:

Young's modulus of (M25) concrete, E	= 25.000x10^6 kN/m²
Young's modulus of (M20) concrete, E	= 22.360x10^6 kN/m²
Density of Reinforced Concrete	= 25kN/m³
Modulus of elasticity of brick masonry	= 3500x10³kN/m²
Density of brick masonry	= 19.2 kN/m³
Assumed Dead load intensities	
Floor finishes	= 1.5kN/m²
Live load	= 4 KN/ m²
Member properties	
Thickness of Slab	= 0.125m
Column size for twelve storeyed	= (0.6m x 0.6m)
Column size for nine storeyed	= (0.45m x 0.6m)
Beam size of twelve storeyed	= (0.375m x 0.6m)
Beam size of nine storeyed	=(0.375m x 0.6m)
Thickness of wall	= 0.230m
Thickness of shear wall	=0.30m

Earthquake Live Load on Slab as per clause 7.3.1 and 7.3.2 of IS 1893 (Part-I)- 2002 is calculated as:

Roof (clause 7.3.2)	= 0
Floor (clause 7.3.1)	= 0.5x4=2 kN/m2

IS: 1893-2002 Equivalent Static method
Design Spectrum
Zone –V
Zone factor, Z (Table2) – 0.36
Importance factor, I (Table 6) – 1.5
Response reduction factor, R (Table 7) – 5.00

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

IS: 1893-2002 Response Spectrum Method: Spectrum is applied from fig.2 of the code corresponding to medium soil sites. The spectrum is applied in the longitudinal and transverse directions.

4.3 Manual Calculation

Natural periods and average response acceleration coefficients:
For twelve-storeyed frame building:
Fundamental Natural period, longitudinal and transverse direction, $Ta=0.075*36^{0.75}=1.102sec$
For medium soil sites, Sa/g = 1.36/T=1.36/1.102=1.234

For twelve-storeyed brick infills buildings:

Fundamental natural period longitudinal direction, Ta= $\frac{0.09x36}{\sqrt{25}} = 0.66$ sec

For medium soil sites, Sa/g = 1.36/0.66=2.060

Fundamental Natural period, transverse direction, T_a= $\frac{0.09x32}{\sqrt{20}} = 0.643$ sec

For medium soil sites, Sa/g = 1.36/0.643=2.11

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

Ah= (0.36/2) x (1.5/5) x 2.060 **=0.11124** in longitudinal direction.
Ah= (0.36/2) x (1.5/5) x 2.11 **=0.1139** in transverse direction.

5. STOREY DRIFTS

The permissible inter storey drift is limited to 0.004 times the storey height, so that minimum damage would take place during earthquake and pose less psychological fear in the minds of people. The storey drifts of different models along longitudinal and transverse directions are shown in Tables 5.1 to 5.4

DRIFT						
STOREY NO'S.	EQUIVALENT STATIC METHOD		RESPONSE SPECTRUM METHOD		PUSH OVER ANALYSIS	
	UX	UY	UX	UY	UX	UY
STORY12	0.281	0.338	0.183	0.222	3.566	4.162
STORY11	0.35	0.404	0.226	0.264	4.124	4.669
STORY10	0.408	0.46	0.266	0.303	4.699	5.188
STORY9	0.452	0.501	0.3	0.335	5.269	5.691
STORY8	0.483	0.529	0.328	0.359	5.827	6.181
STORY7	0.502	0.543	0.349	0.377	6.364	6.643
STORY6	0.508	0.545	0.363	0.387	6.852	7.017
STORY5	0.503	0.534	0.37	0.389	7.25	7.317
STORY4	0.488	0.512	0.371	0.384	7.604	7.551
STORY3	0.463	0.478	0.363	0.37	7.763	7.585
STORY2	0.431	0.438	0.349	0.349	7.858	7.517
STORY1	0.355	0.351	0.294	0.288	7.491	7.028

TABLE 5.1 STOREY DRIFTS(MM) ALONG LONGITUDINAL AND TRANSVERSE DIRECTION FOR MODEL 1

DRIFT						
STOREY NO'S.	EQUIVALENT STATIC METHOD		RESPONSE SPECTRUM METHOD		PUSH OVER ANALYSIS	
	UX	UY	UX	UY	UX	UY
STORY12	0.219	0.269	0.146	0.181	0.443	0.546

STORY11	0.27	0.319	0.177	0.212	0.478	0.587
STORY10	0.313	0.361	0.207	0.241	0.513	0.628
STORY9	0.346	0.392	0.234	0.266	0.548	0.668
STORY8	0.369	0.413	0.256	0.287	0.581	0.705
STORY7	0.383	0.424	0.275	0.302	0.612	0.74
STORY6	0.388	0.425	0.289	0.313	0.643	0.771
STORY5	0.385	0.418	0.298	0.318	0.672	0.797
STORY4	0.374	0.402	0.302	0.318	0.698	0.818
STORY3	0.352	0.373	0.297	0.307	0.708	0.822
STORY2	0.387	0.4	0.346	0.349	0.864	0.975
STORY1	1.274	1.24	1.202	1.145	13.938	12.186

TABLE 5.2 STOREY DRIFTS(MM) ALONG LONGITUDINAL AND TRANSVERSE DIRECTION FOR MODEL 2

DISPLACEMENTS						
STOREY NO'S.	EQUIVALENT STATIC METHOD		RESPONSE SPECTRUM METHOD		PUSH OVER ANALYSIS	
	UX	UY	UX	UY	UX	UY
STORY9	8.8622	10.0526	6.1785	6.9625	186.08	163.48
STORY8	8.2342	9.2756	5.7952	6.4815	175.13	153.76
STORY7	7.4017	8.2849	5.2879	5.8706	161.40	141.69
STORY6	6.4146	7.1363	4.6695	5.1464	144.88	127.21
STORY5	5.3264	5.8886	3.9605	4.3329	125.64	110.34
STORY4	4.1869	4.5977	3.1841	3.4572	103.82	91.18
STORY3	3.0417	3.3152	2.3662	2.549	79.69	70.01
STORY2	1.9319	2.0883	1.5355	1.6409	53.69	47.12
STORY1	0.8899	0.9562	0.7204	0.7661	26.43	23.24

TABLE 5.3 DISPLACEMENTS OF 9 STOREY INFILL STRUCTURE IN MM Medel-3.

DISPLACEMENTS						
STOREY NO'S.	EQUIVALENT STATIC METHOD		RESPONSE SPECTRUM METHOD		PUSH OVER ANALYSIS	
	UX	UY	UX	UY	UX	UY
STORY9	13.1871	15.373	11.277	13.4621	49.4624	48.0587
STORY8	12.6371	14.8261	10.9343	13.1276	48.2244	44.4746
STORY7	11.9308	14.149	10.5004	12.7207	46.8926	40.7936
STORY6	11.106	13.3757	9.9793	12.2449	45.4652	37.0101
STORY5	10.2036	12.5417	9.3798	11.7074	43.9454	33.1076
STORY4	9.2611	11.6806	8.7133	11.1174	42.338	29.0399

STORY3	8.3121	10.8227	7.9925	10.4857	40.6471	24.7732
STORY2	7.3981	10.0041	7.244	9.8337	38.9091	20.4227
STORY1	6.4082	9.1455	6.35	9.0741	36.8034	16.033

TABLE 5.4 DISPLACEMENTS OF 9 GROUND SOFT STOREY STRUCTURE IN MM --Model 4

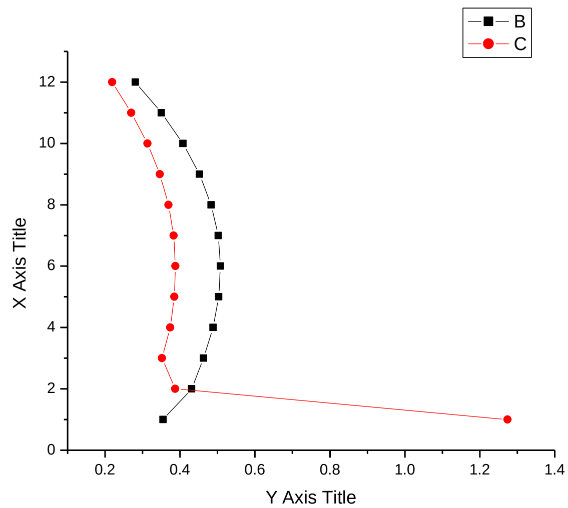
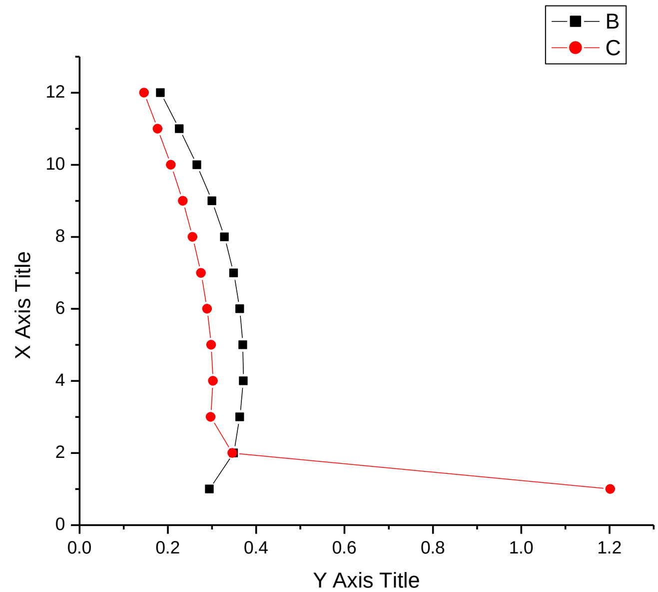


Fig 5.1 drift of linear static analysis of 12th storey buildings in x – direction.

Fig 5.2 drift of linear static analysis of 12th storey buildings in y – direction.



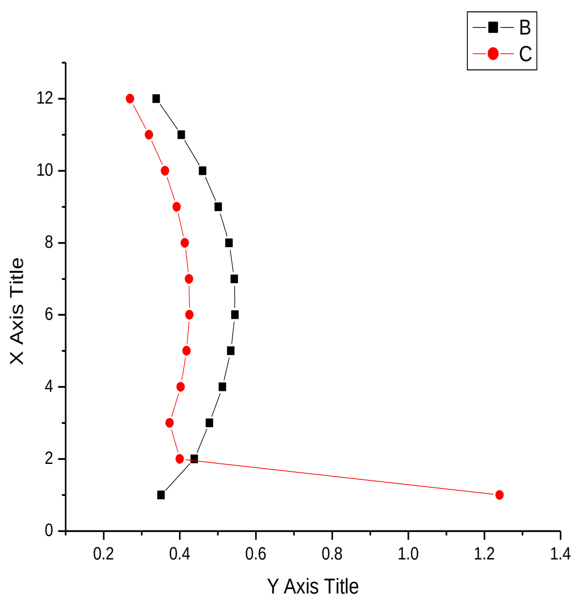


Fig 5.3 drift of linear dynamic analysis of 12th storey buildings in x – direction.

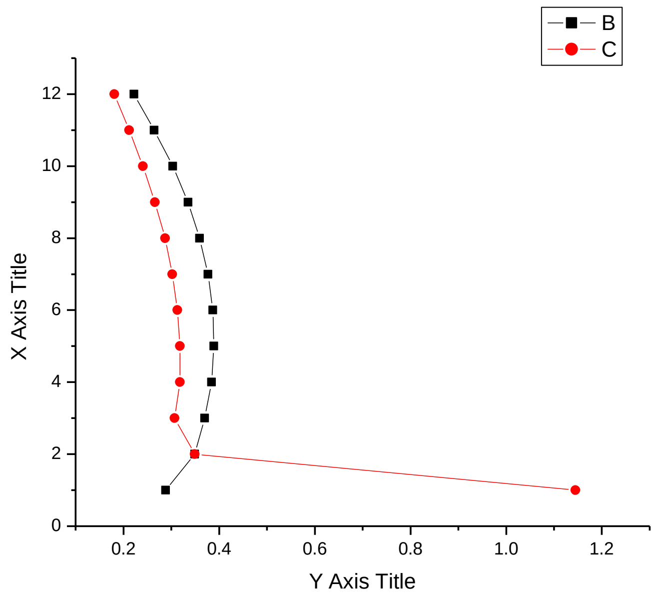


Fig 5.4 drift of linear dynamic analysis of 12th storey buildings in y – direction.

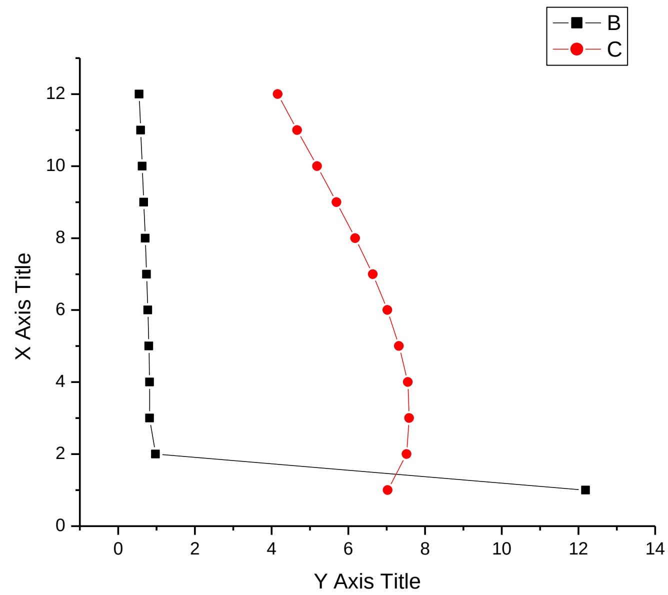


Fig 5.6 drift of linear non static analysis of 12th storey buildings in y – direction.

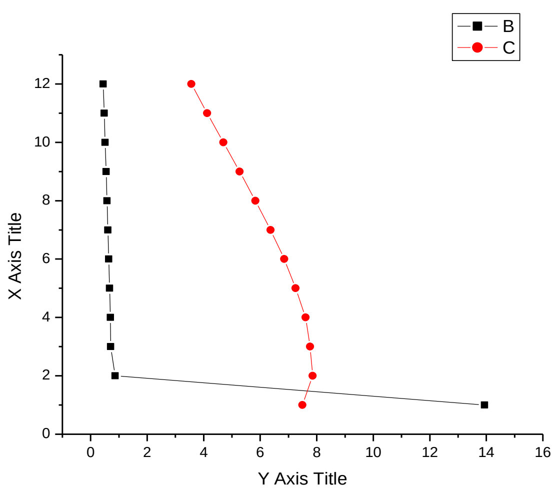


Fig 5.5 drift of linear non static analysis of 12th storey buildings in x – direction.

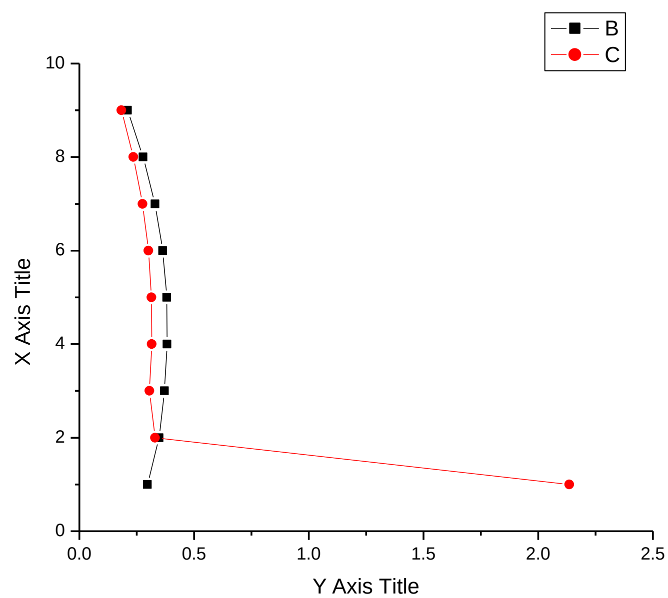


Fig 5.7 drift of linear static analysis of 9th storey buildings in x – direction.

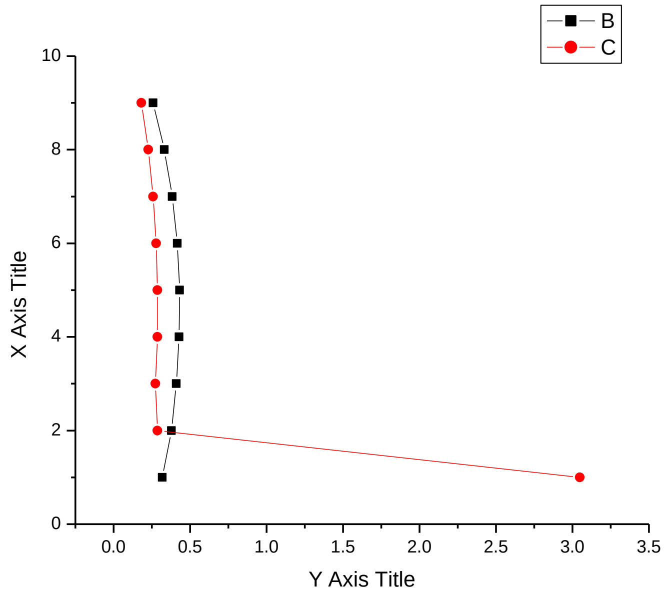


Fig 5.8 drift of linear static analysis of 9th storey buildings in y – direction.

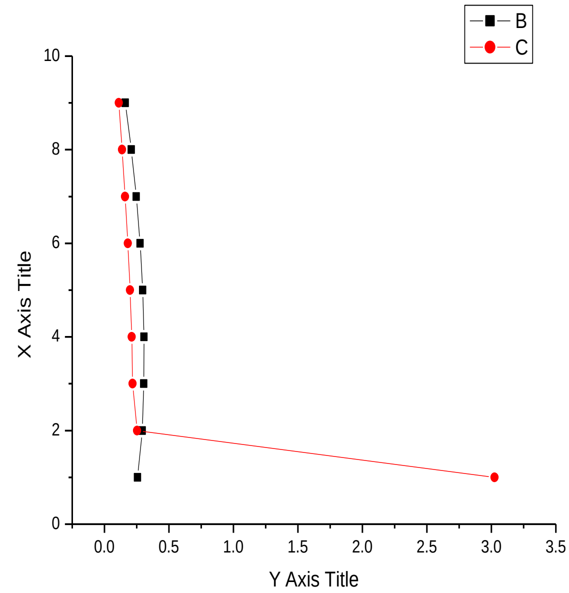


Fig 5.10 drift of linear dynamic analysis of 9th storey buildings in y – direction.

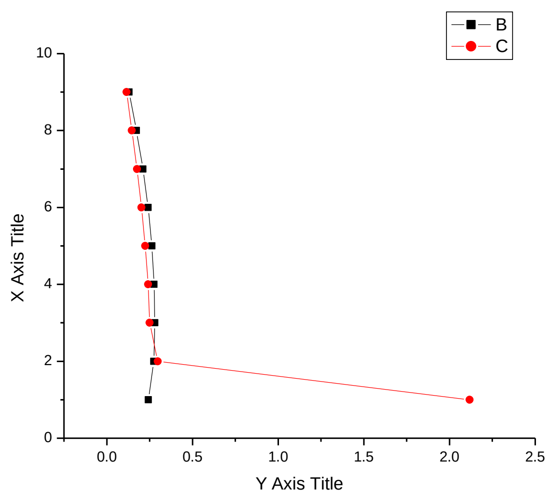


Fig 5.9 drift of linear dynamic analysis of 9th storey buildings in x – direction.

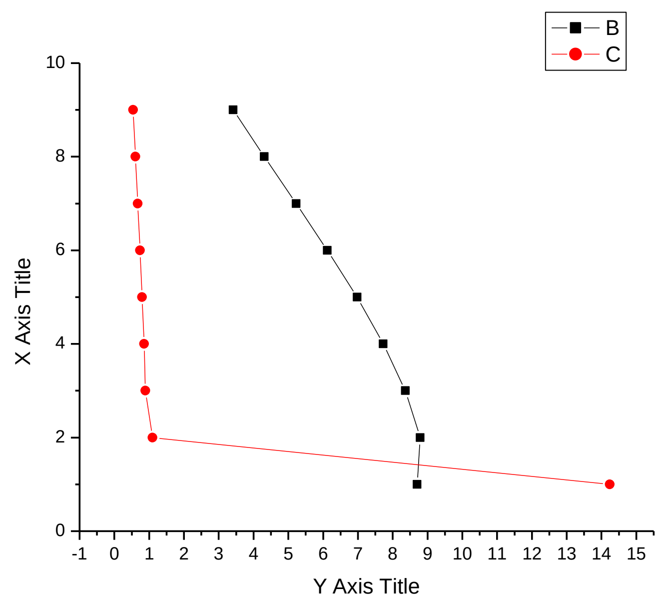


Fig 5.11 drift of linear non static analysis of 9th storey buildings in x – direction.

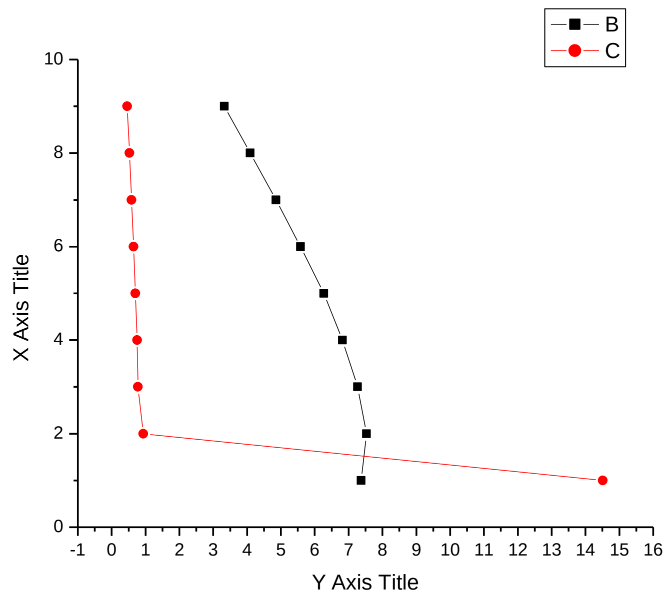


Fig 5.12 drift of linear non static analysis of 9th storey buildings in y – direction.

From the above tables it can be seen that, all storey drifts are within the permissible limit (0.004*h=12mm) except the model-2 and model-4. In model-2 and model-4, the drifts are more than the permissible limit due to soft storeys, this is due to the less stiffness of the structure (because infill walls are not present in the lower storeys) therefore larger drifts are at lower storey than that in above storey because of the stiffness irregularity

The displacement profiles of the various models for the three different analysis performed in this study are shown in figures 5.1 to 5.12. In these graphs, the abrupt changes in the bottom soft storey of model-2 and model-4 indicate the stiffness irregularity. Hence the inter-storey drift demand is largest in the first storey of model-2 and model-4. In transverse direction also models with full infill shows good results as compared with bottom soft storey model-2 and model-4.

5.2 DUCTILITY RATIO (μ) AND RESPONSE REDUCTION FACTOR (R):

Ductility is another factor that can affect the performance of a building during an earthquake. Ductility is the property of certain materials to fail only after large stresses and strains have occurred. Brittle materials, such as non-reinforced concrete, fail suddenly with minimum tensile stresses, so plain concrete beams are no longer used. Other materials, primarily steel, bend or deform before they fail. We can rely on ductile materials to absorb energy and prevent collapse when earthquake forces overwhelm a building. In fact, adding steel rods to concrete can reinforce it and give the concrete considerable ductility and strength. Concrete reinforced with steel will help prevent it from failing during an earthquake.

MODELS	1	2	3	4
Yield displacement (U_{Yield}) (mm)	88.5	28.0	18.1	25.8
Ultimate displacement	456	250	88.2	121

$U_{ultimate}$ (mm)				
Ductility ratio μ	5.15	8.93	4.87	4.69
Reduction factor	3.05	4.11	2.96	2.89

Table 5.5 Response Reduction Factor along longitudinal direction

MODELS	1	2	3	4
Yield displacement (U_{Yield}) (mm)	94.1	32.4	20.3	29.7
Ultimate displacement $U_{ultimate}$ (mm)	405	244	90	189
Ductility ratio μ	4.3	7.53	4.43	6.36
Reduction factor	2.76	3.75	2.8	3.42

Table 5.6 : Response Reduction Factor along transverse direction

The property which enables structure to withstand severe earthquake is ductility. By enhancing ductility in structure the design seismic forces can be reduced, and more economical structure can be obtained. Reinforced concrete structures have less ductility capacity as compared to steel structures. The ductility ratio and response reduction factor for different building models in longitudinal and transverse direction are shown in tables-5.5 and 5.6.

From the above tables it can be seen that, response reduction factor and ductility ratio decreases as the stiffness of brick wall decreases in bottom storey in model-2 and model-4 along longitudinal and transverse direction.

5.3 PERFORMANCE POINT

The performance point of the building models in longitudinal and transverse directions are shown in figure 5.25 to 5.32 as obtained from ETABS. The values of seismic coefficients Ca and Cv for zone-V are taken from the table 5.11.

Seismic Coefficient, C_A				
Soil	Zone II (0.10)	Zone III (0.16)	Zone IV (0.24)	Zone V (0.36)
Type I	0.12	0.19	0.28	0.37
Type II	0.15	0.23	0.31	0.41
Type III	0.23	0.31	0.35	0.36
Seismic Coefficient, C_V				
Type I	0.17	0.26	0.37	0.52
Type II	0.23	0.34	0.46	0.60
Type III	0.34	0.53	0.72	0.91

Table-5.7: Interpolated values of Seismic Coefficient (CA and CV) for the soil type

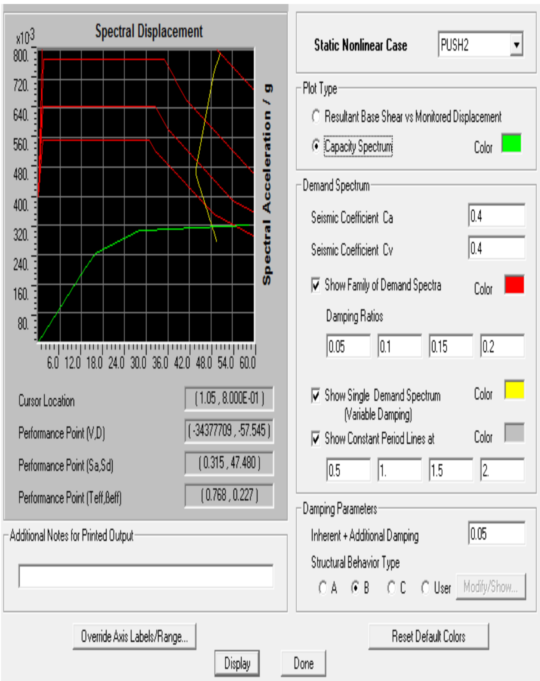


Figure 5.13 : Performance point of twelve storeyed building Model 1 along longitudinal direction

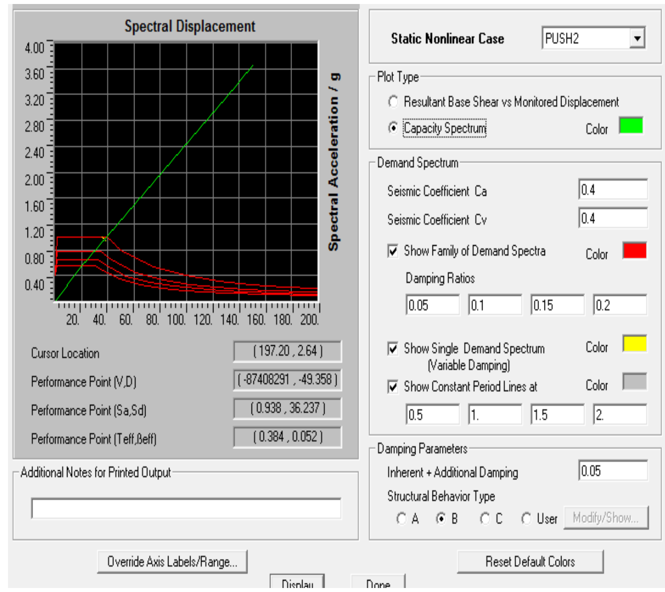


Figure 5.15 : Performance point of twelve storeyed building Model 2 along longitudinal direction

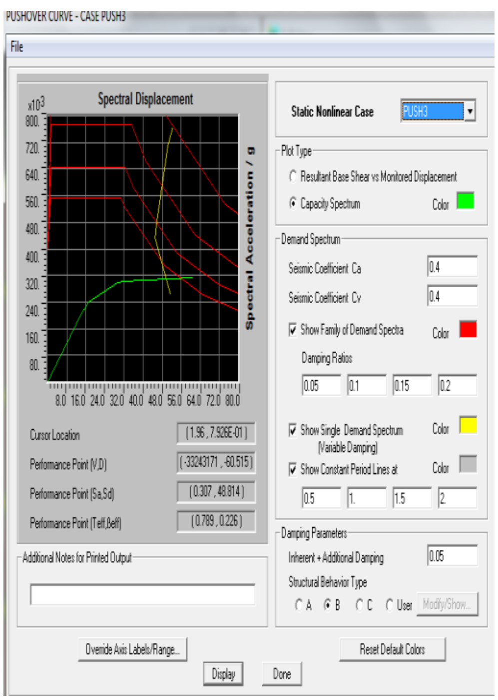


Figure 5.14 : Performance point of twelve storeyed building Model 1 along transverse direction

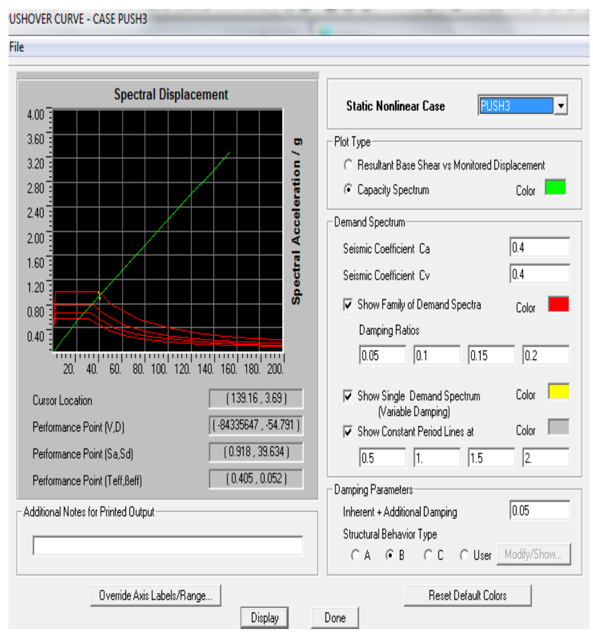


Figure 5.16 : Performance point of twelve storeyed building Model 2 along transverse direction

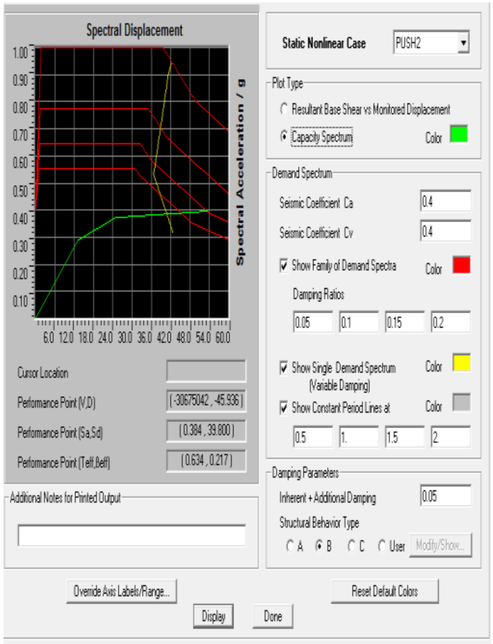


Figure 5.17 : Performance point of nine storeyed building Model 3 along longitudinal direction

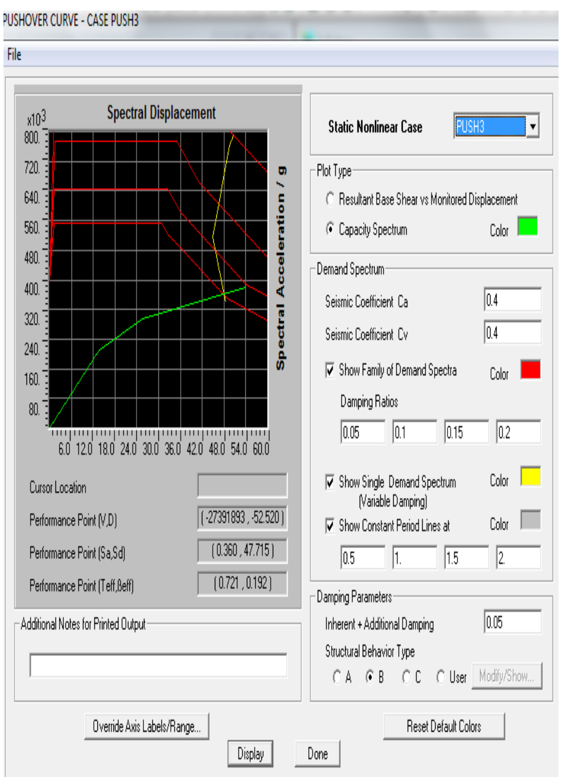


Figure 5.18 : Performance point of nine storeyed building Model 3 along transverse direction

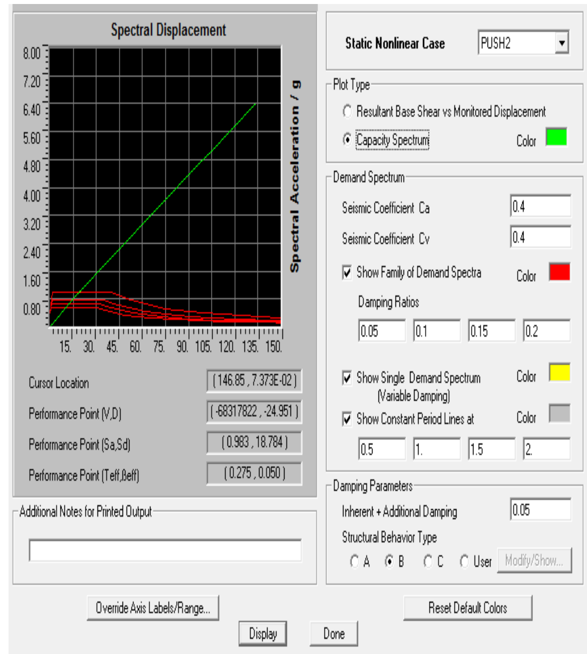
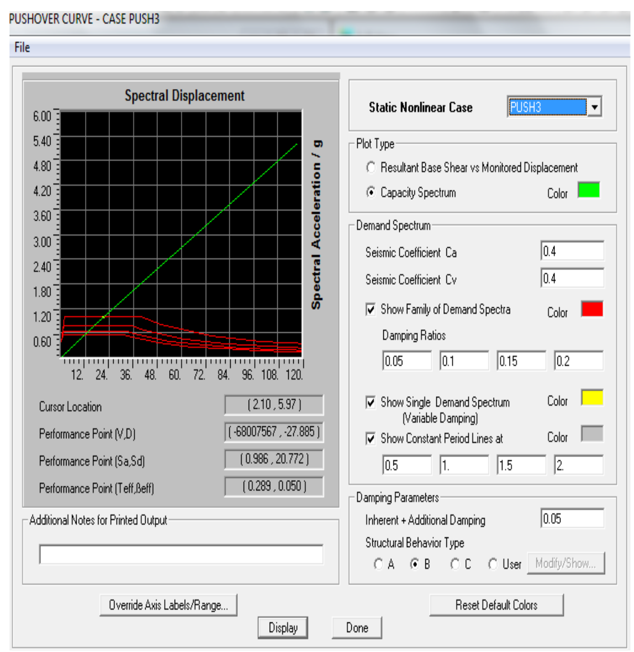


Figure 5.19 : Performance point of nine storeyed building Model 4 along longitudinal direction



5.19:Performance point of nine storeyed building Model 4 along transverse direction

6.SUMMARY AND CONCLUSION

The present work attempts to study the seismic response and performance level of different RC buildings located in seismic zone-V. In this study all important components of the building that influence the mass, strength, stiffness and deformability of the structure are included in the analytical model. To study the effect of infill and soft storey building models. The deflections at different storey levels and storey drifts are compared by performing response spectrum method as well as pushover method of analysis

It is essential to consider the effect of masonry infill for the seismic evaluation of movement resisting RC frames especially for the prediction of its ultimate state. Infills increase the lateral resistance and initial stiffness of the frames they appear to have a significant effect on the reduction of the global lateral displacement.

Infills having no irregularity in elevation having beneficial effects on buildings. In infilled frames with irregularities, such as ground soft storey, damage was found to concentrate in the level where the discontinuity occurs.

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