BEHAVIOUR OF MULTI-STOREY RC BUILDING UNDER SEISMIC LOAD USING PUSHOVER ANALYSIS.

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Abstract: The current work investigates the behavior of a multi-story RC building under seismic load using pushover analysis, employing two (codes IS code and ACI code) where the special moment resistant frame (SMRF) building is located in a medium-seismicity region of India in Pune City. The G+8 to G+20 storeys of the RC buildings have been chosen for this purpose. The structural analysis programmed SAP2000.V20 was used to create a finite element model of the structure. The different models (5 models) of RC buildings were initially designed to resist seismic loads using the responses spectrum analysis method to determine the RC building's characteristics. Pushover analysis is used to predict potential weak areas in the structure by tracking the sequence of damages of each and every member in the structure and determining the weak joints (critical joints) in the RC building. and compare the two codes (IS code and ACI code)

Key Words : Seismic load, Pushover analysis, performance structure, critical joint, SAP2000.V.20

1. INTRODUCTION

The major criteria now-a-days in designing RC structures in seismic zones it’s about control of lateral displacement resulting from lateral forces. In this thesis effort has been made to investigate of the compare between the two code (IS code And ACI code) under seismic load by using pushover analysis and study position on lateral displacement and Base Shear in RC Frames. RC Frames with (G+8,G+11,G+14,G+17 and G+20) are considered to be study under pushover analysis.

Non-linear static analysis (pushover analysis) was carried out for the frames and the frames were then compared with the push over curves between two code IS code and ACI code. Displacement and Base shear is calculated from the curves and compared.

A frame's pushover analysis has become an important tool for studying concrete Behaviour, including its load-deflection pattern and cracks pattern. It aids in the investigation of various properties of concrete members under various load conditions.

Pushover analysis is a popular method for assessing the seismic capacity of existing structures, and it is mentioned in several recent guidelines for retrofit seismic design. It can also be applied to the performance-based design of new buildings that rely on ductility or redundancy to withstand earthquake forces. [1]
The following are some aspects of such studies concerning the Behaviour of multi-story RC buildings under seismic load using pushover analysis. Additionally, many researchers studied Using pushover analysis, create complete pushover-like load–displacement curves from incremental dynamic analysis up to collapse for a variety of structural configurations representing the most common types of RC buildings.

**The A.M. Mwafy, A.S. Elnashai [1]** I did some research on the pushover analysis method, and the main goal of their paper was to develop complete pushover-like load–displacement curves from incremental dynamic analysis to collapse for a variety of structural configurations representing the most common types of RC building. To achieve their goal, they studied 12 buildings divided into three groups: four 8-storey irregular frame buildings, four 12-storey regular frame buildings, and four 8-storey dual frame walls. The four 8-storey irregular frame buildings used an inverted triangular lateral load distribution, which is identical to inelastic Because the former cap trues the characteristics of the most important mode of vibration, time–history analysis for the triangular and multimodal distribution results show differences of less than 4% for the twelve buildings. The multimodal load distribution only represents the distribution of inertia forces in the elastic range; As a result, higher mode effects aren't fully accounted for in the post-elastic domain.

**Krawinkler and Seneviratna [2]** have shown that the pushover analysis provides good predictions of seismic demands for low- rise structures having uniform distribution of inelastic behavior over height. In this procedure, none of the invariant force distributions account for the contributions of higher modes to response or redistribution of inertia forces because of structural yielding and associated changes in the vibration properties of a structure. To overcome these limitations, several researchers have proposed adaptive force distributions that attempt to follow more closely the time-variant distributions of inertia forces.

**Pushover Analysis of RC Building: Comparative Study on Seismic Zones of India (April 2017). P. PoluRaju, V. Mani Deep[3]**: In this study to understand the behavior of G+9 multistoried residential building located in different seismic zones (II, III, IV, V) of India having similar geometrical properties the non-linear static analysis (pushover analysis) has been done using SAP 2000 software. The behavior of a multistoried building has been examined in terms of force-displacement relationships, sequential hinge formations and inelastic behavior of structure etc.

**Effect1of Lateral Load Patterns in Pushover Analysis (November 2009).Abhilash R, Biju V, Thiruvananthapuram[4]**: For the pushover analysis, a regular single bay four-story RCC structure is chosen and different lateral load patterns are applied using the ETABS and SAP2000 software. Four lateral load patterns were chosen Uniform load distribution and equivalent lateral force distribution as defined by FEMA-257 are used in this study, as are lateral load patterns determined by the Upper bond pushover analysis (UBPA) method and lateral loads determined by response spectrum analysis as defined by IS-1893 (2002). Here the structure is modelled first in ETABS and dynamic properties of the structure is calculated, based on that the lateral loads are calculated and the structure is again modelled and analyzed in SAP2000 software by applying different lateral loads.

**Pushover Analysis of RCC Building (2013).Neethu K. N, Saji K. Kannur University, Kerala[5]**: In this paper the pushover analysis is conducted to determine the seismic capacities of an existing building which is asymmetric in plan. Here as per IS 456:20000 and IS 1893:2002 the building frame is designed. The main objective is that to verify the type of performance that a building can give which is designed as per Indian codes. In this study, an
educational building is considered which is situated in Kerala and the seismic performance is checked. The pushover analysis was carried out in SAP2000 software. In this analysis the maximum roof displacement of 640 mm was chosen. From the results it was found that the educational building is seismically safe.

2. OBJECTIVES OF THE STUDY
The following are the objectives of the study:
1. To evaluate the RC building performance under seismic load using pushover analysis method.
2. Estimate the performance factors for RC building for different models using pushover analysis as per IS code And ACI code (US).
3. To find out the critical joints on the RC building with different models under seismic load.
4. To compere the pushover analysis between the IS code And ACI code both under seismic load.

3. CONCEPT OF PUSHOVER ANALYSIS.
Uniform load distribution and equivalent lateral force distribution as defined by FEMA-257 are used in this study, as are lateral load patterns determined by the Upper bond pushover analysis (UBPA) method and lateral loads determined by response spectrum analysis as defined by IS-1893 (2002). Local nonlinear effects are modelled, and the structure is pushed until it reaches a certain point. A mechanism for collapse is created. The base shear and roof displacement can be plotted at each step to generate the pushover curve.

Pushover analysis is a non-linear analysis procedure that is used to estimate a structure's strength capacity in order to evaluate the expected performance of structural systems by estimating the strength and deformation demands in design earthquakes using static inelastic analysis. The pushover is expected to provide information on many response properties that a dynamic analysis or elastic static static static cannot provide.

Pushover vs Conventional Analysis.
To understand pushover analysis (PA), the best approach would be to first look at the similarities between PA and conventional seismic analysis (SA), both Seismic Coefficient and Response Spectrum methods described in IS:1893-2002 for SA, which most readers are familiar with, and then look at how they different:

I. Both SA and PA apply lateral load to the structure in a predefined vertical distribution pattern. The lateral load in SA is distributed either parabolically (using the Seismic Coefficient method) or proportionally to the modal combination (in the direct combination method of Response Spectrum) The distribution in PA is proportional to height raised to the power of ‘k,’ where k (equivalent to ‘2’ in the equation under Cl. 7.7.1 in IS:1893-2002) can be zero (uniform distribution) 1st (the inverted triangle distribution) 2 (parabolic distribution, as in the seismic coefficient method) or a calculated value between 1 and 2, with the value of k based on the structure's time period T according to FEMA 356 (where k is given a value of 2 if T is 2.5 seconds, a value of 1 if T is 0.5 seconds, and intermediate values of T are interpolated). The distribution can also be proportional to the first mode shape or to a combination of modes.
II. The maximum lateral load estimated for the structure is calculated in both SA and PA based on the fundamental time period of the structure.

III. The elastic model is used by SA, whereas the non-linear model is used by PA. This is incorporated in the latter in the form of non-linear hinges inserted into an otherwise linear elastic model generated using a common structural analysis and design software package (such as SAP2000 or STAAD.Pro) that includes PA capabilities.

Capacity Spectrum Method

The nonlinear static pushover analysis is a comprehensive method for evaluating the earthquake response of structures that explicitly takes nonlinear behaviour of structure elements into account. The capacity spectrum method is a pushover analysis approach that compares structure capacity with ground shaking demand to determine peak response during an earthquake.

![Capacity Spectrum Curve](Image)

**Fig 3:** capacity spectrum curve

4. STRUCTURAL MODELLING

The buildings which have used for the present study were with dimensions of different models height (G+8 to G+20), and its area 240m². For the present work, FEM-program SAP2000.V20. software have been used to analyze the different models under seismic load using pushover analysis on two different code (IS code and ACI code) to compare the pushover analysis between the IS code and ACI code both under seismic load.

| Type of building | IS code | ACI code |
|------------------|---------|----------|
| Zone             | III(0.16) | II(0.15)  |
| Number of stories| G+8 to G+20 | G+8 to G+20 |
| Soil             | Soft    | Soft     |
| Importance factor| 1       | 1        |
| Response reduction factors of structures (R) | 4 | 8 |
| Damping ratio of RC structures | 5% | 5% |
| Story height     | 3m      | 3m       |
| Beam M30         | 300x600mm | 300x600mm |
| Column M30       | 300x700mm | 300x700mm |
| Slab M30         | 150mm   |          |
Table 1: - Building data and loading detail used in the modelling.

|                | 2 kN/m² | 2 kN/m² |
|----------------|---------|---------|
| Live load      |         |         |
| Dead load      | 8 kN/m  | 8 kN/m  |
| Density of     |         |         |
| concrete       | 25 KN/m^3 | 25 KN/m^3 |

For analysis purpose ten models considered namely as:

MODEL 1: Structure Pushover Curve – PAX and PAY (G+8) IS code.
MODEL 2: Structure Pushover Curve – PAX and PAY (G+11) IS code.
MODEL 3: Structure Pushover Curve – PAX and PAY (G+14) IS code.
MODEL 4: Structure Pushover Curve – PAX and PAY (G+17) IS code.
MODEL 5: Structure Pushover Curve – PAX and PAY (G+20) IS code.
MODEL 6: Structure Pushover Curve – PAX and PAY (G+8) ACI code.
MODEL 7: Structure Pushover Curve – PAX and PAY (G+11) ACI code.
MODEL 8: Structure Pushover Curve – PAX and PAY (G+14) ACI code.
MODEL 9: Structure Pushover Curve – PAX and PAY (G+17) ACI code.
MODEL 10: Structure Pushover Curve – PAX and PAY (G+20) ACI code.

Fig 4:- plan of the building as shown in SAP2000

Fig 5:- plan of building (Auto CAD).
5. RESULTS AND DISCUSSION

**Fig 6**: 3D view of the model G+8

**Fig 7**: 3D view of the model G+20

**Fig 8**: Capacity curve as per FEMA-356 coefficient method for pushover analysis on PAX (G+20) as IS code.
Fig 9: - Capacity curve as per FEMA-356 coefficient method for pushover analysis on PAY (G+20) AS IS code.

Fig 10: - Capacity curve as per FEMA-356 coefficient method for pushover analysis on PAX (G+20) as ACI code.

Fig 11: - Capacity curve as per FEMA-356 coefficient method for pushover analysis on PAY (G+20) as ACI code.
5.1 VARIATION IN BASE SHEAR AND DISPLACEMENT

The response spectrum analysis and pushover analysis is carried out by using SAP2000 software by following seismic code IS1893 (part I):2016.

5.1.1 BASE SHEAR - The reaction at the base shear to earthquake load on the structure is referred to as base shear. This base shear from a pushover curve was designed in accordance with IS 1893:2016 ACI 318-19. is acting at the structure's base or support, or wherever the structure is fixed.

5.1.2 DISPLACEMENT - Storey displacement is the lateral movement of the structure caused by lateral force. The deflected shape of a structure is most important and most clearly visible point of comparison for any structure. No other parameter of comparison can give a better idea of behavior of the structure than comparison of displacement and this from pushover curve, design displacement as per IS 1893:2016. and ACI 318-19.

![Graphical representation of base shear (IS code).](image1)

![Graphical representation of base shears (ACI code).](image2)
6. CONCLUSIONS

This research provided the pushover analysis of RC of two different codes of IS code And ACI code under seismic load. Followings are the conclusions arrived from the analysis and interpretation of the results.

1. I have given the same data of the modeling of the five different modeling to the IS code And ACI code.
2. The results of these analyses have been compared between the IS code with ACI code of the pushover analysis.
3. I have taken on IS code Zone III=0.16 and on the US code ACI Zone II=0.15
4. Of this analysis the capacity of the building increase on the displacement on the Y direction and the maximum base shear increase on the X-direction of two different codes (IS code and ACI code).
5. I have study the behavior of the structure under seismic load by using the pushover analysis then comparison of displacement also on the different codes (IS code and ACI code). No other parameter of comparison can give a better idea of behavior of the structure than comparison of displacement.
Table. 2.: compare of the displacement of two codes (IS And ACI) code

| Zone   | Value | IS code | ACI code |
|--------|-------|---------|----------|
|        | X     | Y       | X        | Y       |
| Zone III (0.16) | -0.068 | -0.098 | -0.071 | -0.109 |
| Zone II (0.15)  | -0.198 | -0.285 | -0.193 | -0.275 |

6. From analysis and design the results of displacement of tow codes (IS and ACI) under seismic load using pushover analysis the different that the IS code increase on displacement estimated value=0.005 as you see the table no 2.

7. But the pushover analysis its same in IS code And ACI code. of you see the different value it’s as you see the different of the Zone factors of both codes its mode the little different of the value between both code as you see on the table no.2. the different value of zone factor of the (IS and ACI) IS code more them ACI code about value =0.01.

8. I have study the behavior of the structure under seismic load by using the pushover analysis then comparison of base shear on the different codes (IS code and ACI code ) the different between on base shear between IS code and ACI code about approx. =25 as you see the table the ACI code increase on base shear.

Table. 3.: compare of the base shear of two codes (IS And ACI) code

| Value | X direction | Y direction | X direction | Y direction |
|-------|-------------|-------------|-------------|-------------|
| Zone III  | 9031.486    | 4916.261    | 7821.347    | 4511.236    |
| Zone II   | 7795.188    | 5608.772    | 7711.919    | 5630.588    |
7. LIMITATIONS OF STUDY
   I. On this considered ten models of pushover analysis structure
   II. On this structure considered two codes (IS and ACI) every one of the code has five models on both direction X and Y.
   III. considered the zone of the IS code III (0.16) and ACI (0.15)
   IV. Only response spectrum analysis and nonlinear static (pushover analysis) is considered.

8. SCOPE FOR FUTURE WORK
   1. There is more study required for pushover analysis structure with different models on different code.
   2. Study for behavior of soil structure under pushover analysis with different code is required.
   3. Study required for different retrofitting methods on the structure under pushover analysis.
   4. Study for different methods on the structure between pushover analysis and time history method.

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