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A REVIEW ON SEISMIC PERFORMANCE OF RCC HIGH RISE STRUCTURE FOR DIFFERENT ASPECT RATIO

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Abstract: The earthquakes in the Indian subcontinent have led to an increase in the seismic zoning factor over many parts of the country. Under this circumstance, seismic qualification of building has become extremely important. To make a building earthquake resistant, the building should have enough strength, stiffness and inelastic deformation capacity. This can be achieved through the selection of an appropriate building configuration and the careful detailing of structural members. There are several types of aspect ratios depending mainly on geometry and height of the building. The behavior of a building during earthquakes depends on its overall shape, size, height and geometry. Therefore, structural engineering profession has been using the nonlinear static procedure (NSP) or pushover analysis. Nonlinear static analysis, has been developed over the past twenty years and has become the preferred analysis procedure for design and seismic performance evaluation purposes. This paper aims to evaluate the reinforced concrete building to conduct the Pushover Analysis. The pushover analysis shows the pushover curves, capacity spectrum, plastic hinges and performance level of the building. The non-linear static analysis gives better understanding and more accurate seismic performance of building's damage or failure element.

INTRODUCTION

Tall buildings throughout the world are becoming popular day by day. With the advent of modern day construction technology and computers, the basic aim has been to construct safer buildings keeping in view the overall economics of the project. They may be referred to as "Multi Dwelling Unit" or "Vertical cities". The Benefits include, they act as landmarks; create unique skyline and efficient land use.

Although there is no precise definition that is universally accepted, various bodies have defined what 'high-rise' means:

The International Conference on Fire Safety in high-rise Buildings defined a high-rise as "any structure where the height can have a serious impact on evacuation"

The term "high-rise building" means any building having an occupied floors located more than 75 feet above the lowest level given by Fire Department vehicle access.

In India, a building greater than 75ft (23 m), generally 7 to 10 stories, is considered as high-rise. Also a building is considered to be high-rise when it extends higher than the maximum reach available to fire fighters. According to the building code of India, a tall building is one with four floors or more or a high-rise building is one 15 meters or more in height.

On structural point of view, these high rise structures height will be affected by lateral forces produced from wind loads and earthquake loads to the extent that these forces play important role in design process. So the behavior of a multi-storey framed building during strong earthquake motions depends on the distribution of mass, stiffness, and strength in both the horizontal and vertical planes of the building. In multi-storied framed buildings, damage from earthquake ground motion generally initiates at locations of structural weaknesses present in the lateral load resisting frames. The existing building can become seismically deficient since seismic design code requirements are constantly upgraded. Therefore, proper account of actions, material properties, structural systems and method of analysis should be considered while designing the high-rise buildings.

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. Pushover is a static-nonlinear analysis method where a structure is subjected to gravity loading and also displacement-controlled lateral load pattern which continuously increases through elastic and inelastic behavior until an ultimate condition is reached.

Nonlinear static pushover analysis can provide an insight into the structural aspects, which control performance during severe earthquakes. The analysis provides data on the strength and ductility of the structure, which cannot be obtained by elastic analysis. By pushover analysis, the base shear versus top displacement curve of the structure, usually called

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capacity curve, is obtained. Based on the capacity curve, a target displacement which is an estimate of the displacement that the design earthquake will produce on the building is determined. The extent of damage experienced by the structure at this target displacement is considered representative of the damage experienced by the building when subjected to design level ground shaking. Lateral load may represent the range of base shear induced by earthquake loading. It can help demonstrate how progressive failure really occurs, and identify the mode of final failure.

CASE STUDIES

Patel Sumant B. Lecturer, Head of Department, B.B.I.T.Associate Professor,[2016] In this case study the pushover analysis Pushover analysis of an existing R.C.C. building with use of software e-tabs, was carried out effectively to restrengthing the existing building. It deals with the performance based analysis of an existing building. An existing building made with considering shear wall shows its performance in range of Pushover analysis, than building is called safe against predicted earthquake.

VaishnaviV. Deshinge, NilimaB.Gawade,[March 2018], Pushover analysis of RCC building, In this study elastic static analysis, or pushover analysis, has been the ideal method for seismic performance assessment due to its easiness. It is a static analysis that directly includes nonlinear material characteristics. In elastic static analysis procedures include Capacity Spectrum Method, Displacement Coefficient method. Pushover analysis is a static, nonlinear procedure in which the magnitude of the lateral loads is gradually increased, maintaining a predefined distribution arrangement along the height of the building. Pushover analysis can determine the behavior of a building, including the ultimate load and the maximum inelastic deflection.

Nikhil Shedbale PG Student, [2017] Influence of Aspect Ratio on Performance in R.C.C Buildings, The responses of a building during earthquake depends majorly on its overall geometry, shape and size. This paper concentrates on assessing how aspect ratio influences performance based placement of viscoelastic dampers in R.C.C buildings.

Prof. Noor Mohammed, Mohammed Huzaifa Yaman, Shaik Mohammed Siddiq, : et al., 5(8)August, 2016 Non-linear pushover analysis of RCC building with base isolation system. The nonlinear static pushover analysis as introduced by ATC-40 has been utilized for the evaluation of an existing reinforced concrete building frame, in order to examine its applicability. Potential structural deficiency in RC frame, when subjected to a moderate seismic loading. The pushover analysis is a useful tool for accessing in elastic strength and deformation demands and for exposing design weakness. The pushover analysis is a relatively simple way to explore the nonlinear behavior of buildings.

Mr. Dhruvi Y Patel Mr. Piyush Jain, Dr. V. R. Patel[2017] Analysis and Design of RCC Tall-Building with different structural systems. In this study the application of analysis and design of RCC tall building with different structural system is studied through the study of analysis and design of three models of RCC tall building consisting of [10-20-30] stories, The response spectrum shows how building response characteristics vary with building frequency and period. As building period lengthens, accelerations decrease and displacement increases. On the other hand building with shorter periods undergo higher accelerations but smaller displacements.

Kavita Golghate Student, Department of Civil Engineering IES, IPS Academy [6] Pushover Analysis of 4 Storey's Reinforced Concrete Building The earthquakes in the Indian subcontinent have led to an increase in the seismic zoning factor over many parts of the country. Also, ductility has become an issue for all building that was designed and detailed using earlier versions of the codes. Under such circumstances, seismic qualification of building has become extremely important. The structural engineering profession has been using the nonlinear static procedure (NSP) or pushover analysis.

NON LINEAR STATIC PUSHOVER ANALYSIS

The following general sequence of steps is involved in a nonlinear static pushover analysis:

1. Create a model.
2. Define arbitrary static load cases,for use in the pushover analysis. Note that the program also has built-in capability to define the distribution of lateral load over the height of the structure based on both uniform acceleration and mode shapes.
3. Define the pushover load cases.
4. Define hinge properties.
5. Assign hinge properties to frame objects and wall objects. It is important that frame objects and wall objects be designed, e.g., reinforcement should be defined for the concrete frames and walls, prior to running the pushover analysis.
6. Run the pushover analysis by selecting a static nonlinear load case on the Set Load Cases to "Run" form. The load case will be available only if there is at least one frame or wall object with a hinge property assigned to it, and there is at least one pushover load case defined.
7. Review the pushover results.

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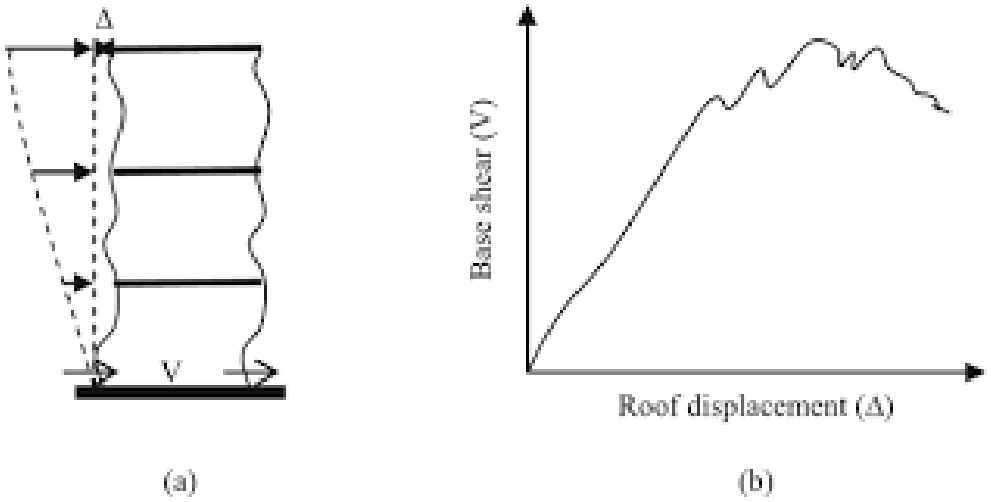

TYPES OF PUSHOVER ANALYSIS

Presently, there are two nonlinear static analysis procedures available. Both methods depend on lateral load-deformation variation obtained by non-linear static analysis under the gravity loading and idealized lateral loading due to the seismic action.

1) Displacement Coefficient Method (DCM), documented in FEMA-356. Displacement Coefficient Method is a non-linear static analysis procedure which provides a numerical process for estimating the displacement demand on structure using a bilinear representation of the capacity curve and a series of modification factors to calculate a target displacement. The point on capacity curve at target displacement is the equivalent of performance point in the capacity spectrum method.

2) Capacity Spectrum Method (CSM), documented in ATC 40 guidelines. Capacity Spectrum Method is a non-linear static analysis procedure which provides a graphical representation of the expected seismic performance of the structure by intersecting the structure's capacity spectrum with the response spectrum (demand spectrum) of the earthquake. The intersection point is called as the performance point, and the displacement coordinate of performance point is the estimated displacement demand on structure for the specified level of seismic hazard.

OBJECTIVE

- To perform a comparative study of the various seismic parameters of reinforced concrete frames with varying number of bays in horizontal configurations and number of stories in vertical configurations to investigate the effect of aspect ratios.
- To study the change in different seismic response parameters along the increasing height and increasing bays.
- To evaluate-base shear, storey overturning moment, storey drift, storey displacements.

In seismic design, the proportions of a building may be more important than its absolute size. For tall buildings the aspect ratio of a building is one of the important considerations than just the height alone. The more slender the building is worse are the overturning effects of an earthquake and greater are the earthquake stresses in the outer columns, particularly the overturning compressive forces, which can be very difficult to deal with. Increasing the height of a building may be similar to increasing the span of a cantilever beam. As the building grows taller there is a change in the level of response to the seismic forces. Therefore, proportions of buildings length-wise width-wise and height-wise need to be considered carefully.

The length divided by width of a building is termed as its Aspect Ratio and the ratio of height to least lateral dimension of a building is termed as its Slenderness Ratio. Increase in length of a building increases the stresses in a floor working as a horizontal distribution diaphragm in a transverse direction. The rigidity of the floor may be insufficient to redistribute the horizontal load caused by an earthquake.

MATERIALS USED IN THE CONSTRUCTION OF HIGH-RISE BUILDINGS IN INDIA

Concrete is an incredibly strong manmade mixture of aggregate (sand and gravel), cement and water that has been used in construction since Roman times.

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- It is very hard and in its normal state can withstand high compression loads but it has one major weakness - it cannot resist tension loads. Many factors will affect how concrete will behave under fire conditions. These may include:
- Quantity and type of aggregate used in the mix design and thus protection of reinforcement
- Type of Cement used
- Water content of the concrete

FACTORS

- Load bearing capacity
- Fire Exposure time
- Temperature
- Application of water (fire fighting Jets)
- Cladding or covering

SOFTWARE USED

I The steps carried out in Etabs: Model initialization where the parameters are assigned using the built in settings, the display units is in metric SI system, the concrete design code used is IS 456:2000.

- The inputs for storey dimension are assigned for aspect ratios for a 10 storey and 20 storey structure with storey height 3m in X and Y direction.
- The material properties are defined as per the model requirements. The grades of concrete are assigned.
- The section properties of the beams and columns are assigned under the frame properties by defining their cross sectional dimensions for RC elements. The slab section properties are defined for one way and two way type of slab.
- Using the drawing tools the beams, columns and slabs are drawn as per the plan dimensions. Flexibility at the base of the columns controls the mode shapes. Lack of rotational fixity at the column bases controls the overall behavior of the buildings. Lack of rotational fixity (Hinges) increases lateral sway in lower storey than in the higher storey and changes responses to shear type. Restraints are assigned of to the base of the model.
- The diaphragms are assigned to the model by selecting the entire model.
- Load patterns, response spectrum function and load cases are defined accordance with the code provision in a sequential order.
- The load combination are defined and assigned.
- Hinges are allotted to the beams and columns.
- Model is checked to eliminate the errors if any.
- Reinforcement details and size of the members are revised by running the response spectrum load cases and pushover load case is run for the revised model.

II The 3D building model is analyzed using Equivalent Static Method. The building models are then analyzed by the software Staad Pro.

- Different parameters such as deflection, shear force & bending moment are studied for the models. Seismic codes are unique to a particular region of country. In India, Indian standard criteria for earthquake resistant design of structures IS 1893 (PART-1): 2002 is the main code that provides outline for calculating seismic design force. Wind forces are calculated using code IS-875 (PART-3) & SP64.

PARAMETERS FOR COMPARATIVE STUDY

- **Capacity curve**

The overall capacity of a structure depends on the strength and deformation capacities of the singular elements of the structure. In order to determine capacities further than the elastic limits, some form of nonlinear analysis is required. This technique uses advanced elastic analysis, overlaid to approximate force-displacement diagram of the overall structure. The mathematical model of the structure is improved to account for reduced resistance of yielding components. A horizontal force distribution is again applied until additional components yield.

- **Demand curve**

Ground motion during an earthquake produces difficult horizontal displacement patterns which may vary with time. Tracing this motion at every time step to determine structural design requirements is judged unpractical. For a given structure and a ground motion, the displacement demands are evaluation of the maximum probable response of the building during the ground motion.

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- **Base shear**

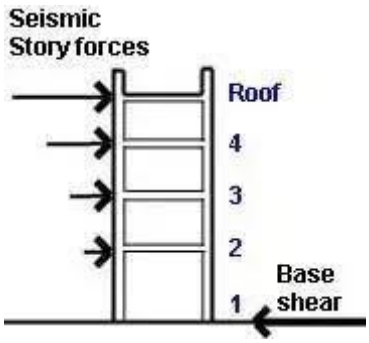
It is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure.

For same storey height, as the aspect ratio increases base shear increases. In case of same number of storey base shear does not increases linearly with linear increase in aspect ratio.

The total design lateral force or design seismic base shear (V_b) along any principal direction of the building shall be determined by the following expression V_b= Ah x W Where,

Ah = Design horizontal seismic coefficient.

W = Seismic weight of the building



- **Storey Drift**

Rahul Pandey,[Januray 2016] has submitted his thesis "Comparative seismic analysis of RCC, Steel and Steel-concrete composite frame" in which he had compared the performance of a (G+7) storey RCC, Steel, and Composite building frame situated in earthquake zone 5 using SAP2000 software. And the results were compared and the conclusion about the storey drift was made that storey drift in X-direction was more for steel frame as compared to composite and RCC frame. And RCC frame has the lowest value of storey drift because of its high stiffness, which indicates that as the value of stiffness increases, storey drift values decreases with it.

The same thesis says that, Base shear for RCC frame is maximum because the weight of RCC frame is more than steel and composite frame. So, Base shear gets reduced for composite frame and for the steel frame as compared to RCC frame.

- **Displacements**

Shashikala Koppad and Dr. S.V. Itti,[Januray2016]had published "Comparative study of RCC and Composite Multi Storeyed Buildings" in which they took a

3-D model in seismic zone 3 and analysed it in STAAD.Pro V8i software. They had concluded that node displacement in composite structure is more as compared to RCC structure. This is because the composite structure is more flexible as compared to RCC structure.

- **Seismic Mass**

It is the seismic weight divided by acceleration due to gravity.

- **Structural Response Factors** S/g

It is a factor denoting the acceleration response spectrum of the structure subjected to earthquake ground vibrations, and depends on natural period of vibration and damping of the structure.

- **Seismic zone**

A seismic zone factor is a rating of the potential intensity of earthquakes in a seismic zone. While most zones are classified based on a combination of frequency and intensity, the seismic zone factor focuses exclusively on the potential intensity.

FUTURE SCOPE

After the summarized report of seismic loading on high rise structures, the following works can be done in the future which are follows:

- Analysis of Tall buildings subjected to wind loads and seismic loads simultaneously.
- Gust Analysis of Tall buildings by IS 875 (Part -3) 2015 and by Etabs software.

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- For different shapes of building wind loads can be obtained by using different codes of practice and wind tunnel testing.
- Gust Factor Analysis on different types of building or structures
- Study of Soil Structure Interaction in along and across seismic responses of Tall Buildings can be taken into consideration.
- Human comfort criteria under dynamic loading can be considered in study.

CONCLUSION

The pushover analysis is a simple way to explore the nonlinear behavior of the buildings. The results obtained in terms of pushover demand, capacity spectrum and plastic hinges the real behavior of structures. In a multi storey building seismic zones are designed and constructed using IS-456-1978 and the revised code IS-1893- 2000 provisions.
Pushover analysis can recognize weak elements by calculating the failure mechanism and account for the rearrangement of forces during advanced yielding. It may help engineers take action for restoration work. Thus performance of pushover analysis mainly depends upon choice of material models involved in the study.

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