Seismic Performance of Multi-Storied RC Moment Resisting Frames Based on Plan Aspect Ratio by Pushover Analysis

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Abstract: **In urban areas, most of the owners, building contractors, engineers are adopting vertical development of buildings for the construction. This is because the horizontal development gets restricted due to increase in population and scarcity of land. Natural hazard like earthquake affects the stability of such structures. Performance of structures in different areas of Northern part of India, during the earthquakes, is reviewed. The earthquake caused damage to heritage structures as well as modern buildings. Both masonry and reinforced concrete buildings showed poor performance. Previous studies reveal that major failures of structures occurred due to improper design procedures. Therefore, it is need of time to analyses & designs such hazard resisting structures so as to save human life and avoid property damage. The behaviour of a building during earthquakes depends critically on its overall shape, size and geometry. Nonlinear pushover analysis has been used to evaluate the seismic performance building with four different plans having same area and height. The results of effects of plan aspect ratio on seismic response of buildings have been presented in terms of displacement, base shear. And most suitable configuration of building which gives maximum base shear at performance point is also obtained.**

***Index Terms*- Aspect ratio, Base shear, Pushover analysis, Seismic Performance**

I. INTRODUCTION

Earthquakes are one of the most feared natural phenomena that are relatively unexpected and whose impact is sudden due to the almost instantaneous destruction that a major earthquake can produce. Severity of ground shaking at a given location during an earthquake can be minor, moderate and strong which relatively speaking occur frequently, occasionally an rarely respectively. Design of structures for earthquakes is different from that for any other natural phenomenon, like wind and wave. An earthquake imposes displacement on the structure, while winds and waves apply force on it. The displacement imposed at the base of the structure during an earthquake causes inertia forces to be generated in it, which are responsible for damage in the structure. As a consequence of this, the mass of the structure being designed assumes importance; the more the mass, the higher is the inertia force. After a whole gamut of earthquake experiences collected during the 20th century from across the world, today the earthquake engineering community believes that there are four virtues of an earthquake-resistant structure. These are:

1. Sufficient strength – capacity to resist earthquake forces,
2. Adequate stiffness – capacity to not deform too much,
3. Large ductility –capacity to stay stable even after a damaging earthquake, and
4. Good configuration – features of building size, shape and structural system that are not detrimental to favourable seismic behaviour.

A. CONFIGURATION

Configuration is critical to good seismic performance of buildings. The important aspects affecting seismic configuration of buildings are overall geometry, structural systems, and load paths. Various issues related to seismic configuration are discussed in this section. Plan Aspect Ratio 1) It is not good to have buildings with large plan aspect ratio, just like it is not good to have buildings with large projections. During earthquake shaking, inertia force is mobilized in the building, usually at the floor levels where the mass is large. The inertia force then is distributed to different lateral load resisting systems (columns and/or structural walls). It is preferred to distribute this lateral inertia force to various lateral load resisting systems in proportion to their lateral load resisting capacities. This is achieved when the floor slabs do not deform too much in their own (horizontal) plane. This condition, when floor slab helps in distributing the inertia force to different lateral load resisting systems in proportion to their stiffness, is known as rigid diaphragm action. However, the inertia force is distributed based on tributary area when floor slabs deform in their plane. This leads to overloading of members with less capacity and thus causing undue damage to buildings. Floor slabs in buildings with large plan aspect ratio (>4) may not provide rigid diaphragm action.

B. MOMENT RESISTING FRAMES

Moment- Resisting Frame: It is frame in which members and joints are capable of resisting forces primarily by flexure.

1. Ordinary Moment-Resisting Frame(OMRF):It is a moment-resisting frame not meeting special detailing requirement for ductile behaviour.
2. Special Moment-Resisting Frame (SMRF): It is a moment-resisting frame specially detailed to provide ductile behaviour and comply with the requirements given in IS 4326 or IS 13920.

II. PUSHOVER ANALYSIS (NONLINEAR STATIC ANALYSIS)

The static pushover analysis is becoming a popular tool for seismic performance evaluation of existing and new structures. The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake induced forces. 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.

A. PURPOSE OF DOING PUSHOVER ANALYSIS

The method is simple to implement and provides the information about strength, deformation and ductility of the structure as well as the demand. From this analysis, the lateral strength of the structure and its force-displacement relationship, which indicates the capacity of than force control was used to study the formation of mechanisms and structural behaviour characteristics after mechanism formation. The analysis consists of sequential elastic analysis in which the structure is subjected to monotonically increasing lateral force with an invariant height wise distribution until the target displacement is reached.

B. PERFORMANCE POINT

Building performance level can be determined by target displacement using capacity spectrum method (ATC 40). The capacity spectrum method allows for a graphical comparison between the structure capacity and the seismic demand. The intersection of demand spectrum and capacity spectrum is the performance point of the structure. If the base shear at performance point is greater than design base shear then the structure is safer. The design base shear is calculated as per IS : 1893:2002. At the performance point, the resulting responses of the building should then be checked using certain acceptability criteria. The Performance Point thus obtained from pushover analysis is then compared with the calculated target displacement.

III. OBJECTIVES OF THE STUDY

The objectives of the present study are as follows:

1. To evaluate the effects of different plan aspect ratio on the performance level of buildings by nonlinear static pushover analysis.
2. To investigate the performance point of building in terms of base shear and displacement.
3. To find most suitable configuration with larger ductility.

IV. METHODOLOGY

The methodology worked out to achieve the above-mentioned objectives is as follows:

First of all Review the existing literature and Indian design code provision for designing SMRF building after that do the modeling of building without considering infill strength/stiffness, modeling of SMRF is done by considering fixed end support condition. Nonlinear analysis of the selected building model is performed and a comparative study on the results obtained from the analyses should be done. Observations of results and discussion to be carry on for the same analysis and finally conclusions are drawn.

A. Building Details and Modeling for Analysis

This Chapter deals with the selection and design of building frames as per the design code procedures. The designed frames are modeled for nonlinear analysis. It is necessary to develop a computational model to perform any kind of analysis. The parameters defining the building models, the basic assumptions and the geometry of the selected buildings for the study is discussed. This includes the development of concentrated plasticity hinges at the critical sections of beams and columns

B. Building Configuration and Design Details

Consider four six -storey buildings with 4m storey height. Thus, the four buildings have plan aspect ratios of 1, 1.5, 2, and 4. A detailed description of all the frames considered is presented in Table 1.

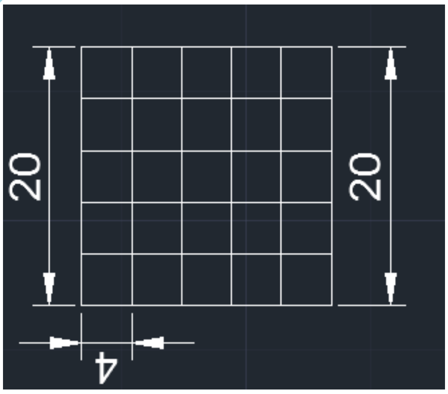


Figure 1: Aspect ratio 1

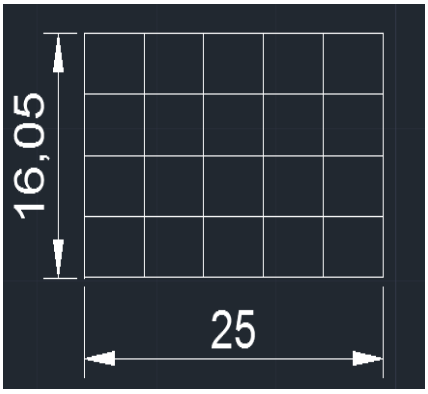


Figure 2:Aspect ratio 1.5

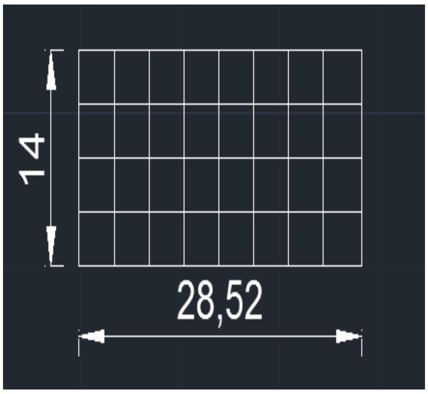


Figure 3: Aspect ratio 2

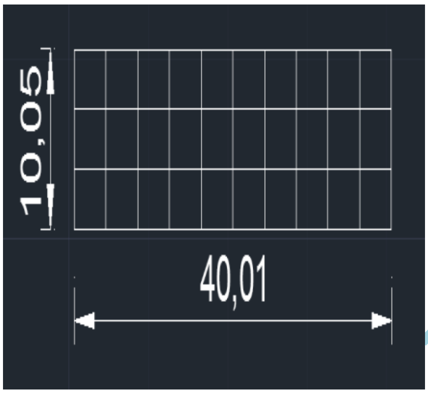


Figure 4:Aspect ratio 4

The storey height is 4m, which is same for all frames. Each frame is designed as MRF considering response reduction factor is 5. IS code suggests a response reduction factor of 5 for SMRF. The design of the frames is carried out by conducting linear static analysis of bare frames and accounting for all the load combinations suggested by IS 1893(2002). The material properties and the geometric parameters considered in the study are listed in Table1. M25 concrete is used at the design stages, along with Fe415 steel. The detailed description about seismic data is given in the Table No.1.

Table 1: Assumption of Material properties and geometric parameters

Sr no.	Design parameter	Value
1	Unit weight of concrete	25kn/m3
2	Characteristic strength of steel	Fe415
3	Modulus of elasticity of steel	2e5
4	Slab thickness	120mm

Table 2: Seismic Design Data assumed for Special Moment Resisting Frames

Sr no.	Design parameter	Value
1	Seismic Zone	IV
2	Zone factor(Z)	0.24
3	Response reduction factor (R)	5
4	Importance factor(I)	1.5
5	Soil type	Medium soil
6	Frame type	SMRF

The loads considered for designing the frames are given in Table 3. The loads are calculated using the material properties and the element dimensions.

Table 3:Loads considered for designing buildings

Sr no.	Load type	Value
1	Self-weight of beams and columns	As per dimensions
2	Floor finish	$2KN/m^2$
3	Live load	$3KN/m^2$

V. RESULT AND DISCUSSION

A. Performance Assessment of Designed Frames

The buildings are modelled in SAP2000 for nonlinear analysis. The pushover analyses of all the frames discussed in the previous sections is conducted. The base shear versus roof displacement at each analysis step is obtained. The pushover curves are presented in each case. A comparison study is carried out to observe the difference in behaviour of buildings.

1) Design base shear values

The design base shear is calculated as per IS: 1893: 2002.The design Base shear,

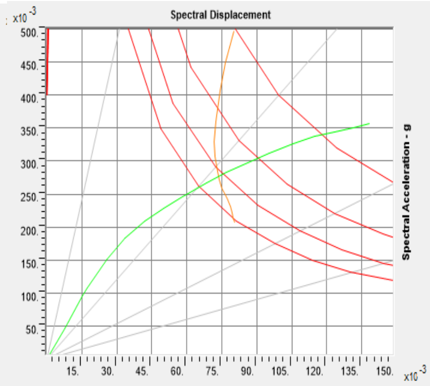
$V_b = A_h \times W$ …….. IS: 1893 (Part 1): 2002, clause 7.7.1

Table 4:Design base shear values

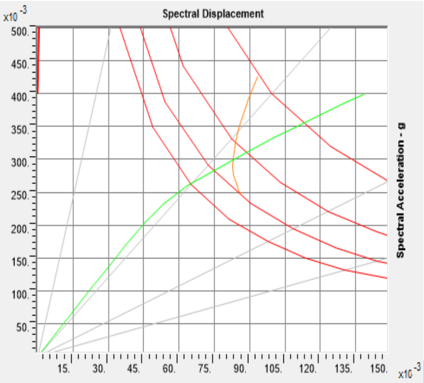
Sr No.	Building configuration	Ta	Sa/g	Ah	Base shear(Vb) KN
1	Aspect Ratio 1	0.813	1.672	0.0601	2884.8
2	Aspect Ratio 1.5	0.813	1.672	0.0601	2884.8
3	Aspect Ratio 2	0.813	1.672	0.0601	2877.6
4	Aspect Ratio 4	0.813	1.672	0.0601	2884.8

2) Performance Point Determination of Special Moment Resisting Frame

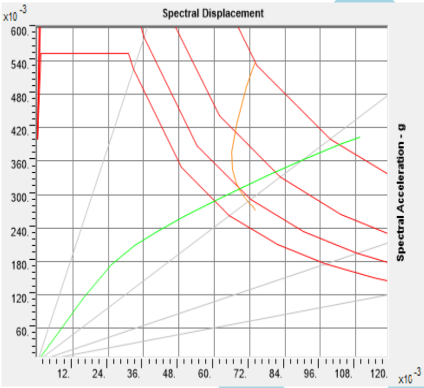
The seismic demand is also related to the nonlinear behaviour of the structure and is obtained iteratively. The intersection of the demand spectrum with the nonlinear pushover response is called "Performance Point". It corresponds to the state the structure is expected to reach under the considered earthquake. Depending on the position and state of the performance point , the analyst may decide on how safe or vulnerable the structure is and where possible strengthening should be performed. For pushover analysis the various pushover cases are considered such as push gravity, push X .The various load combinations are also used for this purpose. After pushover analysis the demand curve and capacity curves are obtained to get the performance point of the structure. The performance point is obtained as per ATC 40 capacity spectrum method. Following curves are the capacity curves which show performance point of the SMRF for different aspect ratios.



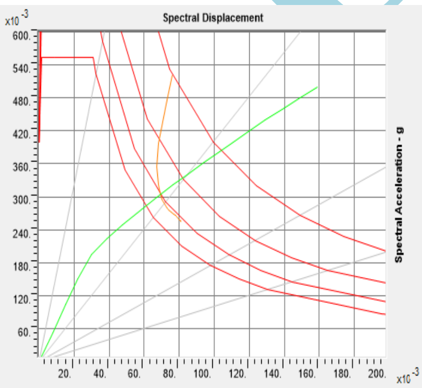
Aspect ratio 1 (performance point- 3652.976,0.092)



Aspect ratio 1.5(performance point-3496.653,0.104)



Aspect ratio 2(performance point- 4186.134,0.084)



Aspect ratio 4(performance point-4087.492,0.085)

Table 5: Base shear and displacement at Performance point

Sr No.	Building configuration	Design base shear	Base shear at performance point	Displacement
1	Aspect ratio 1	2884.8	3652.976	0.092
2	Aspect ratio1.5	2884.8	3496.653	0.104
3	Aspect ratio 2	2877.6	4186.134	0.084
4	Aspect ratio 4	2884.8	4087.492	0.085

All four buildings were analysed for static nonlinear (pushover) analysis in x direction using SAP2000. The Base shear versus displacement graphs have been plotted and compared for all models. Maximum base shear has been found in Case 3 (building with plan aspect ratio of 2) and Case 2 shows the least value of base shear as shown in Figures. Displacement value is same for case 3 and case 4, while least value is for case 2.Ductile behaviour is more for case 3. All frames are safe because base shear at performance point is higher than design base shear. The number of hinges increases with increase in plan aspect ratio.

VI. CONCLUSIONS

Following conclusions are obtained after analysis:
1) The plan dimensions have significant effect on the seismic behaviour of the buildings.
2) The building with plan aspect ratio 1.5 shows the least base shear.
3) The nonlinear static pushover analysis is performed to investigate the performance point of the building frame in terms of base shear and displacement.

VII. REFERENCES

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