International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
ISSN: 2457-0362
www.ijarst.in

SEISMIC EVALUALTION OF MULTISTORIED BUILDINGS WITH GROUND SOFT STORY AND WITH INFILLS

V.N.V.DHANALAKSHMI, Email id: vepuridhana@gmail.com
G. MADHAVI, Email id: madhavisuji108@gmail.com

A.M. REDDY MEMORIAL COLLEGE OF ENGINEERING AND TECHNOLOGY
NARASARAOPET

Abstract: Recent building codes for seismic design and evaluation in Europe and American feature performance based criteria that entail the estimation of inelastic response of the building due to seismic. These seismic demands can be accurately determined by employing methods of nonlinear time history analysis. Simplified methods based on nonlinear static analysis, known as pushover analysis method and nonlinear dynamic analysis, known as time history analysis method, have been developed by several regulations to satisfy the performance-based criteria for seismic design and evaluation of buildings. This thesis deals with 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 outweighs the warning against such buildings from engineering community. In this study, 3D analytical model of multistory buildings has 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 performed. 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 performed 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 structures.

Keywords *-nonlinear static analysis (pushover analysis), soft story, ground soft, infill, mass, strength, stiffness, inelastic behavior, drift ratio, ductility coefficients.*

1. INTRODUCTION

The capacity of structural members to undergo inelastic deformations governs the structural behavior 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

IJARST
International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362

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. In recent seismic guidelines and codes in Europe and USA, the inelastic responses of the building are determined using nonlinear static methods of analysis known as the pushover methods.

2. ANALYTICAL MODELLING

Seismic codes give different methods to carry out lateral load analysis, while carrying out this analysis infill walls present in the structure are normally considered as nonstructural elements and their presence is usually ignored while analysis and design. However even though they are considered as non-structural elements, they tend to interact with the frame when the structures are subjected to lateral loads.

In the present study lateral load analysis as per the seismic code for the following type of structures, bare frame, full infill, base soft storey, central core wall, shear wall in x & y direction and along with central core wall, shear wall in corners & along with central core wall is carried out and an effort is made to study the effect of seismic loads on them and thus assess their seismic vulnerability by performing pushover analysis. The analysis is carried out using ETABS analysis package.

A. DESCRIPTION OF THE SAMPLE BUILDING

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

SYMMETRIC BUILDING MODELS:

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

Model 2: Twelve storied 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 storeys

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.

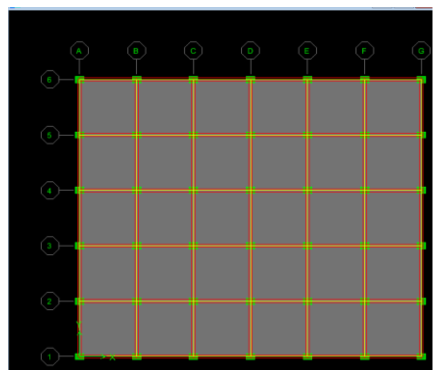


Figure.1: Plan Layout

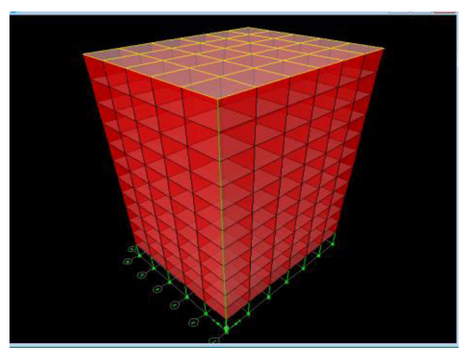


Figure.2: Elevation of twelve storied Building Model 1 (full infill)

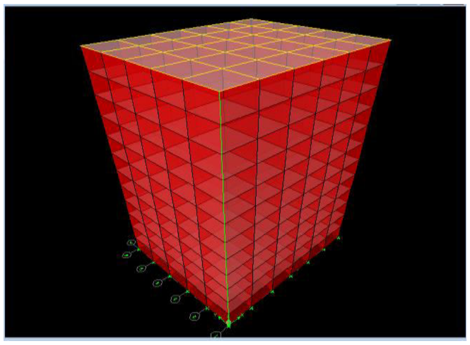


Figure.3: Elevation of twelve storied Building Model 2 (ground soft)

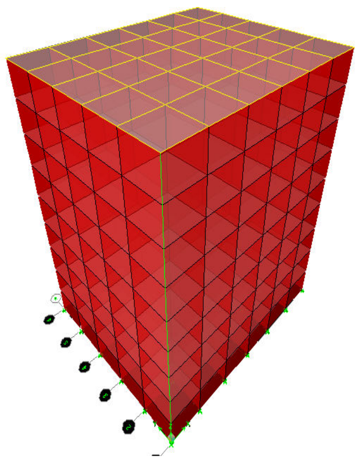


Figure.4: Elevation of nine storied Building Model 3 (full infill)

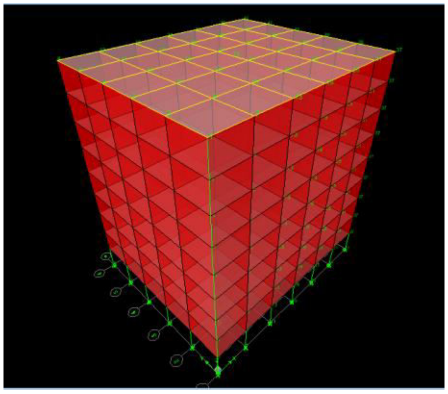


Figure.5: Elevation of nine storeyed Building Model 4 (ground soft)

a. Example Buildings Studied

The plan layout, elevation and 3D view of the reinforced concrete moment resisting frame building of twelve storied building for different models is shown in Figures 5.1,. In this study, the plan layout is deliberately kept similar for all the buildings for the study. The each storey height is kept 3.5 m for all the different buildings models. The building is considered to be located in the seismic zone-V and intended for office use. In the seismic weight calculations only 50% of the floor live load is considered. The input data given for all the different buildings is detailed below.

b. Design Data:

Material Properties:

Young's modulus of (M25) concrete, E= 25.000×10^6 kN/m²

Young's modulus of (M20) concrete, E= 22.360×10^6 kN/m²

Density of Reinforced Concrete= 25kN/m³

Modulus of elasticity of brick masonry= 3500×10^3 kN/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 storied= (0.6mx0.6m)

Column size for nine storied= (0.45mx0.6m)

Beam size of twelve storied= (0.375m x 0.6m)

Beam size of nine storied= (0.375m x 0.6m)

Thickness of wall= 0.230m

Thickness of shear wall

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)

Floor (clause 7.3.1)

IS: 1893-2002 Equivalent Static method

Design Spectrum

Zone –V

Zone factor, Z – 0.36

Importance factor, I – 1.5

Response reduction factor, R – 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.

B. Manual Calculation

Natural periods and average response acceleration coefficients:

For twelve-storied 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-storied brick infills buildings:

=0.30m

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

=0

=0.5x4=2 kN/m2

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.

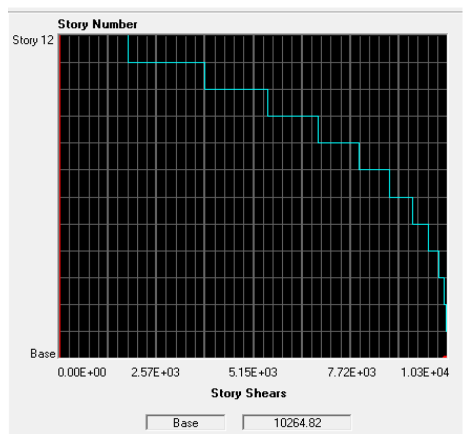


Figure.6: Shear diagram for twelve storeyed Model 1 along longitudinal and transverse direction

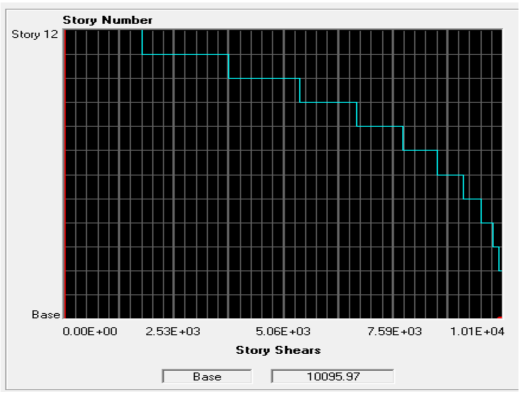


Figure.7:Shear diagram for twelve storied Model 2 along longitudinal and transverse direction

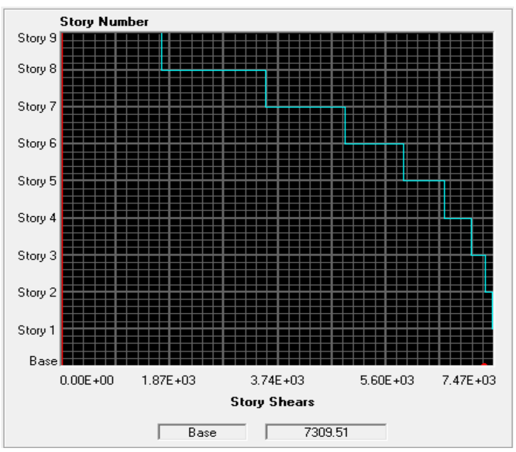


Figure.8:Shear diagram for nine storied Model 3 along longitudinal and transverse direction

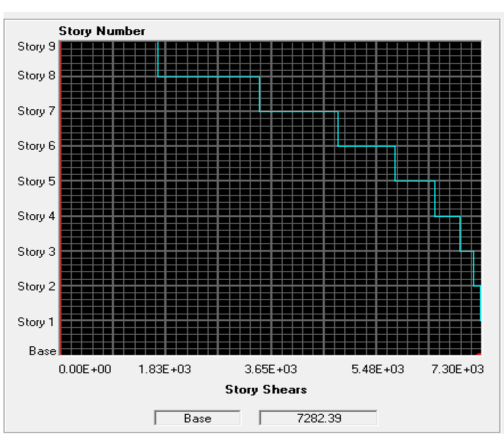


Figure.9: Shear diagram for nine storied Model 4 along longitudinal and transverse direction

4. RESULTS & DISCUSSIONS

Most of the past studies on different buildings and unsymmetrical buildings have adopted idealized structural systems without considering the effect of masonry infill and concrete shear walls. Although these systems are sufficient to understand the general behaviour and dynamic characteristics of unsymmetrical buildings, it would be interesting to know how real buildings will respond to earthquake forces. For this reason, hypothetical buildings, located on level ground having similar ground floor plan have been taken as structural systems for the study.

In this chapter, the results of the twelve selected buildings are presented and discussed in detail. The results are including of all different building models and the response results are computed using the response spectrum and pushover analysis. The analysis and design of the different building models is performed by using ETABS analysis package.

The results of natural period of vibration, base shear, lateral displacements and storey drifts, ductility, reduction factor & overall performance for the different building models for each of the above analysis are presented and compared. An effort has been made to study the effect of in fills, concrete core wall and vertical irregularities and mass irregularities in seismic analysis.

A. LATERAL DISPLACEMENTS

For better comparability the displacement for each model along the two directions of ground motion are plotted in graphs as shown in figure 11 to 20.

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. From the graphs, it is observed that displacement profile of model-2 and model-4 changes abruptly, it indicated the stiffness of infill masonry is not present. It is observed that displacement profile has changed, the stiffness irregularity is due to open ground storey and presence of masonry infill wall in the upper storeys. On the other hand nearly, all models show a smooth displacement linear profile, which is due to the presence of full infill brick wall.

Equivalent Static Method:

As compared to Model 1, Model 2 have 3.68% of less displacement than Model 1, in longitudinal direction and 3.49% less in transverse direction.

As compared to Model 3, Mode 4 have 48.8% of less displacement than Model 3 in longitudinal direction and 52.92% less in transverse direction.

Response Spectrum Method:

As compared to Model 1, Model 2 have 7.33% of less displacement than Model 1, in longitudinal direction and 5.42% less in transverse direction.

As compared to Model 3, Mode 4 have82.52% of less displacement than Model 3 in longitudinal direction and 93.35% less in transverse direction. Push Over Analysis:

In Pushover Analysis different building Models have pushed to its failure and correspondingly displacement is noted.

From the graphs 10 to 11 and 16 to 17. As compared to Model 1, Model 2 have 62.033% of more displacement than Model 1, in longitudinal direction and 15.59% more in transverse direction.

As compared to Model 3, Model 4 have 2.76 times more displacement than Model 3, in longitudinal direction and 2.41 times more in transverse direction.

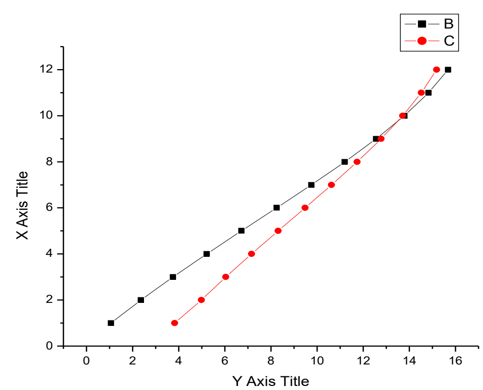


Figure.10: displacement of linear static analysis of 12^{th} storey buildings in x – direction.

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362

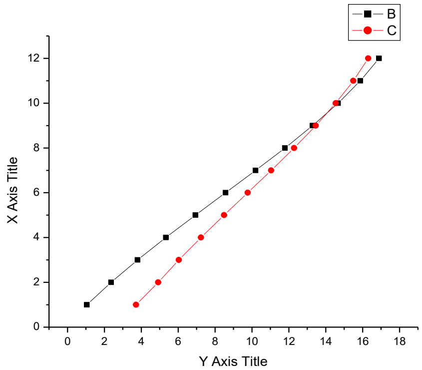


Figure.11: displacement of linear static analysis of 12th storey buildings in y – direction.

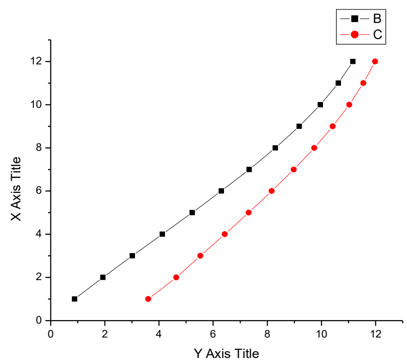


Figure.12: displacement of linear dynamic analysis of 12th storey buildings in x – direction.

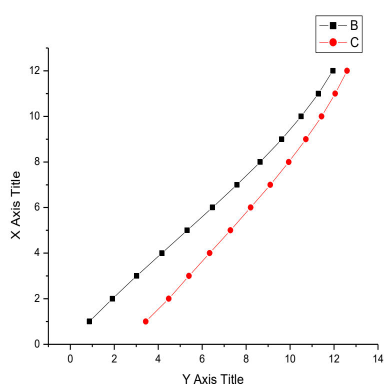


Figure.13: displacement of linear dynamic analysis of 12th storey buildings in y – direction.

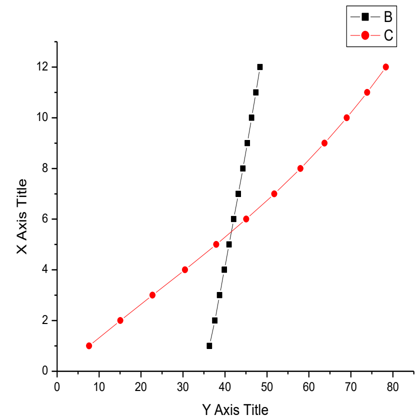


Figure.14: displacement of linear non static analysis of 12th storey buildings in x – direction.

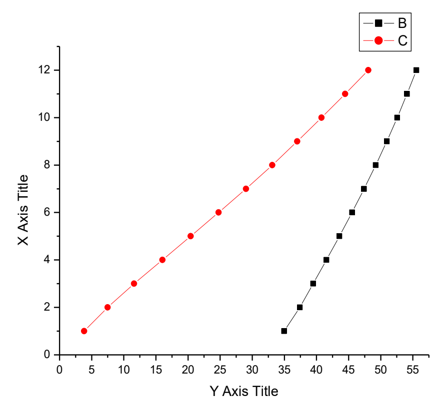


Figure.15: displacement of linear non static analysis of 12th storey buildings in y – direction.

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362
IJARST

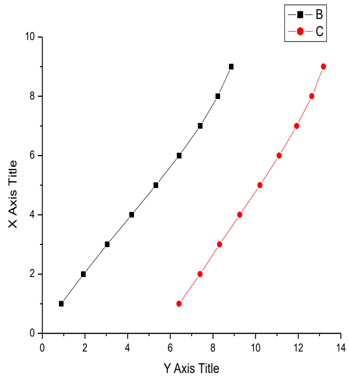


Figure.16: displacement of linear static analysis of 9th storey buildings in x – direction.

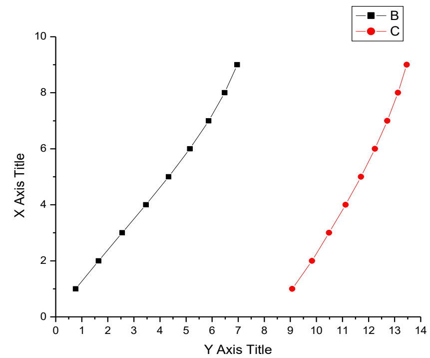


Figure.19: displacement of linear dynamic analysis of 9th storey buildings in y – direction.

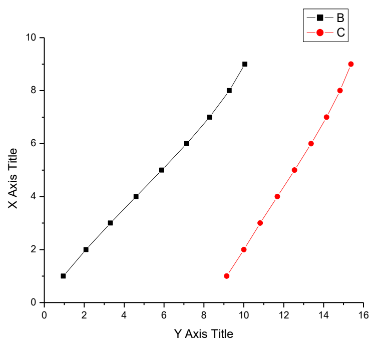


Figure.17 displacement of linear static analysis of 9th storey buildings in y – direction.

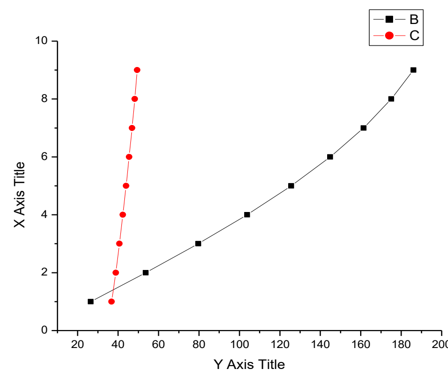


Figure.20: displacement of linear non static analysis of 9th storey buildings in x – direction.

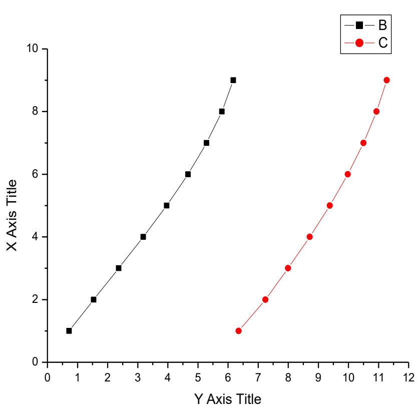


Figure.18: displacement of linear dynamic analysis of 9th storey buildings in x – direction.

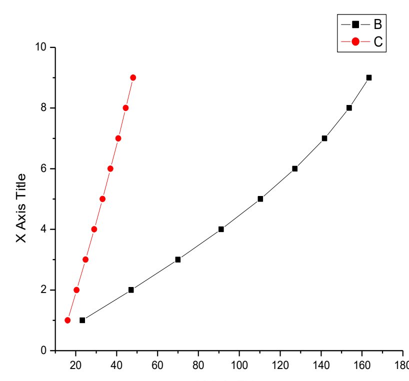


Figure.21: displacement of linear non static analysis of 9thstorey buildings in y – direction.

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
ISSN: 2457-0362
www.ijarst.in

B. 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.

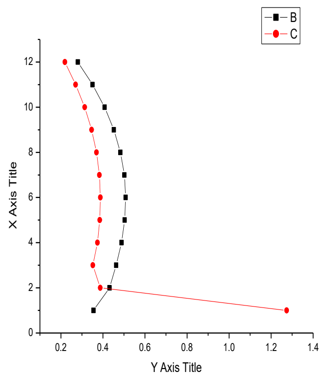


Figure.22 drift of linear static analysis of 12th storey buildings in x – direction.

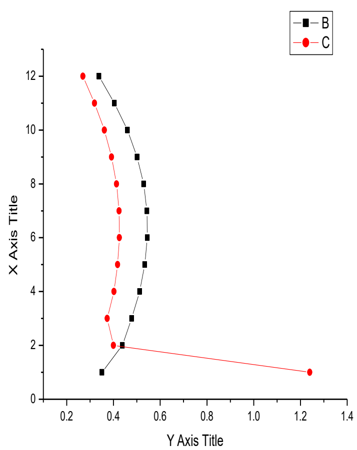


Figure.23: drift of linear static analysis of 12th storey buildings in y – direction.

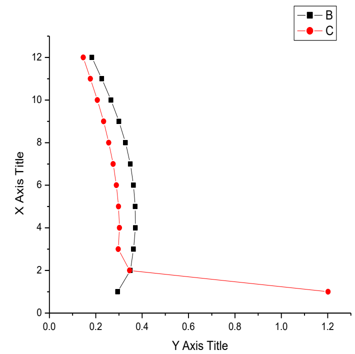


Figure.24: drift of linear dynamic analysis of 12th storey buildings in x – direction.

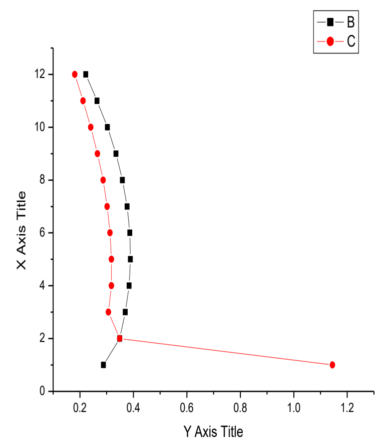


Figure.25: drift of linear dynamic analysis of 12th storey buildings in y – direction.

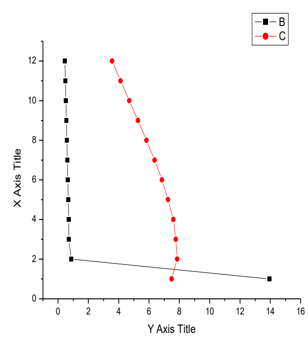


Figure.26 drift of linear non static analysis of 12th storey buildings in x – direction.

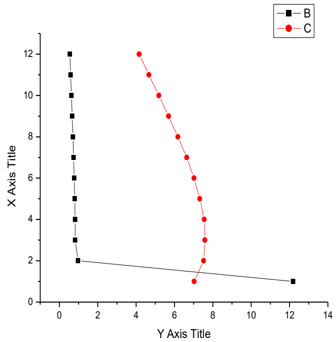


Figure.27: drift of linear non static analysis of 12th storey buildings in y – direction.

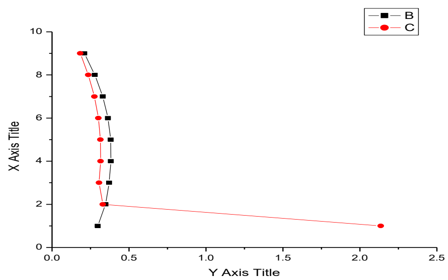


Figure.28: drift of linear static analysis of 9th storey buildings in x – direction.

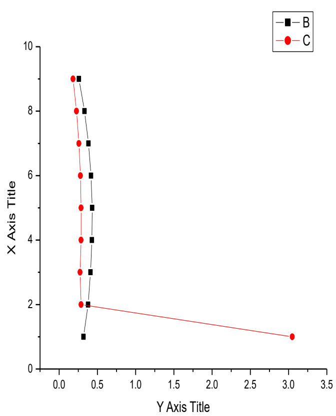


Figure.29: drift of linear static analysis of 9th storey buildings in y – direction.

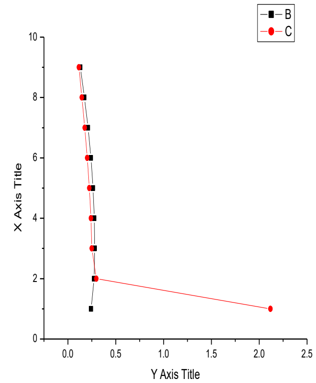


Figure.30: drift of linear dynamic analysis of 9th storey buildings in x – direction.

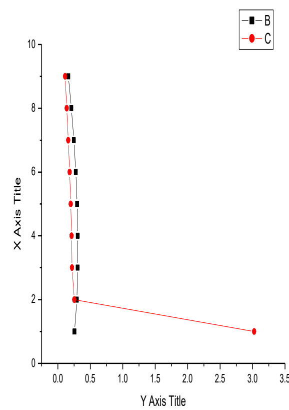


Figure.31: drift of linear dynamic analysis of 9th storey buildings in y – direction.

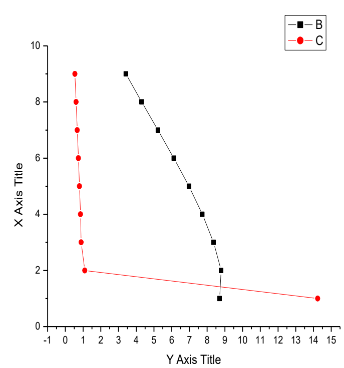


Figure.32: drift of linear non static analysis of 9th storey buildings in x – direction.

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
ISSN: 2457-0362
www.ijarst.in

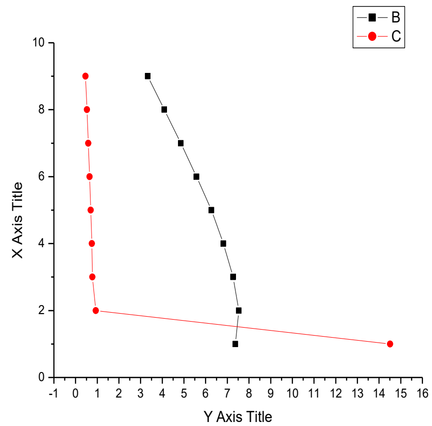


Figure.33: drift of linear non static analysis of 9th storey buildings in y – direction.

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 21to 26. 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.

C. DUCTILITY RATIO (μ) AND RESPONSE REDUCTION FACTOR (R):

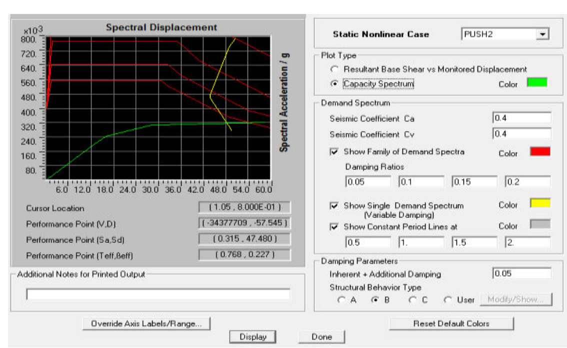
DUCTILITY:

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.

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.

D. PERFORMANCE POINT

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



International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362

Figure.34:Performance point of twelve storied building Model 1 along longitudinal direction

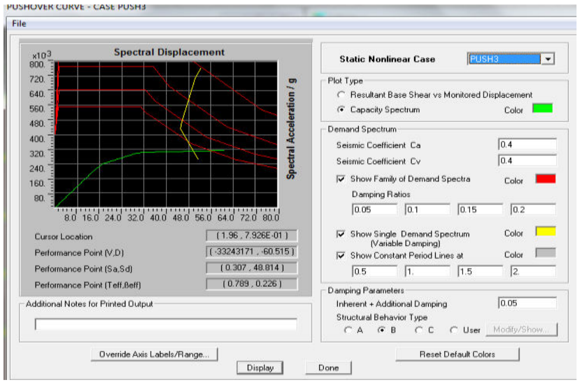


Figure.35: Performance point of twelve storied building Model 1 along transverse direction

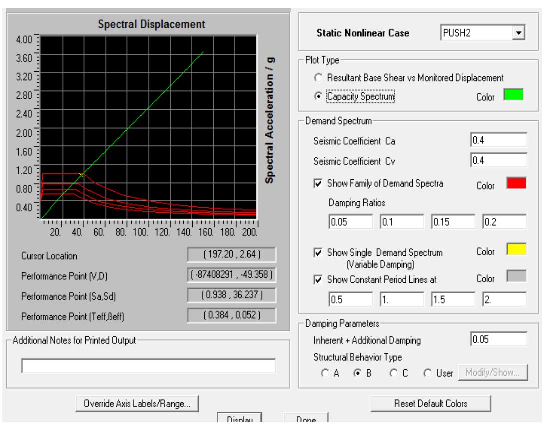


Figure.36: Performance point of twelve storied building Model 2 along longitudinal direction

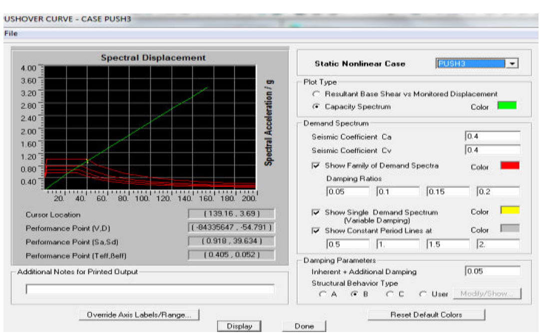


Figure .37: Performance point of twelve storied building Model 2 along transverse direction

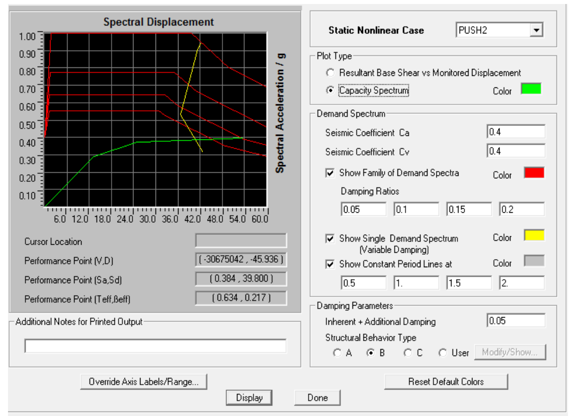


Figure.38: Performance point of nine storied building Model 3 along longitudinal direction

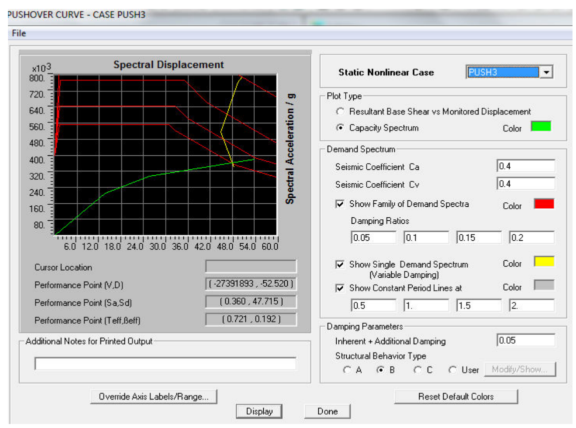


Figure .39: Performance point of nine storied building Model 3 along transverse direction

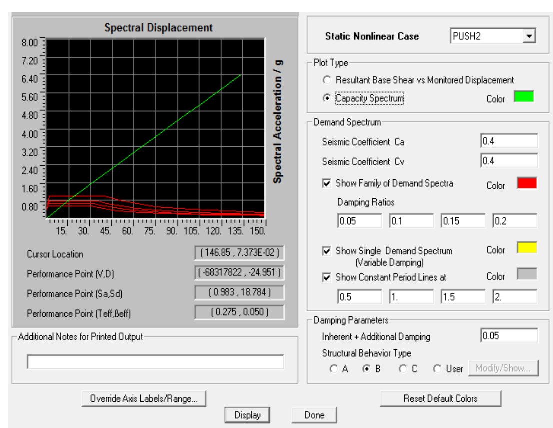


Figure.40: Performance point of nine storied building Model 4 along longitudinal direction

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
ISSN: 2457-0362
www.ijarst.in

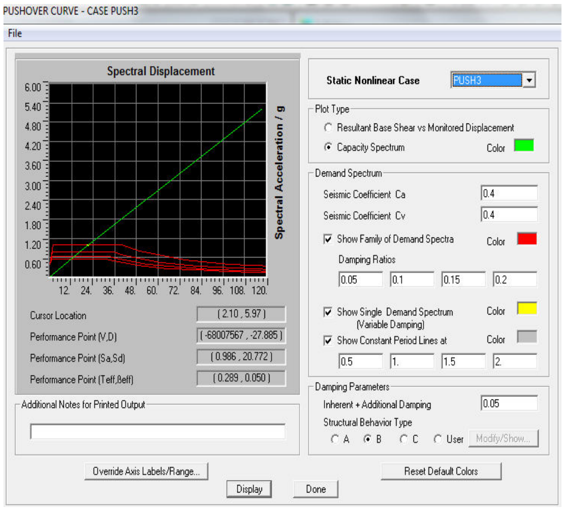


Figure.41: Performance point of nine storied building Model 4 along transverse direction

From above figures it can be seen that demand curve is increasing the capacity curve which shows the performance of the all models are good

5. CONCLUSION

Based on the results from the linear and nonlinear static pushover analysis performed on the three storey building following observations are made.

There are god reasons for advocating the use of the inelastic pushover analysis for demand prediction, since in many cases it will provide much more relevant information that an elastic static or dynamic analysis, but it would be counterproductive to advocate this method as a general solution technique for all cases.

The pushover analysis is a useful, but not infallible till for assessing inelastic strength and deformation demands and for exposing design weaknesses.

Its foremost advantage is that it encourages the design engineer to recognize important seismic response quantities and to use sound judgment concerning the force and deformation demands ands and capacities that control the seismic response close to failure, but it needs to be recognized that in some cases it may provide a false feelings of security if its short comings and pitfalls are not recognized.

AS the push was incrementally applied on a control node plastic hinges corresponding to various levels (I.O,L.S and C.P) the vulnerability of different beam and column members can be recognized.

Depending on the degree of importance of a particular structure the retrofitting of they may be taken up.

Since neither national building code nor any of earthquake related codes in India illustrate the categorization of the building for structural retrofitting, no generalized retrofitting procedure may be defined.

The introduction of bracings in the ground storey was done based on the proposed car parking plan and incorporated them rationally without affecting the functionality of the open ground storey.

The bracings proved to eliminate the soft storey failure mechanism and also brought down the global response of the structure and are recommended for preventing much damage or collapse of the building in an earthquake of higher magnitude.

It may be concluded from the pushover analysis that there is an increase in initial stiffness and strength of the infilled frame, compared to the bare frame, despite the wall's brittle failure modes. However, it fails at a relatively lower drift level that the bare frame (at around one third of the roof displacement).

For the considered earthquake the existing building can survive collapse but may suffer little damage in the ground storey columns which show soft storey mechanism of failure.

No retrofitting is required if design level earthquake for Zone II is considered, as the structures performance is in immediate occupancy level i.e., no structural damage is expected. Only nominal repair works may be carried out.

6. FUTURE SCOPE

Further studies can be conducted on high rise buildings (sky-scrapers) by providing more thickness of shear walls. Studies can be conducted by providing shear wall at various other locations and also by providing dual system, which consists of shear wall (or braced frame) and moment resisting frame such that the two systems are designed to resist the total design force in proportion to their lateral stiffness considering the interaction of dual system at all floor levels. The moment resisting frames may be designed to independently resist at least 25% of design seismic base shear. For better ductility beam-column junction study can also be made. And further study an existing building can be considered for evaluation. Where, a preliminary investigation using FEMA-273 can be done before evaluation of the existing building using mathematical modelling with the help of FEA package and further it can be evaluated using Non-Linear Dynamic Analysis and other software's like sap & this investigation can also be done on Sloping RCC buildings constructed on hills in hill stations where land is at high cost and it will also attract the tourists. Various damping mechanisms and its applications on structures can also be studied. Studies can also be conducted by modelling the structures having base isolation system.

7. REFERENCES

a. Arlekar, N.J., Jain K.S., and Murthy, C.V.R. *"Seismic Response of RC Frame Buildings with Soft First Storeys"*, Proceedings of the CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, New Delhi, 1997.

b. Krawinkler, H., and Seneviratna, G.D.P.K. (1998): *Pros & Cons of Pushover Analysis of Seismic Performance Evaluation*.

c. Ashraf Habibullah, Stephen Pyle, *"Practical three-dimensional non-linear static pushover analysis*" Structure Magazsanine, Winter, 1998.

d. MOHAMED NOUR EL-DINABD-ALLA "Application of recent techniques of pushover for evaluating seismic performance of multistory buildings", Faculty of Engineering, Cairo University Giza, Egypt September 2007.

e. KasımArmagan KORKMAZ, Fuat DEM_R and Mustafa S_VR_ "Earthquake assessment of R/C structures with masonry infill walls" SuleymanDemirel University, Civil Engineering Department, Cunur, Isparta, TURKIYE armagan@mmf.sdu.edu.tr. (Received: 06.08.2007; Accepted: 03.10.2007

f. IS: 1893 (Part-I) 2002 (2002): Criteria for Earthquake Resistant Design of Structures, Part-I General Provisions and Buildings, Fifth Revision, Bureau of Indian Standards, New Delhi

g. Kanitkar, R., and Kanitkar, V., *"Seismic Performance of Conventional Multi-storey Buildings with Open Ground Storey for Vehicular Parking*", Indian Concrete Journal, February 2004.