Pushover Analysis of Stiff Structures

Ashwini H.R[1], Dr.K.Manjunatha[2], Dr.C.M Ravikumar[3]
Department of Civil Engineering
[1]M.tech Student, U.B.D.T. College of Engineering Davangere, Karnataka, India
[2] Professor, U.B.D.T. College of Engineering Davangere, Karnataka, India
[3]Assistant Professor, U.B.D.T. College of Engineering Davangere, Karnataka, India

Abstract*-Earthquake is one of the major natural event to make the structure to collapse now a days. India is divided into four seismic zones, structures situated in high seismic zones experiences huge damage when earth shakes, hence to prevent these harms seismic design is also considered while designing the structures located in any of the seismic zone. The stiffness can be defined as the force required to cause unit deformation, when the stiffness of the structure is increased there is reduction in displacement with the increase in the shear carrying capacity of the structure which results in better seismic performance of the building. This be will achieved by providing the bracing system into the building. Braced frames are known to be efficient structural system for structure subjected to high lateral frame compared to bare frame. For this study a five storey building is considered which is located in seismic zone V as per seismic map of India. The three types of bracing system such as Diagonal bracing Inverted V bracing, X bracing are considered for ISMC, ISMC and ISA double angle section with different bracing pattern are considered. For Modelling and Analysis Computer package SAP 2000 is used for the analysis. Results of this study revealed that X bracing reduces the Displacement significantly compared to inverted V bracing and Diagonal Bracing. It was found that various arrangement of bracing system has great influence on seismic performance of building frame and double angle section gives better performance as compared to ISMB and ISMC sections.*

Keywords-Pushover Analysis;Storey Displacement ; Base Shear;

I. INTRODUCTION

In recent decades structures are commonly constructed as tall structures. Structures are classified as two types that are rigid structure and flexible structure. High rise structures are usually flexible structures and are likely to be influenced to seismic induced forces. Our capacity to build seismically safe structures has gradually increased in the recent years.

Usually the structure in high seismic areas is more susceptible to damage. Structure has to withstand to lateral load along with gravity load which can develop high stresses. The concern about the multi-storey structures is the lateral stiffness. While analysing and designing of multi-storey structures, the most important things that are to be considered are the loads, displacement and inter-storey drift for safe and pleasant living of the occupants. Thus the problem faced by the structural engineers is to restrict deflection to minimum while increasing the height of the structure. Inter storey drift and displacement can be controlled through suitable structural bracing system.

The most commonly used structural systems for resisting lateral forces in Reinforced Cement Concrete and Steel structure is by adding shear wall, steel bracings and claddings system. Many of RCC frame structures built in seismic areas are expected to perform badly in an earthquake. Whereas braced frames are known to be efficient structural system for structures subjected to high lateral forces compared to bare frames.

It is the fact that Reinforced Concrete frame structure can be better in terms of resistance to horizontal forces by adding steel bracing system. Steel bracing system have both economic and practical advantages and they are faster to carry out the work. Usually the steel bracings are inserted in between the vertical members and also the use of bracing system will result into minimum disturbance in the structure.

In the present study three types of bracing i.e. Diagonal bracing, Inverted V bracing, X bracing were considered for ISA, ISMB and for ISMC sections for different bracing pattern for analysing the structure, and pushover analysis were carried out to determine the base shear capacity of the structure, so many software packages were available for analysing the pushover analysis i.e. E-tabs SAP 2000 e.tc , in the present study SAP 2000 has been used for analysing the frame and results were compared.

Scope For Present Work

In the present study, an effort is made to study the extent to which cross, diagonal and inverted steel bracing systems are succeeded in a multi-storey RCC frame structure and its arrangement and with respect to percentage reduction of displacement and base shear in comparison to unbraced reference model.

Objectives Of Present Study

- To perform the Pushover analysis for framed building without bracing system.
- To perform the pushover analysis for framed building with Diagonal, Inverted-V and X- Bracing system.
- To compare the pushover analysis results of braced frame building with frame building and without bracing system.

II. MODELLING AND ANALYSIS OF THE STRUCTURE

The choice of available method depends on the time, situations and accuracy factors. When a large number of existing buildings have to be evaluated within a short period and when very few structures to be evaluated for accuracy, i.e. dams, reservoirs, power plants etc which leads to other disasters. So it is very important to know the importance factor for new structures and performance criteria for existing structures in order to obtain the evaluation effectively. Here one of the most simple and popular method is considered for the analysis of braced building called Static pushover analysis, description is given below.

Non Linear Static Pushover Analysis:

A static nonlinear pushover analysis is a procedure used to gauge seismic structural deformations. The procedure involves using monotonically increasing horizontal loads in a prearranged manner to the structure and plotting the total applied shear force and the lateral displacement associated with it at each and every step until the structure reaches the failure condition. The application of the incremental horizontal load on the structure is shown in the below figure.

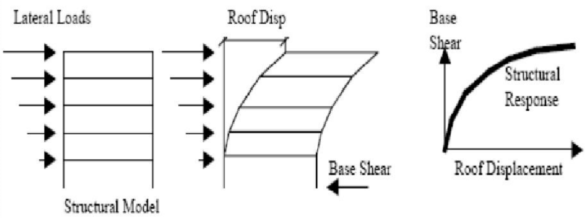


Fig. Pushover curve

Significance Of Pushover Analysis:

The linear procedures used for analysis of the structures don't give legitimate information about the actual forces acting on the buildings during earthquake scenarios. Since structures exhibit nonlinear behaviour during the earthquakes, using the nonlinear analysis is quiet necessary in order to investigate whether the structure is capable of fulfilling required performance levels or not. Legitimate use of the pushover analysis can provide vital information regarding the expected performance of the structural components and its systems.

The fundamental goal of using pushover analysis is to investigate the expected performance of structural systems by assessing its strength and deformation demands in design earthquakes and comparing them with the available capacities at the performance levels. Global codes, for example, ATC 40 [1], FEMA 356 provide detailed procedure and proper guidelines to carry out the nonlinear static pushover analysis and to utilize it to get the performance of the structures under a given earthquake scenario.

Terminologies Used In Pushover Analysis:

The two important terminologies used in pushover analysis are demand and capacity. Demand is the demonstration of the earthquake ground motion whereas capacity is the account of the structures ability to resist the seismic demand. The performance of the structure is reliant on the route in which the structure is equipped for taking care of the demand. I.e. the structure should possess adequate capacity to resist the demand of the earthquake in a manner that the performance of the structure is capable of satisfying the design objective.

Capacity:

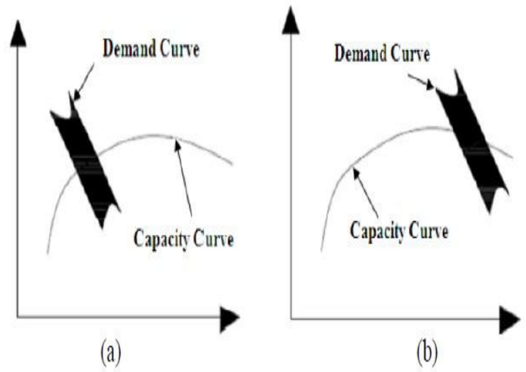
The capacity of any structure relies on upon strength and deformation capacities of the individual parts of the structure. So as to focus on the capacities beyond the elastic limits nonlinear investigation methodologies such as the pushover analysis is needed. On account of pushover analysis at first the load is applied to the mathematical model of the structure and the load is expanded in the same proportion till some members fall flat. The mathematical model of the structure is then adjusted with very little stiffness to ensure that hinges are formed. The load is then again expanded to the new altered model until some different components fail. This system is repeated till the structure reaches an extreme utmost such that instability from P-Δ effects are considerably past the wanted execution level, an component reaching a lateral deformation level at which loss of gravity burden conveying capacity occurs. In this way pushover analysis procedure utilizes progression of consecutive elastic analyses, superimposed to approximate a force displacement capacity diagram of the general structure. The mathematical model of the structure is altered keeping in mind that resistance of yielding components is reduced. A lateral force distribution is again connected on the model until a predetermined limit is reached. Pushover capacity curves rough how structure behaves after surpassing the elastic limits.

Demand:

Demand is a representation of the quake ground movement that the structure is being subjected. On account of pushover analysis demand is spoken to by an estimation of the displacements or deformations that the structure is required to undergo. This is opposite to that of ordinary linear elastic analysis methodology where demand is spoken to by prescribed lateral forces connected to the structure. Ground motions acting amid a seismic tremor produces complex horizontal acceleration and therefore displacement patterns in structures change time. Following these movements at each progression to determine structural design requirement is not found economical. For nonlinear analysis an arrangement of lateral displacements is utilized as a design outline. For a given structure and ground movement, the displacement demand is an evaluation of the maximum expected reaction of the building amid the grounds movement.

Performance:

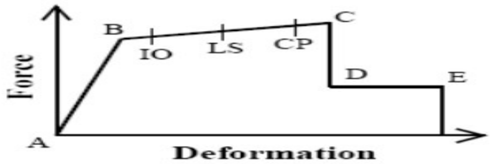
A performance check can be done for the building once the capacity curve and demand displacement are built up. Performance point is a point where demand curve and capacity curve meets with one other as shown in fig.



Seismic demand v/s capacity a) Safe design b) Unsafe design

Force deformation characteristics:

In pushover examination models are pushed in monotonically increasing order until target displacement is reached or structure loses balance whichever happens first. Pushover curve is a plot of base shear force v/s roof displacement. The peak of the curve demonstrates the maximum lateral load carrying capacity of the structure. The tangent at zero load level indicates the initial stiffness of the structure. The break down is accepted when structure losses its 75% strength and corresponding roof displacement is termed as „maximum roof displacement‟. A generalized force-deformation curve of a non-degrading casing component is shown in fig.



In the above figure, Point A represents the unloaded condition and point B represents yielding of the component. The ordinate at C relates to nominal strength and abscissa at C compares to the deformation at which degradation of the strength starts. The drop from C to D speaks to the initial failure of the element. The residual resistance from D to E permits the frame components to maintain gravity loads.

Operational (A-B): Operational, implies the post-earthquake damage condition of the building in which no significant harm has occurred to the structural and non-structural segments and they are able to bolster the building’s intended function.

Immediate Occupancy (B-IO): Immediate Occupancy implies the post-earthquake harm state in which only restricted non-structural damage has happened. Essential access and life safety systems such as entryways, stairways, lifts, fire cautions, stay in capacity.. The danger of life threatening injury as a consequence of this damage is very low.

Life Safety (IO-CP): Life Safety is the post-earthquake damage state in which potentially critical and costly damage has occurred to non-structural parts however there is no threatening to life safety.

Collapse Prevention (LS-CP): Collapse Prevention implies that the building is on the verge of experiencing fractional or total failure. Because of the significant degradation of structures quality and stiffness the structure may encounter fractional or total failure.

MODELLING

Table 1: Shows the structural detailing for Analysis

Structure	Reinforced concrete frame structure
Number of storeys	5 storey
Floor to Floor height	3m
No. of bays	5,3(X,Y axis) of 6m each
Beam Size	250mmX500mm
Column Size	500mmX500mm
Lateral force	Applied in ratios

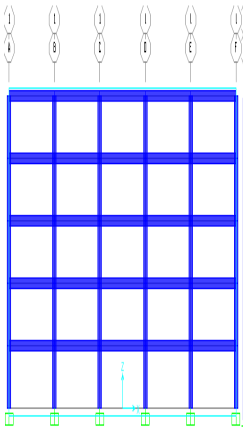
M20 and Fe 415 grade were considered for the analysis.

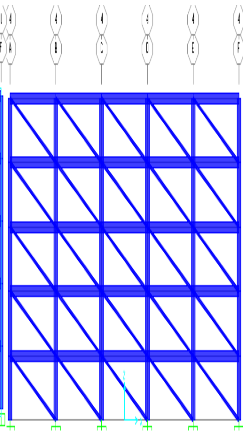
Seismic parameters considered

Table 2 various parameters considered for the seismic investigation as per IS 1893 – 2002

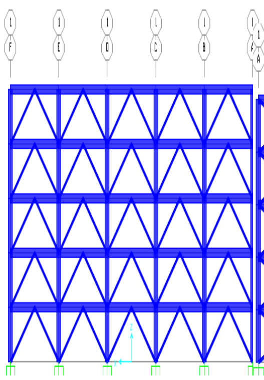
Zone, zone factor Z	v, 0.36
Importance factor, I	1
Soil type	II
Response reduction factor R	5
Percentage of imposed load considered during seismic load calculation	25%
Damping ratio	0.05
Eccentric ratio	0.05
Method of Analysis	Pushover analysis

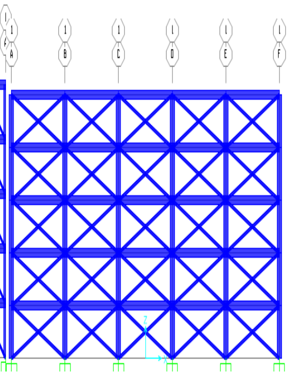
Different Types Of Bracing Patterns Used In The Study





MODEL –MB **MODEL -MD**



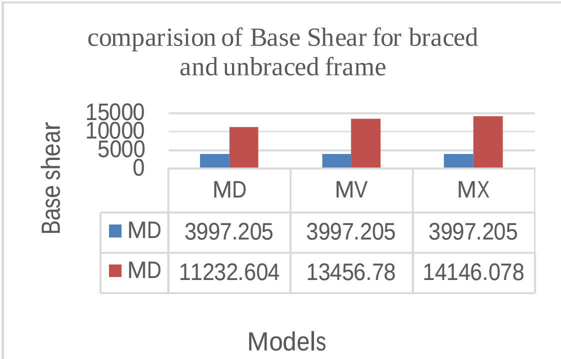


MODEL-MV **MODEL- MX**

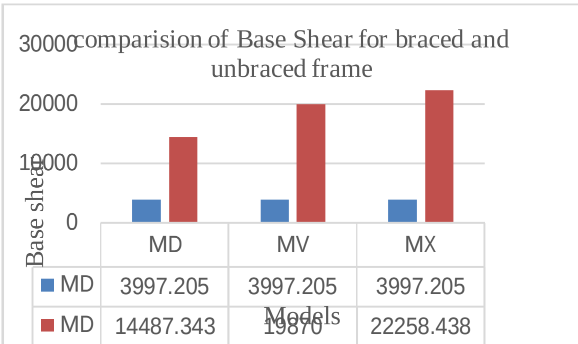
Similar type of bracing pattern are considered for ISA, ISMB and ISMC section.

III. RESULTS AND DISCUSSIONS

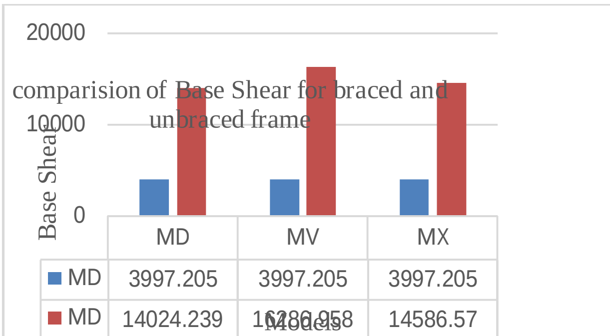
In the present study pushover analysis is carried out for five storey building. Different bracing material such as Angle sections, ISMB sections and ISMC sections are considered in various locations of bracing for the framed building. Attempt is made to know the maximum reduction in displacement corresponding to type and pattern of the bracing, and performance of displacement with respect to base shear graphs are plotted below



Using ISMB Sections

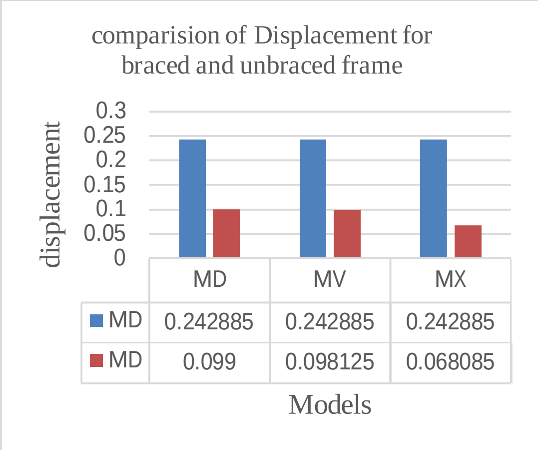


Using ISA Sections

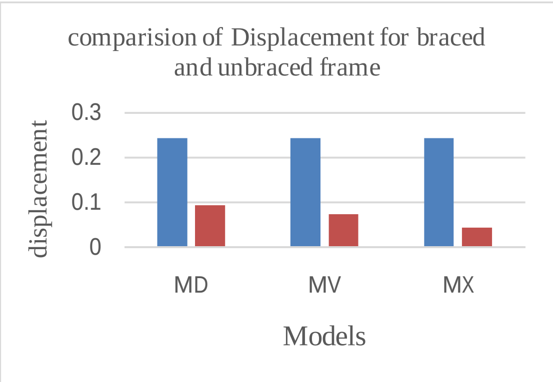


Using ISMC Section

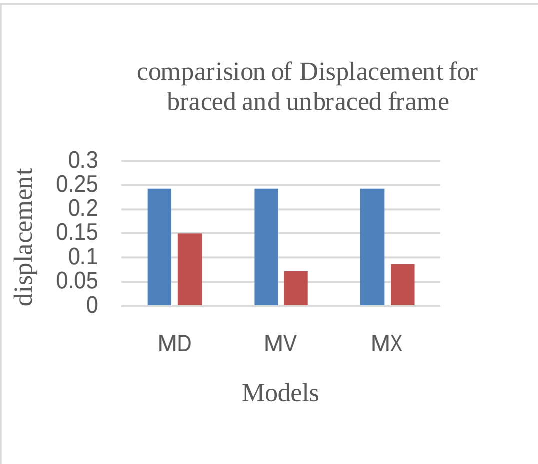
Below graph shows the comparison of displacement a for different bracing for ISMB, ISA and ISMC sections (i.e. Diagonal, Inverted V, X bracing), by referring the above fig it can be seen that provision of bracing reduces the top storey displacement effectively, it can be noted that provision of X bracing is effectively decreases the displacement of the frame.



Using ISMB Sections



Using ISA Sections



Using ISMC Section

VI. CONCLUSIONS

The present work is focused on the NSP analysis of stiff structure by considering different Bracing patterns. The Performance was studied in terms of Base Shear with Storey displacement, Hinge states and Ductility ratio. The following conclusions were made.

The provision of Bracing enhances the Base shear carrying capacity of frames. From the graph it can be seen that base shear capacity increase for Diagonal , Inverted V and X bracing, increase in an average of about 50 to 70%.when compare to bare frame model.

From the above graph , it can be observe that displacement level at roof level for the RC framed structure for Diagonal, Inverted V and X bracing reduce up to 50 to 60% as compare to bare frame.

It can be observed from that and bare frame has got more Performance displacement and Less Base Shear and compare to other models. It can be seen that the bracing have increased the level of performance both in terms of Base shearing carrying capacity and roof displacement.

Bare frame is having the Hinge state between CP-C , for the same model when it is analysed for different Bracing pattern (i.e ISA, ISMB and ISMC section) there is a increase in Hinge performance state i.e in between IO-LS.

By comparing ISA, ISMB and ISMC section, use of ISA double angle section increases the Performance level in terms of Base Shear caring capacity and displacement.

By comparing Diagonal, Inverted V and X bracing, X bracing found to be more effective in enhancing the performance of the structure.

REFERENCES

[1] Bhosle Ashwini Tanaji, Prof. Shaikh A. N. (2015) . “Analysis of r ofReinforced Concrete Building with Different Arrangement of Concrete and Steel Bracing system”. Vol(12), Issue(5),pp .08-12.

[2] Danish Khan, Aruna Rawat. (2016). “ Nonlinear Seismic Analysis of Masonry Infill RC Building with Eccentric Buildings at Soft Storey Level” . Procedia Engineering 161,pp.9-17.

[3] Hendramawath A safarizki , S.A Kristiawan and Basuki ,(2013). “Evaluation of use of Steel Bracing Improve Seismic Performance of Reinforced Concrete Buildings” . procedia Engineering, pp.447-456.

[4] Kevadkar M.D and Kodag P.B, “Lateral Load Analysis of R.C.C. Building”, International Journal of Modern Engineering Research (IJMER) Vol. 3, Issue.3, May-June. 2013 ISSN: 2249-6645, pp. 1428-1434.

[5] Madan S.K , Malik R.S, Sehgal (2015). “ Seismic Evaluation with Shear Walls and Braces for Buildings”International Journal of Structural,Construction and Architectural engineering, Vol.2.

[6] Mehmet Inel, Hayri Baytan Ozmen(2006),. “ Effects of plastic hinge properties in non linear analysis of reinforced concrete Buildings”. Engineering Structures.pp.1494-1502.

[7] Retrofitted RC Fames with Different Steel Braces” Mehrzad TahamouliRoudsari, Alireza Entezari, Mohammad Hessam Hadidi, Omid(2017), “Experinental Assesment of

[8] Massumi A and Tasnimi A.A,(2008) “Strengthening of low ductile reinforced concrete frames using stee X-bracings with different details”, The 14th world Conference On Earthquake Engineering.

[9] Mohammed Idrees Khan and Mr.Khalid Nayaz Khan,(2014) “Seismic Analysis of Steel Frame with Bracings Using Pushover Analysis”, International Journal of Advanced Technology in Engineering and Science, Vol.(2), Issue (07), ISSN (online): 2348 – 7550.

[10] Tianjian Ji,(2003).“Concept for designing Stiffer Structures.” The Structural Engineer,pp.36-42.