

PUSHOVER ANALYSIS BY USING X-BRACING AT DIFFERENT LOCATION IN RC BUILDING

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ABSTRACT

Earthquake is the sudden movement of tectonic plates in the earth's crust. An earthquake that releases energy in the form of waves that travel through the earth's crust and cause the shaking of the ground. They can cause large scale loss of life and property and disrupts essential services such as Water Supply, Sewerage systems, Communication and power, Transport etc. and destroy villages, towns and cities but the aftermath leads to destabilization of the economic and social structure of the nation. The result in damage to the structures, hence we need to design the buildings to withstand these earthquakes. Pushover analysis has been the preferred method for seismic performance evaluation due to its simplicity.

In this paper, G+9 RC building is modeled and analyzed by using X-bracing at different location. The computer aided analysis is done by using SAP2000 to find out the effective lateral load system during earthquake in high seismic areas. The structure has been evaluated using Pushover Analysis, a non-linear static procedure, which may be considered as a series of static analysis carried out to develop a pushover curve for the building. The main aim of this study is that the performance of the building is evaluated in terms of Lateral displacement and Base shear (Pushover or capacity curve). In the present study, seven model of bracing at different location has been analyzed by using pushover analysis. It shows the behaviour of the components and failure mechanism in a building. The various parameter and guidelines are used from as per IS 1893:2002 (part-1) and IS 13920-1993.

Keyword: Pushover curve (Base shear Vs Displacement), Different location of X-bracing.

I. INTRODUCTION

Earthquake is one of the most life threatening, environmental hazardous and destructive natural phenomenon's that causes shaking of ground. They not only destroy villages, towns and cities but the aftermath leads to destabilization of the economic and social structure of the nation. Ground shaking (earthquake) is caused by body waves and surface waves. The severity of ground shaking increases as magnitude increases and decreases as distance from the fault increases. Earthquake in India the range for earthquake 3.5 to 9.1 intensity. The seismic waves range from approx. 3 km/s up to 13 km/s, depending on the density and elasticity of the medium. Although the physics of seismic waves is complex, ground shaking can be explained in terms of body waves, compression, or P, and Shear, or S, and surface waves, Rayleigh and Love. The 'P' and 'S' waves mainly cause high-frequency vibrations; whereas, Rayleigh waves and Love waves, which arrive last, mainly cause low-frequency vibrations.[1] Body and surface waves cause the ground, and consequently a building, to vibrate in a complex manner. The size of the earthquake can be measured by Magnitude (M) which was obtained by recording the data of motions on seismograms. This can be measured by MMI scale (Modified Mercallie Intensity) or Richter scale.[5]

1.1 Basic Seismic Design Philosophy

Severity of ground shaking at a given location during an earthquake can be minor, moderate and strong. Thus relatively speaking, minor shaking occurs frequently; moderate shaking occasionally and strong shaking rarely. This is a major objective of seismic design codes throughout the world.

1. Under minor but frequent shaking, the main members of the buildings that carry vertical and horizontal forces should not be damaged; however buildings parts that do not carry load may sustain repairable damage.
2. Under moderate but occasional shaking, the main members may sustain repairable damage, while the other parts that do not carry load may sustain repairable damage.
3. Under strong but rare shaking, the main members may sustain severe damage, but the building should not collapse.

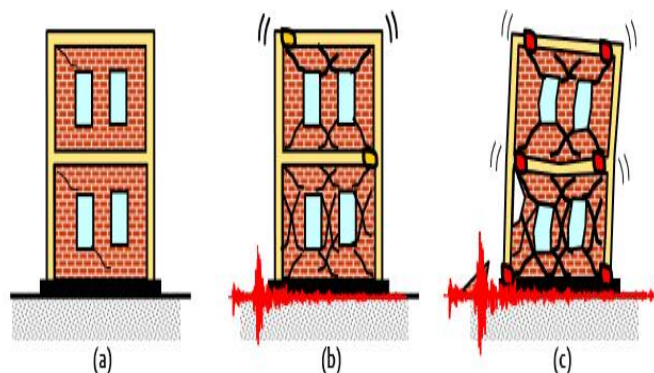


Fig. 1.1 Earthquake-Resistant Design philosophy for buildings

Earthquake resistant design is therefore concerned about ensuring that the damages in buildings during earthquakes are of acceptable variety, and also that they occur at the right places and in right amounts.

Earthquake resistant buildings, particularly their main elements, need to be built with ductility in them. Such buildings have the ability to sway back-and-forth during an earthquake, and to withstand the earthquake effects with some damage, but without collapse.

The RCC structure plays an important role in the construction industry. Now a day, it is necessary to design a structure to perform well under seismic loads. The objective of earthquake-resistant design is to construct a building so that it can withstand the ground shaking caused by body and surface waves.

1.2 Methods of Seismic Analysis

Methods for Seismic analysis of buildings may be classified as follows:

- 1) Equivalent Static Analysis (Linear Static)
- 2) Response Spectrum Analysis (Linear Dynamic)
- 3) Pushover Analysis (Nonlinear Static)
- 4) Time History Analysis (Nonlinear Dynamic)

The analysis procedure teaches us how to identify the earthquake forces and its demand. Depending on the importance and cost, the method of analyzing the structure varies from linear to non-linear. Both the linear and nonlinear analysis procedures can be performed statically as well as dynamically. The static non-linear procedure indicates which part of the building fails first.

Linear Static Analysis

Linear static analysis defines a way to represent the effect of earthquake ground motion when series of forces are act on a building, through a seismic design response spectrum. The applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting. This method assumes that the building responds in its fundamental mode. In this method first the design base shear is computed for the whole building, and it is then distributed along the height of the building. The lateral forces at each floor level are distributed to individual lateral load resisting element.[2]

Non Linear Static Analysis

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The load is incrementally increased in accordance to a certain predefined pattern. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity. On a building frame, plastic rotation is monitored, and a plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. Pushover analysis may be classified as displacement controlled pushover analysis when lateral displacement is imposed on the structure and its equilibrium determines the forces. Similarly, when lateral forces are imposed, the analysis is termed as force-controlled pushover analysis. Response of structure beyond maximum strength can be determined only by displacement controlled pushover analysis. Hence, in the present study, displacement-controlled pushover method is used for analysis of the RC building. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity. Beyond elastic limit, different states such as Immediate Occupancy, Life Safety Collapse prevention and collapse are defines as per ATC 40 and FEMA 356.

Many methods were presented to apply the nonlinear static pushover (NSP) to structures. These methods can be listed as:

- (1) Capacity Spectrum Method (CSM) (ATC)
- (2) Displacement Coefficient Method (DCM) (FEMA 356)

1.3 Capacity Curve

Nonlinear Plastic Hinge Pushover Analysis requires the development of the force deformation curve for the critical section of beams and column by using some guideline. Such a curve is presented in the figure.

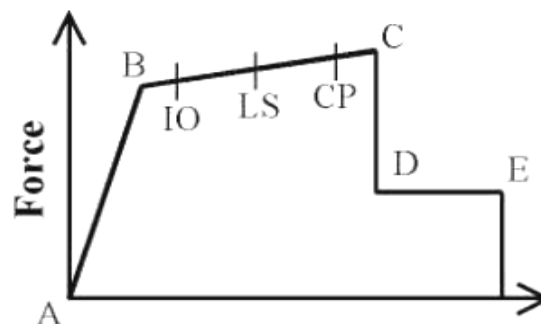


Fig.1.2 Force-Deformation relationship

Point A corresponds to unloaded condition. Point B represents yielding of the element. The ordinate at C corresponds to nominal strength and abscissa at C corresponds to the deformation at which significant strength degradation begins. The drop from C to D represents the initial failure of the element and resistance to lateral loads beyond point C is usually unreliable. The residual resistance from D to E allows the frame elements to sustain gravity loads. Beyond point E, the maximum deformation capacity, gravity load can no longer be sustained.[10]

Immediate occupancy IO: Damage is relatively limited; the structure retains a significant portion of its original stiffness. Life safety level LS: Substantial damage has occurred to the structure, and it may have lost a significant amount of its original stiffness. However, a substantial margin remains for additional lateral deformation before collapse would occur. Collapse prevention CP: At this level the building has experienced extreme damage, if laterally deformed beyond this point, the structure can experience instability and collapse.

II. INTRODUCTION TO BRACING

Bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure. Bracing has been used to stabilize laterally for the majority of the world's tallest building structures as well as one of the major retrofit measures. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing stiffness and strength against horizontal shear. A bracing system improves the seismic performance of the frame by increasing its lateral stiffness and capacity. Through the addition of the bracing system, load could be transferred out of the frame and into the braces, bypassing through columns.

Braced frames are efficient structural systems for buildings subjected to seismic or wind lateral loadings. Therefore, the use of bracing systems for retrofitting reinforced concrete is a frame with inadequate lateral resistance is attractive. In the presence of these deficiencies the upgrading of seismic performance may be realized with the introduction of new structural members such as bracing systems or RC shear walls. The use of bracing systems for RC buildings may have both practical and economical advantages. In particular, this system offers advantages such as the ability to accommodate openings and the minimal added weight of the structure.[9]

Types of Bracing Systems:

There are mainly two types of bracing systems.

- i) Concentric bracing system.
- ii) Eccentric bracing system

Concentric bracing increases the lateral stiffness of the frame which in turn increases the natural frequency and also decreases the lateral storey drift. Further, the bracing increases the axial compression in the columns to which they are connected by decreasing the bending moments and shear forces in the column.

Eccentric bracing improves the energy dissipation capacity and reduces the lateral stiffness of the system. At the point of connection of eccentric bracings on the beams, the vertical component of the bracing force due to earthquake causes concentrated load.[4] There are some type of bracing is X-type or cross bracing, Digonal type, Cheveron type, K-type, V-type.

III. METHODOLOGY OF PUSHOVER ANALYSIS

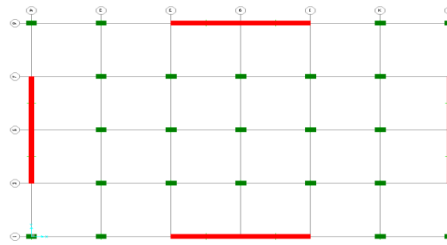
In order to strengthen and resist the buildings for future earthquakes, some procedures have to be adopted. One of the procedures is the static pushover analysis which is becoming a popular tool for seismic performance evaluation of existing and new structures. The design structure should be good strength, stiffness and ductility to perform well under seismic loads. Base shear capacity of the structure can be increased by using X-bracing in the structural system. There are some different location of X-bracing used to increases shear capacity. To estimate these property and other properties pushover analysis is performed. A simple computer-based pushover analysis is a technique for performance-based design of building frameworks subject to earthquake loading. Pushover analysis attains much importance in the past decades due to its simplicity and the effectiveness of the results.

The software used for the present study is SAP2000. It is product of Computers and Structures, Berkeley, USA. SAP2000 is used for analyzing general structures including bridges, stadiums, towers, industrial plants, offshore structures, buildings, dam, silos, etc. SAP2000 is objecting based, meaning that the models are created with members that represent physical reality. Results for analysis and design are reported for the overall object, providing information that is both easier to interprets and consistent with physical nature.[3]

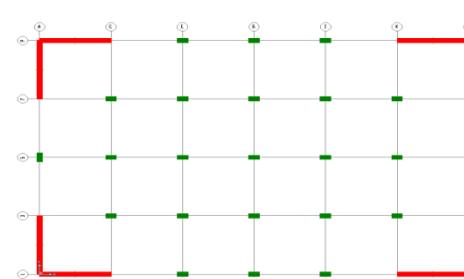
IV. PARAMETERS OF RC BUILDING

S.N	Parameters	Values
1	Building use	Residential
2	Size of building	24mx16m
3	No. of floors	G +9
4	Floor height	3.0m
5	size of column	300x600 mm
6	size of beam	300x450 mm
7	Slab thickness	125mm
8	Zone of building	V
9	Z	0.36
10	Live load at typical floor	3KN/m ²
11	Live load on terrace	1.5 KN/m ²
12	Floor finish load	1KN/m ²
13	Water proofing load	2KN/m ²
14	Terrace finish load	1KN/m ²
15	Earthquake Load	As per IS-1893 (part-1)-2002
16	Type of soil as per IS-1893	Type- II, Medium
17	Response reduction factor	5 (SMRF)
18	Importance factor	1
19	Section	ISMC300
20	Support	Fixed support

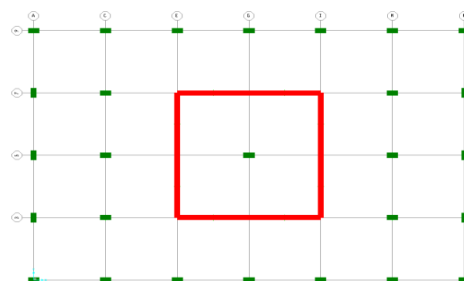
V. DIFFERENT LOCATION OF SHEAR WALL IN RC BUILDING



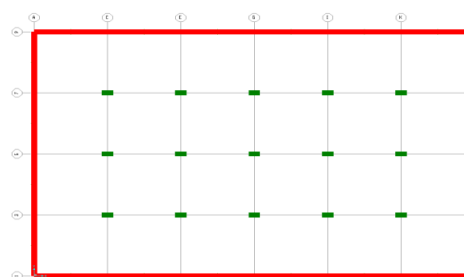
Model-I Bracing at center



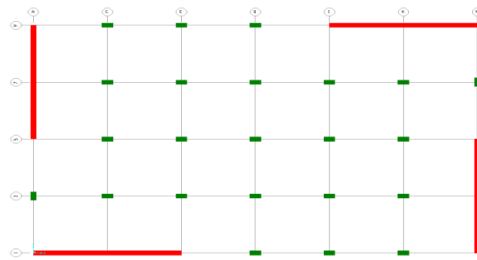
Model-II Bracing at corner



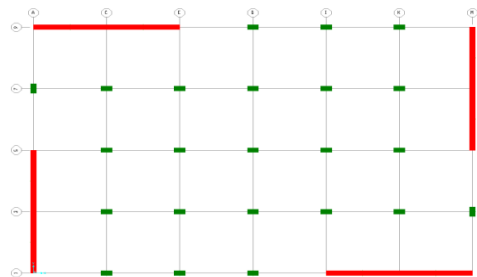
Model-III Bracing at inner core



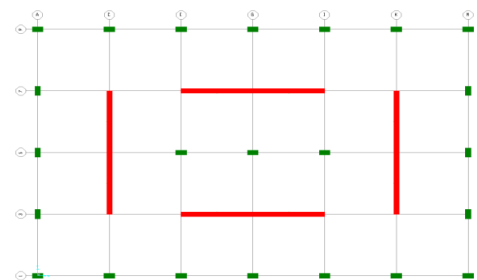
Model-IV Bracing at outer periphery



Model-V Bracing at outer side opposite corner



Model-VI Bracing at outer side opposite corner

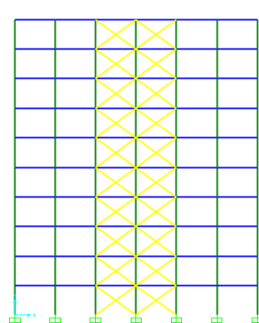


Model-VII Bracing at mid span of building

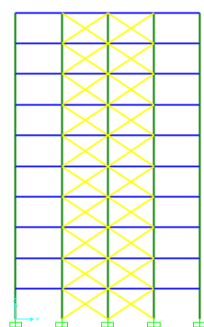
VI. ELEVATION VIEW OF DIFFERENT LOCATION OF BRACING PROVIDE IN RC BUILDING

Here seven different location of X-bracing is provided in the RC frame structure building and the elevation of XZ direction and YZ direction are shown in below figure.

Model-I

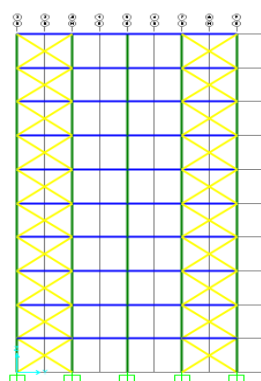


XZ-direction

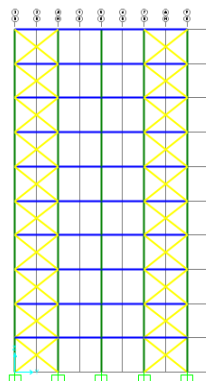


YZ-direction

Model-II

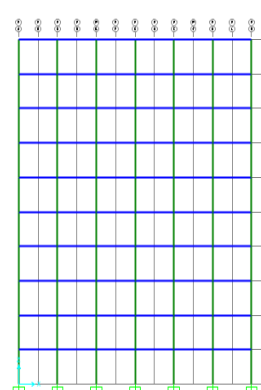


XZ-direction

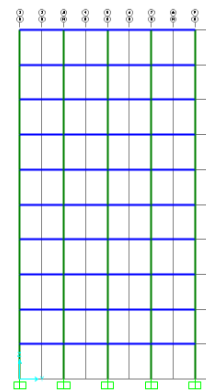


YZ-direction

Model-III

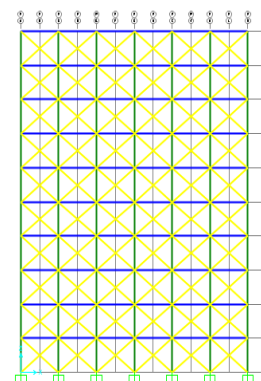


XZ-direction

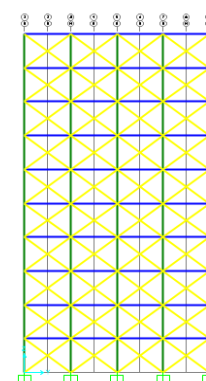


YZ-direction

Model-IV

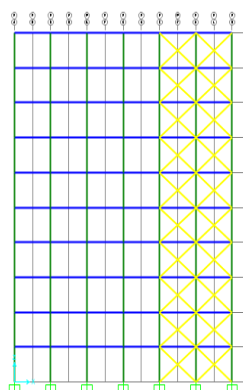


XZ-direction

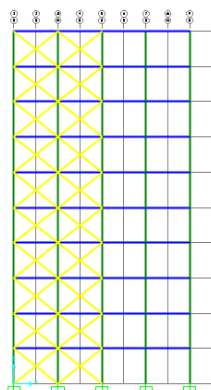


YZ-direction

Model-V

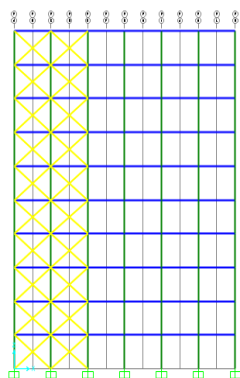


XZ-direction

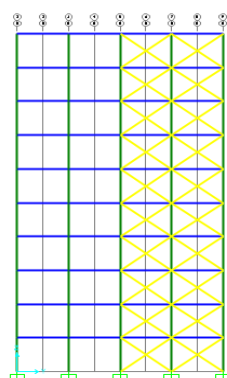


YZ-direction

Model-VI

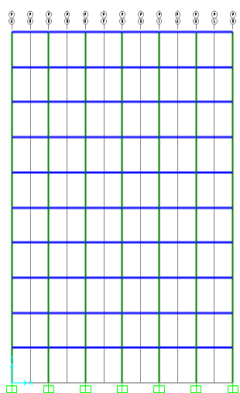


XZ-direction

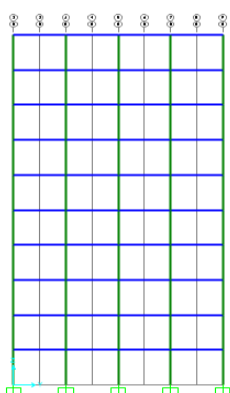


YZ-direction

Model-VII



XZ-direction



YZ-direction

VII. RESULTS

7.1 Results of base shear and displacement of shear wall

After analysis the models the following result values are obtained.

Model-I			
Direction	Shear (kN) at different levels		
	IO	LS	CP
X	3646.7798	5794.5762	6577.627
Y	3321.256	3991.8645	4553.2202
Displacement (m) at different levels			
X	0.0279	0.0779	0.1233
Y	0.0285	0.04	0.051

Model-II			
Direction	Shear (kN) at different levels		
	IO	LS	CP
X	2700	3645.7627	4454.2373
Y	2142.7119	3483.7288	4241.6948
Displacement (m) at different levels			
X	0.0216	0.0324	0.0527
Y	0.0206	0.0412	0.0616

Model-III			
Direction	Shear (kN) at different levels		
	IO	LS	CP
X	3322.0337	5315.2544	6905.085
Y	2658.9832	3772.8813	5264.0679
Displacement (m) at different levels			
X	0.0216	0.0432	0.0714
Y	0.0229	0.0354	0.0525

Model-IV			
Direction	Shear (kN) at different levels		
	IO	LS	CP
X	5423.7295	10033.898	15674.576
Y	3240	5601.356	7990.1694
Displacement (m) at different levels			
X	0.0129	0.0258	0.0419

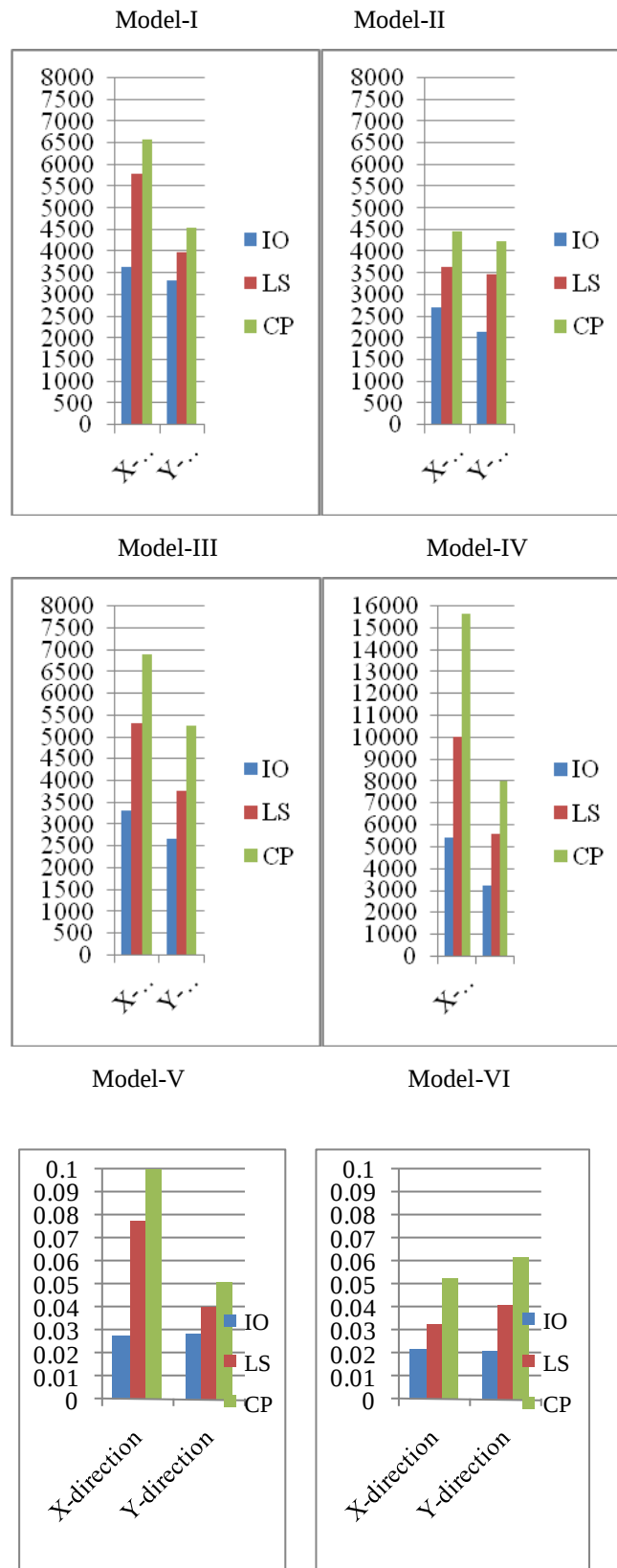
Y	0.0121	0.0222	0.0326
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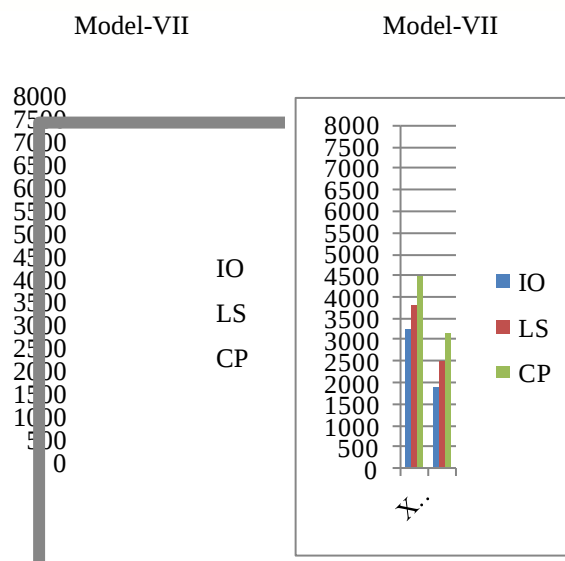
Model-V			
Direction	Shear (kN) at different levels		
	IO	LS	CP
X	3552.8813	4158.3052	4668.1357
Y	2343.0508	2657.6272	3167.4575
Displacement (m) at different levels			
X	0.0265	0.037	0.047
Y	0.0192	0.0224	0.028

Model-VI			
Direction	Shear (kN) at different levels		
	IO	LS	CP
X	3212.2034	3773.5593	4506.4409
Y	1865.7627	2462.3728	3145.7627
Displacement (m) at different levels			
X	0.0249	0.035	0.0495
Y	0.016	0.0224	0.0313

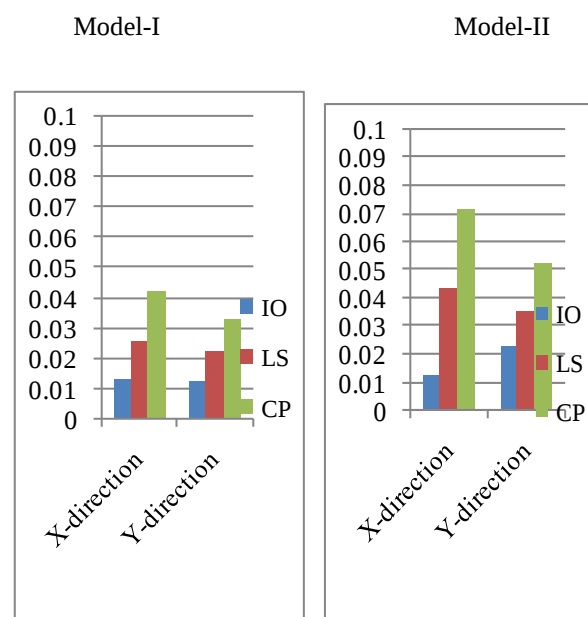
Model-VII			
Direction	Shear (kN) at different levels		
	IO	LS	CP
X	331.1865	5526.1016	6532.8813
Y	3110.5083	4981.0171	6136.9492
Displacement (m) at different levels			
X	0.0222	0.051	0.0841
Y	0.0251	0.0516	0.0841

7.2 Base Shear Value Shows in Bar Chart

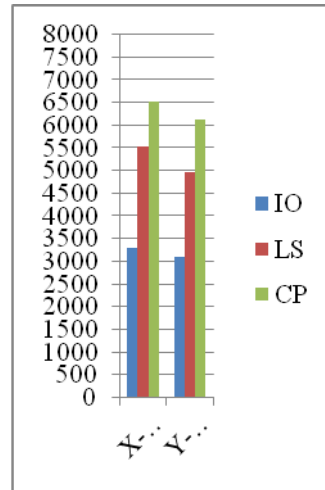




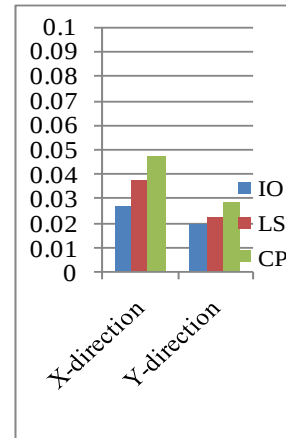
7.3 Displacement Value Show in Bar Chart



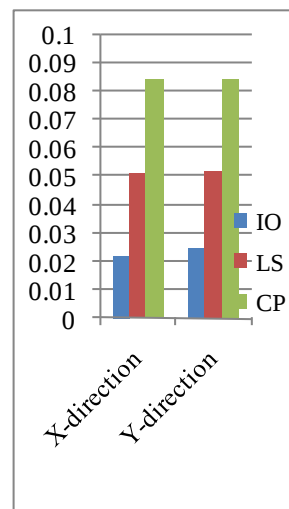
Model-III



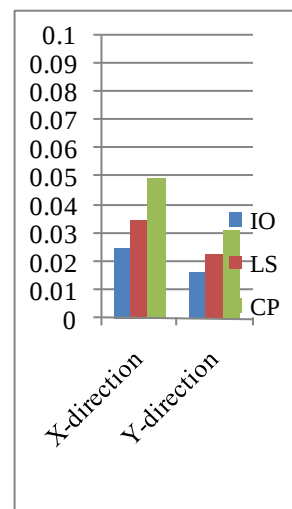
Model-IV



Model-V



Model-VI



VII. CONCLUSION

The pushover analysis is very good approach to assess the adequacy of a structure to seismic loading.

From the present investigation and the results obtained it can be concluded as following:

- 1) In medium high rise buildings provision of X-bracing is found to be effective in enhancing the overall seismic capacity of the structure.
- 2) The results obtained in terms of base shear which show capacity of the building and displacement gave an insight into the real behavior of structures.
- 3) In all type of models the base shear and displacement values are goes on increasing.

- 4) Providing bracing at periphery locations reduces the displacements and displacement also depends on the location of bracing.
- 5) The observation of results will gives that bracing Model IV is effective in resisting the seismic force.
- 6) It is observed that base shear is minimum for model-VI and maximum for model-IV building.
- 7) The result obtained from model-VII base shear is different but displacement is same in both direction.

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