International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 4 Issue 6, September-October 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Performance Based Analysis of RC Framed Structure with and without Dampers for Different Seismic Zones

Ritu T Raj[1], Dr. S Vijaya[2], Dr. B Shivakumara Swamy[3], Mary Bhagya Jyothi. J[4]

[1]M Tech Student, [2]Head of the Department, [3]Associate Professor, [4]Assistant Professor,

[1, 2, 3, 4]Department of Civil Engineering, Dr. Ambedkar Institute of Technology, Bengaluru, Karnataka, India

ABSTRACT

The primary requirement of humans on planet earth is food, clothing and shelter. Prehistoric men and women used to live on trees but steadily they started developing the shelters for protection against natural calamities like rains, cold etc. and also from attack against wild animals. Soon humans grew in knowledge and they started living together, forming communities to ensure additional security and man became a social animal. Now these communities developed and started exploding forming villages which later on transformed into cities and became the commercial centres of a region. Soon within these commercial centres, land for horizontal expansion became extinct. The social animal started expanding vertically constructing multi-storied structures.
The present study focuses on 12 levelled multi-storey structure. The structures are considered to be located at various seismic zones. The Performance of the structure is found out by static nonlinear structure. Further, these structures are provided with seismic dampers. The Modelling and analysis are carried out using ETABS software. The performance of these structures is studied and compared using various parameters such as displacement, storey drift, base shear and time period. Along with these results performance of building is predicted based on demand capacity graphs. The results are extracted and conclusions are drawn.

From the pushover analysis, the performance point is found out for all the models. And also, it found that, weakest junctions of the models. The Pushover analysis shows the models with dampers are having base shear than the models without damper. The increase in percentage of base shear is around 45%. The introduction of damper causes the improvement in lateral load carrying capacity by 45%. The base shear values are lesser for Zone II and highest for Zone V. There is a linear increase in base shear values for increase in severity of zones. From the pushover analysis base shear, it is noticed that all the models are having lesser base shear values in case of equivalent static analysis than pushover analysis except Model type A4. This shows that, the model Type A4 is UNSAFE. The models can be made SAFE by introducing Dampers as in Models Type B4.

KEYWORDS: *Seismic Damper, Pushover analysis, Equivalent Static Analysis, Base Shear, Drift, Performance point*

How to cite this paper: Ritu T Raj | Dr. S Vijaya | Dr. B Shivakumara Swamy | Mary Bhagya Jyothi. J "Performance Based Analysis of RC Framed Structure with and without Dampers for Different Seismic Zones" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-6, October 2020, pp.1461-1468, URL: www.ijtsrd.com/papers/ijtsrd35702.pdf

IJTSRD35702

1. INTRODUCTION

Earthquakes are considered to be one of the most unpredictable and devastating natural hazards. Earthquakes pose multiple hazards to a community, potentially inflicting large economic, property, and population loss. One of the measures used in order to combat or reduce the devastating effects of earthquakes is through the seismic risk assessment of existing buildings.

Several procedures have been developed in order to allow communities to prevent and mitigate losses in the event of an earthquake. One such technique is assessing existing buildings to determine which buildings are safer if an earthquake is to occur. However, the amount of structures is too large and would take a significant amount of time and resources to be assessed in detail. A preliminary assessment is then introduced in order to determine which buildings should be prioritized for a detailed assessment. One such tool is the American tool FEMA by the Applied Technology Council and Federal Emergency Management Agency (ATC 2002) [1]. It should be emphasized that preliminary assessment procedures are merely tools for prioritization and cannot actually determine if a building is definitely safe from earthquakes.

A. Pushover Analysis

Pushover analysis is one of the methods available for evaluating buildings against earthquake loads. As the name suggests, a structure is induced incrementally with a lateral loading pattern until a target displacement is reached or until the structure reaches a limit state. The structure is subjected to the load until some structural members yield. The model is then modified to account for the reduced stiffness of the building and is once again applied with a lateral load until additional members yield. A base shear vs. displacement capacity curve and a plastic hinging model is produced as the end product of the analysis which gives a general idea of the behaviour of the building.

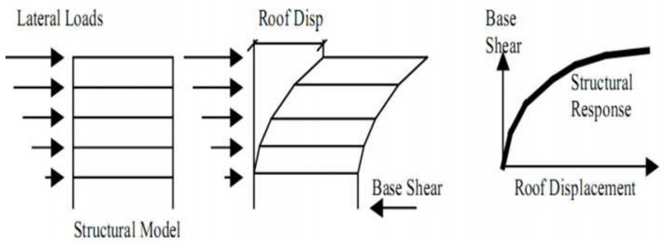


Fig 1: Static approximation used in pushover analysis

The figure shows a simple conversion of base shear versus roof displacement relationship using the dynamic properties of the system, and the result is termed as capacity spectrum for the structure. First figure shows a structural model which experiences lateral loads and second shows how roof displacement takes places. Base shear will be acting against the lateral loads to decrease the roof displacement. Last shows the graph of base shear versus roof displacement and the structural response of the model.

B. Damping system

Damper systems are designed and manufactured to protect structural integrities, control structural damages, and to prevent injuries to the residents by absorbing seismic energy and reducing deformations in the structure.

Seismic dampers permit the structure to resist severe input energy and reduce harmful deflections, forces and accelerations to structures and occupants. There are several types of seismic dampers namely viscous damper, friction damper, yielding damper, magnetic damper, and tuned mass damper.

Damper used in this study is of viscous damper of damping coefficient 0.5.

The values of damping coefficient varies from the 0.2 to 2.0 depending on the specific application. In some cases it varies with a range of 0.3 to 1.0.

C. Objectives

The following objectives are considered in the present studies

- To analyse the RC framed building subjected to static analysis.
- To understand the seismic behaviour of structure subjected to static nonlinear analysis.
- To understand the performance point and hinges formations in the structure.
- To understand the behaviour of structure with damper.
- To study the performance of structure for different seismic zones.

2. METHODOLOGY

- Literature review is carried out for related journals.
- The modelling is carried out using ETABS software.
- Modelling is carried out for various seismic zone with and without damper.
- Analysis is carried out for static linear and static nonlinear analysis.
- Results such as displacement, time period, drift, base shear, performance points are extracted and tabulated.
- Conclusions are drawn based on the results

A. Methods of analysis

There are many methods available for the seismic analysis of a selected building to find out the forces developed in structure due to seismic activity. Mainly analysis is done on the basis of model of structure selected, materials used in the structure and also on the external inputs.

I. **Equivalent static analysis** is also called as equivalent lateral force method. Seismic analysis on a building is done on a assumption of the horizontal force is similar to the dynamic loading, In this method periods and shape of higher mode of vibration are not required so the effort for the analysis is less, except for the fundamental period. The base shear is calculated depends on the mass of structure, its fundamental periods of vibration and shapes. Firstly the base shear is calculated for a entire structure then along the height of building distribution is done. At each floor level the lateral force obtained are distributed to each structural elements. This method is usually adopted for a low to medium height building.

II. **Pushover Analysis** After assigning all properties of the model, the displacement-controlled pushover analysis of the building model is carried out. The models are pushed in monotonic increasing order in a particular direction till the collapse of the structure. For this purpose, value of maximum displacement at roof level and number of steps in which this displacement must be applied, are defined. The global response of structure at each displacement level is obtained in terms of the base shear, which is presented by pushover curve. Pushover curve is a base shear force versus roof displacement curve, which tells about the shear force developed at the base of the structure at any push level. The peak of this curve represents the maximum base shear, i.e. maximum load carrying capacity of the structure; the initial stiffness of the structure is obtained from the tangent at pushover curve at the load level of 10% that of the ultimate load and the maximum roof displacement of structures is taken that deflection beyond which collapse of structure takes place.

The static linear analysis is carried out and later nonlinear pushover analysis is done. The results are extracted and tabulated. Seismic evaluation of all the models is carried out by nonlinear static pushover analysis, for all the gravity designed and seismic designed building models along both longitudinal and transverse direction.

B. Capacity Curve

The overall capacity of a structure depends on the strength and deformation capacities of the individual components of the structure. In order to determine capacities beyond the elastic limits, some form of nonlinear analysis is required. This procedure uses sequential elastic analysis, superimposed to approximate force-displacement diagram of the overall structure. The mathematical model of the structure is modified to account for reduced resistance of yielding components. A lateral force distribution is again applied until additional components yield.

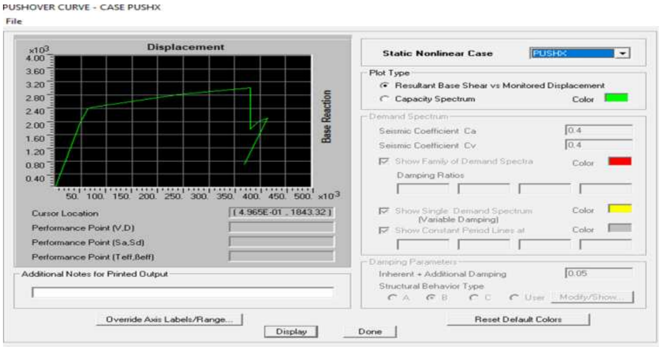


Fig 2: Typ. Capacity curve

C. Demand Curve

Ground motion during an earthquake produces complex horizontal displacement patterns which may vary with time. Tracking this motion at every time step to determine structural design requirements is judge impractical. For a given structure and a ground motion, the displacement demands are estimate of the maximum expected response of the building during the ground motion. Demand curve is a representation of the earthquake ground motion. It is given by spectral acceleration (Sa) Vs. Time period (T) as shown.

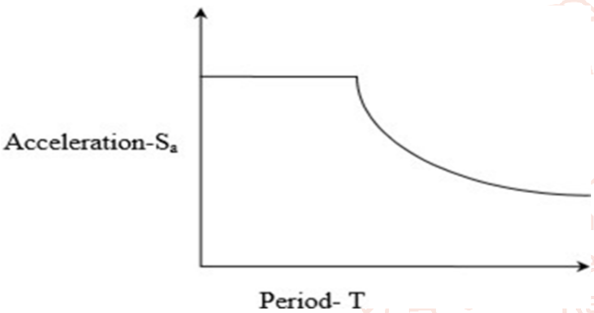


Fig 3: Typ. Demand curve

D. Performance Point

Performance point can be obtained by superimposing capacity spectrum and demand spectrum and the intersection point of these two curves is performance point. Check performance level of the structure and plastic hinge formation at performance point. A performance check verifies that structural and non-structural components are not damaged beyond the acceptable limits of the performance objective for the force and displacement implied by the displacement demand.

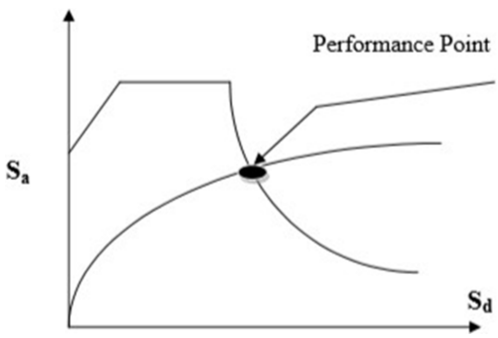


Fig 4: Performance Point

3. MODELLING AND ANALYSIS

In the modeling G+12 storey building is considered for the analysis and modeling is done in ETABs software.

Model A1: Multi Storey RC Structure in Seismic Zone 2.
Model A2: Multi Storey RC Structure in Seismic Zone 3.
Model A3: Multi Storey RC Structure in Seismic Zone 4.
Model A4: Multi Storey RC Structure in Seismic Zone 5.
Model B1: Multi Storey RC Structure with damper in Seismic Zone 2.
Model B2: Multi Storey RC Structure with damper in Seismic Zone 3.
Model B3: Multi Storey RC Structure with damper in Seismic Zone 4.
Model B4: Multi Storey RC Structure with damper in Seismic Zone 5.

Table 1 - Material Properties and Design Parameters

Sl. No.	Description	Data
1.	Seismic Zone	II, III, IV, V
2.	Seismic Zone Factor (Z)	0.1, 0.16, 0.24, 0.36
3.	Importance Factor (I)	1.5
4.	Response Reduction Factor (R)	3
5.	Damping Ratio	0.05
6.	Soil Type	Hard Soil (Type I)
7.	Height of the building	36m (12 Storey)
8.	Story to story Height	3.0 m
9.	Span Length	4m
10.	Column Size used	C400x400
11.	Thickness of Slab	125mm
12.	Floor Finish	1.5KN/m^2
13.	Live Load	4.0KN/m^2
14.	Grade of Concrete (f_{ck})	M40
15.	Grade of Reinforcing Steel (f_{yr})	Fe 500

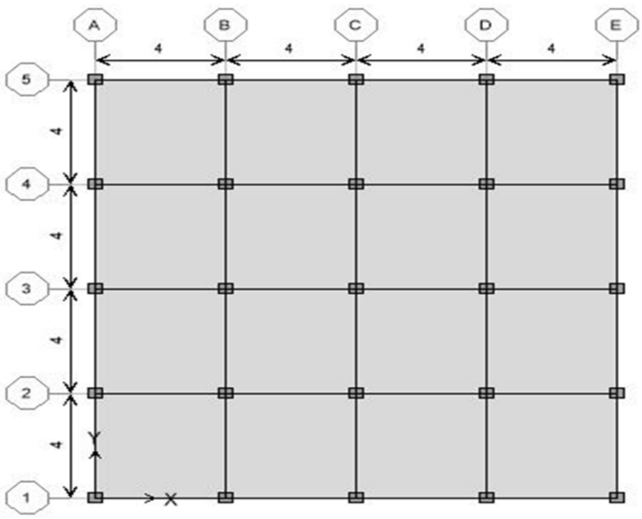


Fig 5: Normal building plan

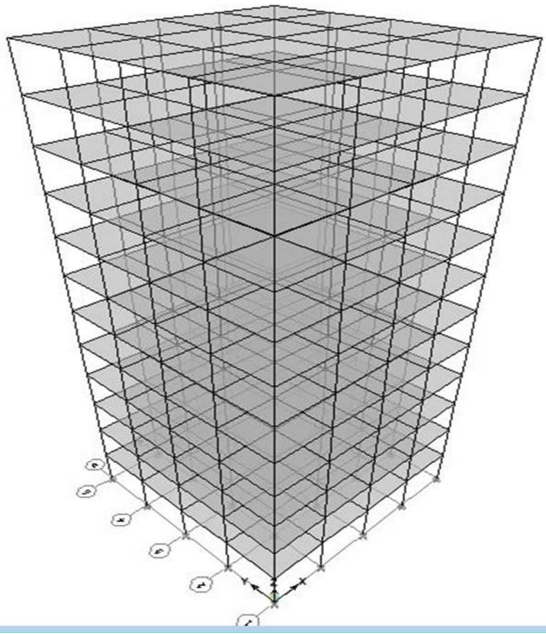


Fig 6: Isometric view

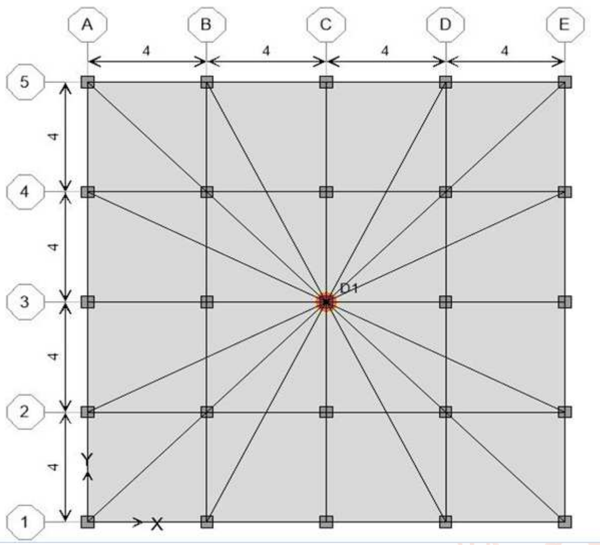


Fig 7: Diaphragm view

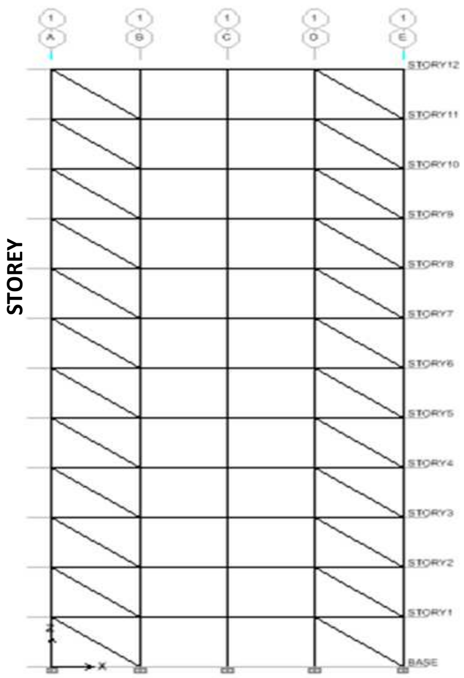


Fig 8: Elevation view with dampers

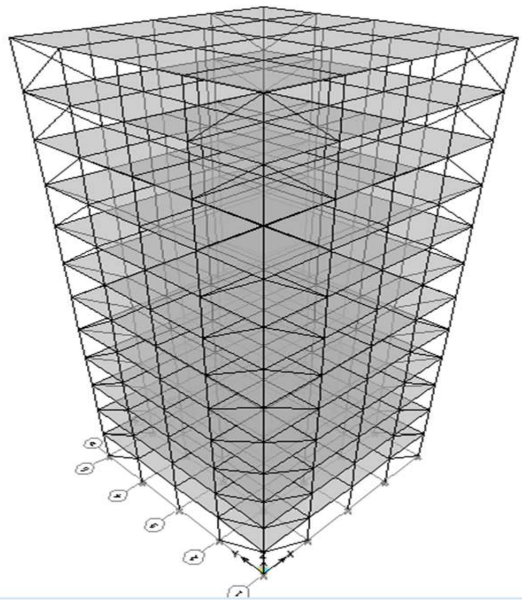


Fig 9: Viscous dampers at exterior corner Isometric view

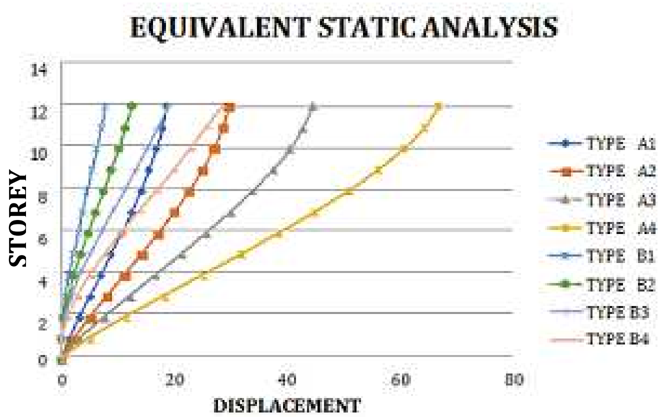
4. RESULTS AND DISCUSSION

Modelling of building is done with the all the defined loads as per the codal provisions. Then the analysis of the structure is done with both Equivalent static method and Pushover analysis method. After the analysis various storey responses are compared and comment should be made on those results. Storey responses includes storey displacement storey drifts, base shear, time period, frequencies are considered and compared. Then pushover curve is also obtained in result and the performance check is done for all the models.

I. From Equivalent Static Analysis

A. Storey displacement

Storey displacement is an main storey response that get reduced after adding dampers to the structures. For a G+12 storey building with and without viscous dampers the displacement value obtained for both equivalent static method for different seismic zones are shown below



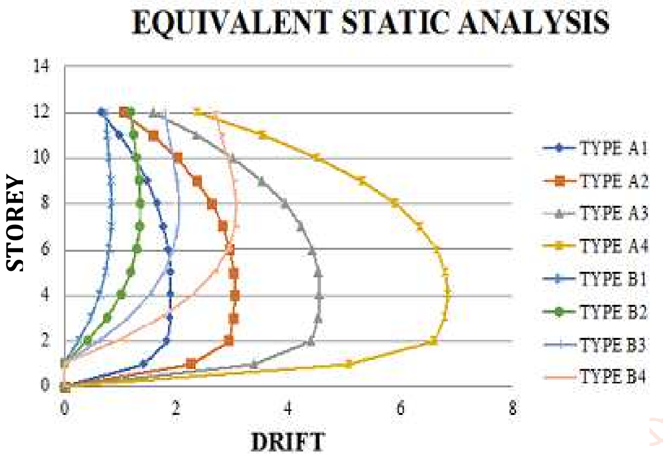
Graph 1: Storey displacement in x direction for Static method

From the graph, it is obvious that model present in zone V i.e., model type A4 is exhibiting highest displacement and model type A1 is having lesser displacement compared to other models without dampers. However, the displacements are reducing by introducing damper in the model. There is a considerable reduction of around 58%.

This is a significant reduction and the models with dampers can be adopted in seismic zone V

B. Storey drifts

The inter storey drifts values for the considered building in all seismic zones is shown in the graph below. As per IS 1893:2016 for a storey with minimum assigned lateral force, having partial load factor 1.0 the storey drift value does not exceed 0.004 times the height of a storey.

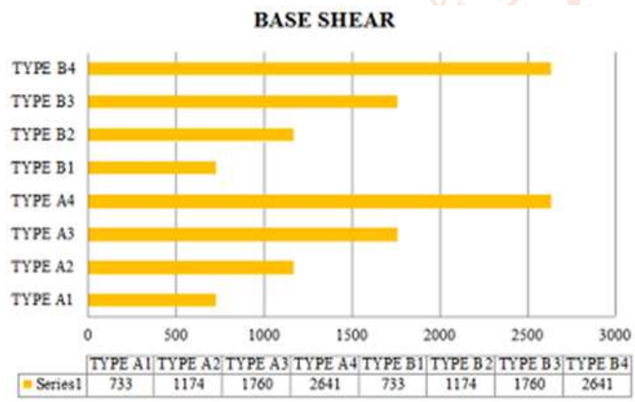


Graph 2: Storey drift in x direction for Static method

From the above observation the drift values are very nominal and are in line with displacement results. However, model A4 is exhibiting highest drift values comparatively but within the limit.

C. Base shear

Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity. It is calculated using the seismic zone, soil material, and building code lateral force equations

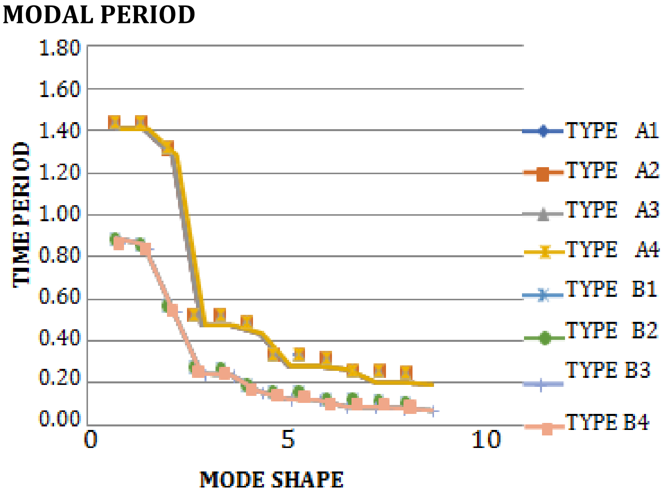


Graph 3: Base shear in x direction for Static method

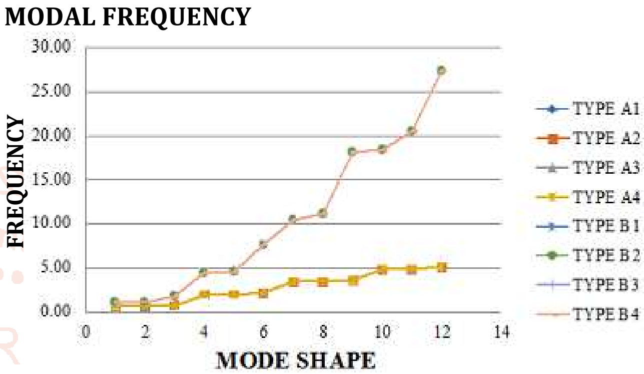
From the above observation we have seen that the base shear values are independent of dampers. Hence the values are same in case of models in same zone. However, the model A4 and B4 is having maximum base shear. The base shear increases with severity of zone.

D. Modal periods and frequencies

During earthquake or wind, all modes are excited in different manner. Depends on the spatial distribution and frequency content of the load the length of dynamic loading excites the modes of vibration. In this study 12 modes are considere and their time period and frequencies.



Graph 4: Modal periods

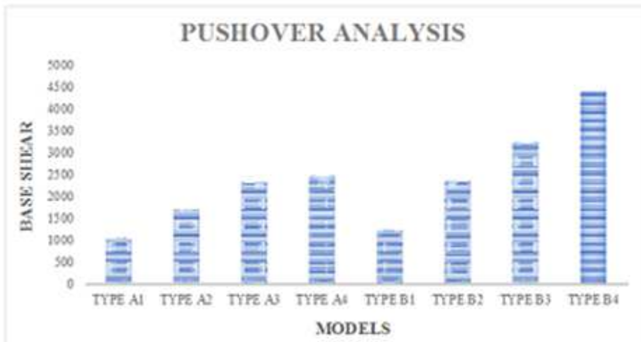


Graph 5: Modal frequency

The time period for a without damping building is more as compared to the damping building. The time period is inversely proportional to the frequency of the structure. so the natural frequency of the damped building is more compared to the building without damper. As the frequency of the structure increases the stiffeness of structure is also increses because stiffeness is directly proportional to the frequency. for a higher elevation building the frequency is more because of more mass.

II. From Pushover Analysis

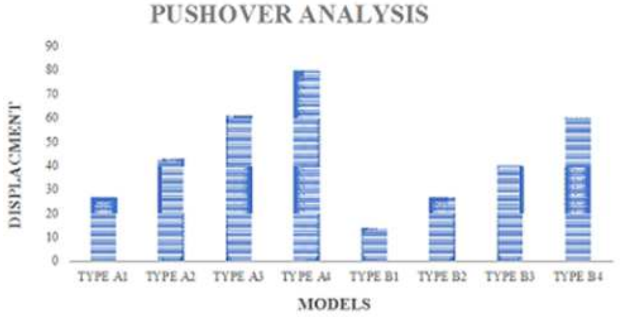
E. Base Shear



Graph 6: Base Shear in pushover analysis in x direction

The base shear value of model Type B4 is more compared to all other models. This is the performance level of the model as the model B4 can bear the maximum base shear values before failure. This indicates the model B4 can withstands for maximum load carrying capacity

F. Displacement

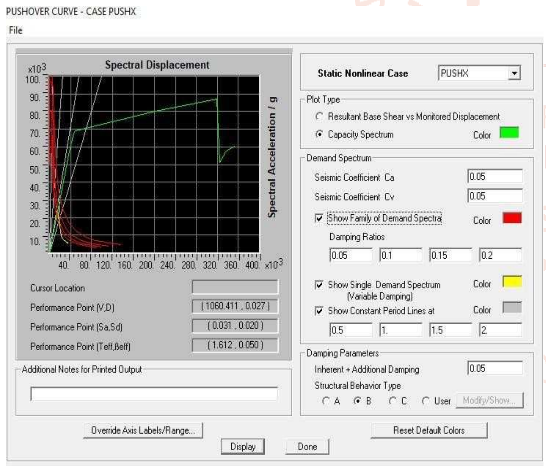


Graph 7: Displacement in pushover analysis in x direction

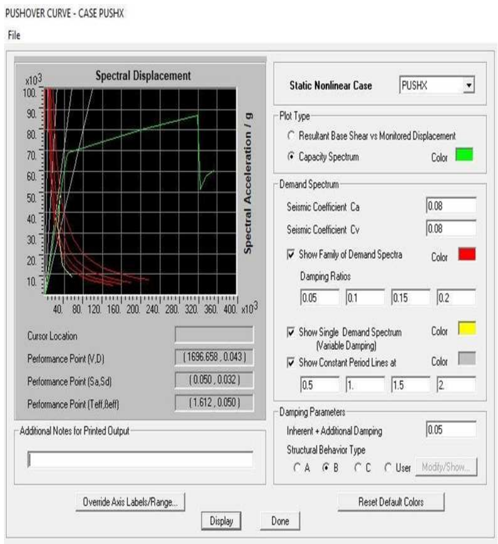
The model type B1 will undergo lowest level of displacement. The displacement level of models can be reduced for models with dampers. It is observed that the models with dampers having lesser displacement and is around 25%

G. Pushover Analysis curve

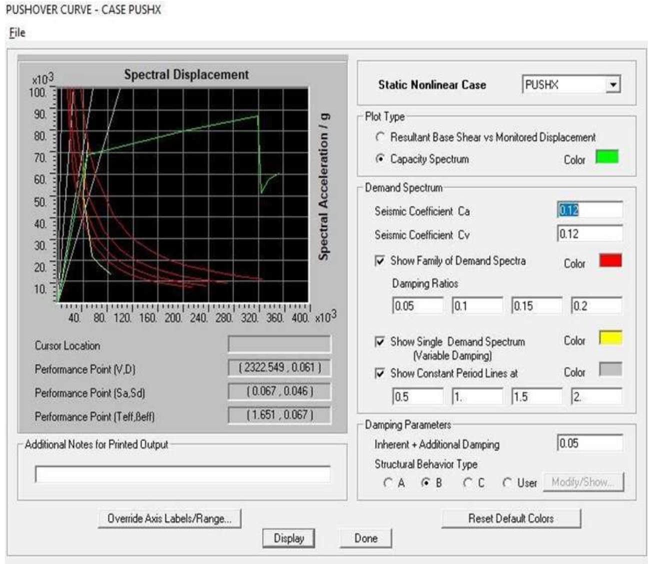
Performance point can be obtained by superimposing capacity spectrum and demand spectrum and the intersection point of these two curves is performance point. The below figures show super imposing demand spectrum and capacity spectrum. A performance check verifies that structural and non- structural components are not damaged beyond the acceptable limits of the performance objective for the force and displacement implied by the displacement demand.



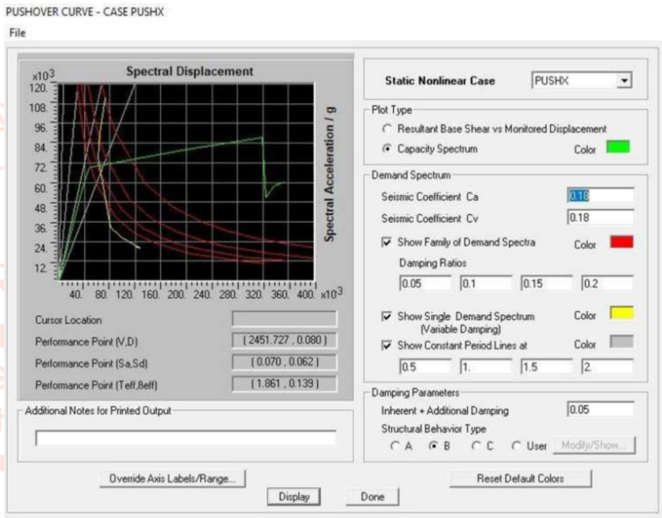
Graph 8: Pushover curve of Model A1



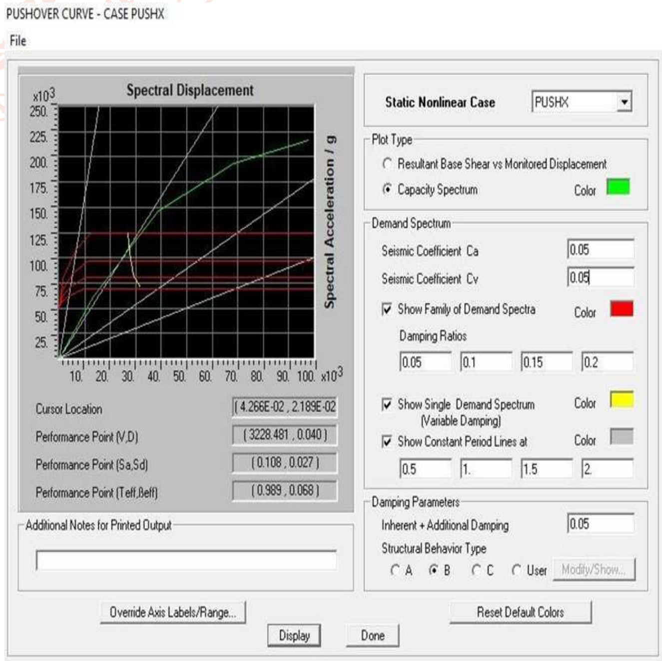
Graph 9: Pushover curve of Model A2



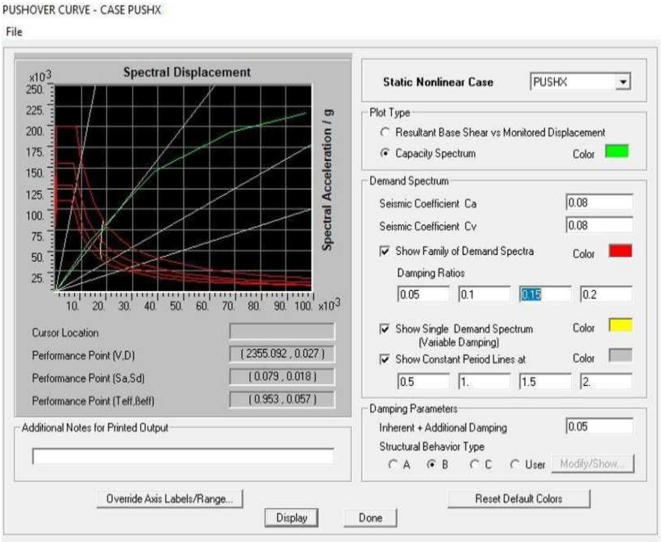
Graph 10: Pushover curve of Model A3



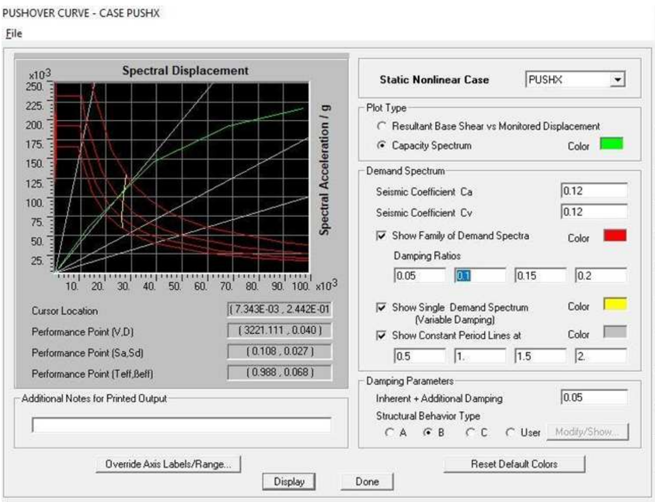
Graph 11: Pushover curve of Model A4



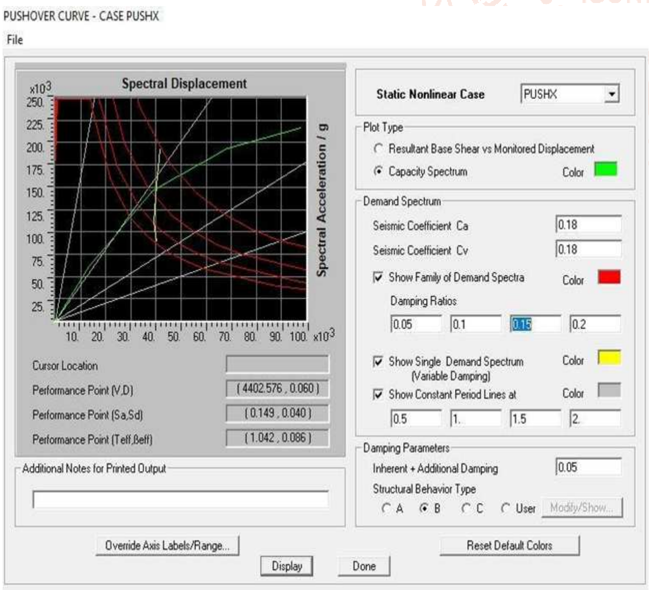
Graph 12: Pushover curve of Model B1



Graph 13: Pushover curve of Model B2



Graph 14: Pushover curve of Model B3



Graph 15: Pushover curve of Model B4

PUSHOVER CURVE

File

Step	Displacement	Base Force	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
0	0.0000	0.0000	1540	20	0	0	0	0	0	0	1560
1	0.0498	1970.9694	1430	130	0	0	0	0	0	0	1560
2	0.0610	2329.8997	1410	150	0	0	0	0	0	0	1560
3	0.0627	2360.8848	1390	170	0	0	0	0	0	0	1560
4	0.0655	2392.3416	1340	220	0	0	0	0	0	0	1560
5	0.0733	2437.2188	1235	85	120	120	0	0	0	0	1560
6	0.2416	2814.2649	1180	70	75	225	0	10	0	0	1560
7	0.3819	3019.2317	1180	70	75	155	0	0	80	0	1560
8	0.3819	1766.1912	1180	70	75	155	0	0	80	0	1560
9	0.3953	1979.3300	1180	70	75	155	0	0	80	0	1560
10	0.3982	2004.0344	1180	70	75	145	0	10	80	0	1560
11	0.4148	2094.9626	1180	70	75	115	0	10	110	0	1560
12	0.3693	680.7993	1560	0	0	0	0	0	0	0	1560

Table 2 – Typ. Pushover curve table

The above table indicates the displacement values and base shear values for different step values. The performance point lies between step 5 and 6. Hence, the building lies in LS-CP condition. The table also indicates the failure formation hinges (weak points).

5. CONCLUSIONS

- There is a linear increase in the displacement values for different zones. The displacement values increase with increase in severity of zone.
- There is a significant reduction in the displacement values when the structure is provided with damper system. It is observed that, the models with dampers can reduce up to 58% in displacement values.
- The drift values are within the limit. i.e., h/250 = 4000/250 = 16. However, all the models are having lesser drift values than limiting. It is also observed that, the model located in zone V is having highest drift values and also drift values are increasing at the bottom storeys compared to upper level.
- From the base shear values, it is observed that the increase in base shear value is due to increase in severity of seismic zone. The structure located in Zone V suffers more base shear than structure located in zone II. However, the increase in percentage is around 1.6 times, 2.4 times and 3.6 times of Zone II values compared with zone III, Zone IV and Zone V respectively.
- Even though the models are provided with dampers, the base shear values are models with and without base shear for a particular zone remains same. Hence, it is concluded that base shear value is independent of dampers and is dependent only on building dynamics.
- From the modal analysis, it is observed that, the time period is independent of Seismic zones.
- However, the introduction of dampers will make the
- structure brittle and reduces its flexibility.
- The Models with Dampers Type B1-B4 is having same time period value. There is a reduction of time period for Models type B1-B4 by 40% compared with models type A1-A4.
- The frequency of the structure is more in case of Model type B1-B4 compared with models A1 to A4. The frequency is same for models A1, A2, A3 and A4. Similarly, it is also same for Models B1, B2, B3 and B4.
- The Pushover analysis shows the models with dampers are having base shear than the models without damper. The increase in percentage of base shear is around 45%. The introduction of damper causes the improvement in lateral load carrying capacity by 45%.

- The base shear values are lesser for Zone II and highest for Zone V. There is a linear increase in base shear values for increase in severity of zones.
- The target displacement of the models without dampers are decreased by providing dampers.
- The reduction in displacement values is around 25%.
- From the pushover analysis, the performance point is found out for all the models. And also, it found that, weakest junctions of the models.
- From the pushover analysis base shear, it is noticed that all the models are having lesser base shear values in case of equivalent static analysis than pushover analysis except Model type A4. This shows that, the model Type A4 is UNSAFE. The models can be made SAFE by introducing Dampers as in Models Type B4.

REFERENCES

[1] Adrian Fredrick C. Dyaa, Andres Winston C. Oretaa, The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5) "Seismic vulnerability assessment of soft story irregular buildings using pushover analysis".

[2] Szabolcs Vargaa, Cosmin G. Chiorean, World Multidisciplinary Civil Engineering- Architecture-Urban Planning Symposium 2016, WMCAUS 2016 "Seismic Assessment of Reinforced Concrete Frameworks Through Advanced Pushover Analysis and Nonlinear Response of A SDOF Oscillator".

[3] Djamal Yahmia, Taïeb Brancia, Abdelhamid Bouchaïrb, Eric Fournely, X International Conference on Structural Dynamics, EURODYN 2017 "Evaluation of behaviour factors of steel moment-resisting frames using standard pushover method".

[4] Ruifu Zhanga, Chao Wanga, Chao Panb,, Hua Shena, Qingzi Gec, Luqi Zhang, "Simplified design of elastoplastic structures with metallic yielding dampers based on the concept of uniform damping ratio".

[5] Liyu Xiea, Li Zhanga, Chao Panb, Ruifu Zhanga,, Tianli Chen, "Uniform damping ratio-based design method for seismic retrofitting of elastoplastic RC structures using viscoelastic dampers".

[6] M Salman A. R. Shaikh, K R Ghadge, S I Khan, "Seismic Evaluation and Comparative Study of Various Retrofitting Techniques of RC Building".

[7] Shruti S. Mane1, Dr. Y. M. Ghugal, "A Review on Seismic Analysis of Buildings using Passive Energy Dissipating Devices".

[8] Ansa Haseeb T A1, Geethika G Pillai, "Seismic Performance Evaluation of RC Building Connected With and Without X-Braced Friction Dampers".

[9] Prof. S. D. Patil1, Dr. H. R. Magarpatil, "Seismic Performance of Framed Structure with Buckling Restrained Braces & Dampers- A Review".