Inelastic seismic analysis of six storey RC building

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Abstract - Occurrence of the earthquake is unpredictable, but we can adopt preventive measures to overcome problems during earthquake. In this case, various organizations in the earthquake threatened countries have come up with documents, which serve as guidelines for assessment of the strength, expected performance and safety of existing buildings as well as for carrying out the necessary strengthening required. The present paper deals with detailed discussions on non-linear static analysis methods various structural performance levels of building. Seismic evaluation followed by information about various strengthening techniques for beam and column. The study includes the Pushover Analysis of G+6 storey building using SAP 2000 with default and user-defined hinges. And conclude that model with user-defined hinge properties is more successful for capturing hinging mechanism.

Key Words: *1* Pushover Analysis, 2 Performance,3 Default 4 User-defined Hinges.

1. Introduction

Earthquake is generated by sudden release of energy in earth's crust that creates seismic waves. It has the capability for causing damages, by the natural hazards. In nature, earthquake forces are accidental & uncertain natural hazards. An engineer requires the tools for analyzing structures under the effect of these types of forces. Performance based design have attained the new dimension in the area of seismic design ideology. Performance based design is a technology which is used to assess the behavior of field ground motion. Earthquake loads are modeled to assess the action of structure with a clear understanding that hazard is to be anticipated but it should be regulated. Pushover analysis is an iterative procedure shall be looked upon as an alternative for the orthodox anal y sis procedures and the inelastic analysis. Performance-based seismic engineering (PBSE) create structures with certain seismic performance. For anal y zing of seismic performance, a mathematical model of the structure is required to determine the force and displacement demands in various components of the structure. There are several methods of analysis, to analyze the seismic performance of the structures using elastic and inelastic methods. The force demand of each component of the structure is obtained and compared with available capacities by performing an elastic analysis. Elastic anal y sis methods are based on static lateral force procedure, dynamic procedure and elastic procedure using demand-capacity ratios. These methods are also known as force-based methods which assume that structures respond elastically to earthquakes. Inelastic anal y sis procedures basically include inelastic static analysis and inelastic time history analysis which is also known as pushover analysis. Building model is anal y zed by using inelastic static analysis. Inelastic static analysis, or pushover anal y sis, has been the preferred method for seismic performance evaluation due to its simplicity . It is a static analysis that directly in corporates nonlinear material characteristics. Inelastic static analysis procedures include Capacity Spectrum Method, Displacement Coefficient Method and the Secant Method (Sermin,2005).The performance based earthquake engineering (PBEE) also known as performance based seismic Engineering (PBSE) is rapidly growing concept that is present in all guidelines that were published: VISION 2000 (SEAOC,1995) ATC-40(1996), FEMA-273(1997)and FEMA-356(2000). PBEE involve design, construction, evaluation, monitoring the function and maintenance of engineered facilities whose performance under seismic loads responds to several needs and objectives of owners, users and society.

1.1 Pushover Methology

deformations. It's an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structure or structural element.

The analysis involves applying horizontal loads, in a prescribed pattern, to the structure incrementally , i.e. pushing the structure and plotting the total applied shear force and associated lateral displacement at each increment, until the structure or collapse condition. In technique a computer model of the building is subjected to a lateral load of a certain shape (i.e. Inverted triangular or uniform). The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded. Pushover analysis can provide a significant insight into the weak links in seismic performance of a structure. The performance criteria for pushover analysis are generally established as the desired state of the building given roof-top or spectral displacement amplitude. The seismic response of RC building frame in terms of performance point and the effect of earthquake forces on multi story building frame with the help of pushover analysis is carried out in this paper. In the present study a building frame is designed as per Indian standard i.e. IS 456:2000 and IS 1893:2002. The main objective of this study is to check the kind of performance a building can give when designed as per Indian Standards. The pushover analysis of the building frame is carried out by using structural analysis and design software SAP 2000.

2. Document Related to Pushover Analysis

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3.CASE STUDY DETAILS:

For obtaining performance point a building frame of G+6floors is considered. It is consisting of two bays in both the directions. The spacing along X and Y directions is 5m and the story height is taken as 3m. The frame is located in seismic zone III.

Design Data:

1. Grade of concrete used is M 25 and grade of steel used is Fe 415.
2. Floor to Floor height is 5 m and Ground floor height 4.1 m.
3. Plinth height above GL is 1.1 m.
4. Slab Thickness is 100 mm.
5. Wall Thickness is 230 mm.
6. Size of columns is 600mm X 600mm, 500mm X 500 mm and size of beams 230mm X 600 mm.
7. Live load on floor is 4 kN/m2 and Live load on roof is 1.5kN/m2.
8. Floor finishes is 1kN/m2 and roof treatment is 2kN/m2
9. Site located in Seismic Zone III.
10. Building is resting on medium soil. 11. Take Importance Factor as 1.
12. Building frame type is Special Moment Resting Frame (SMRF).

Description of Building Frame:

No. Bays along X axis: 2
No. Of bays along Y axis: 2
Spacing along X axis: 7.5m
Spacing along Y axis:7. 5m
Slab: 100mm thick

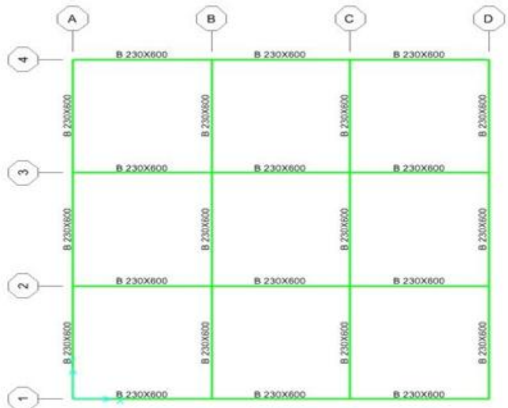


Fig:1 Plan of the building

fig-2: Plan of the building

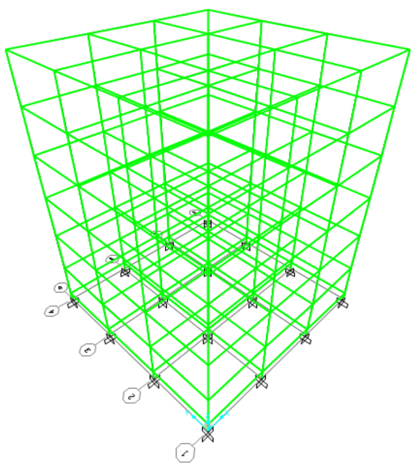


fig-3: 3D model of building

4.CALCULATION OF DESIGN BASE SHEAR

For obtaining the performance point of the building frame in terms of base shear the design base shear is calculated for determining the safety of the frame. 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 [6] as follows: The seismic weight of building is found to be 32677 KN (Wi)The infill walls in upper floors may contain large openings, although the solid walls are considered in load calculations. Therefore, fundamental time period T is obtained by using the following formula

T_a = 0.075 h0.75 IS 1893 (Part 1):2002, Clause 7.6.1

T_a = 0.075 x (30)0.75

T_a = 0.96 sec.

Zone factor, Z = 0.16 for Zone III IS: 1893 (Part1):2002, Table 2

Importance factor, I = 1.0, Medium soil site and 5% damping

Sa/g=1.36/0.97=1.42 IS: 1893 (Part 1): 2002, Figure 2.

Ductile detailing is assumed for the structure. Hence, Response Reduction Factor, R, is taken equal to 5.0. It may be noted however, that ductile detailing is mandatory in Zones III, IV and V. Hence, horizontal seismic coefficient is calculated as

A_h = (Z/2)×(I/R) ×(Sa/g) IS: 1893 (Part 1): 2002,clause 6.4.2

A_h = (0.16/2) ×(1.0/5) ×1.42 = 0.022

The design Base shear, VB = A_h×W IS: 1893 (Part 1): 2002,clause 7.7.1

VB = 0.022x 14069.78 = 563.916KN

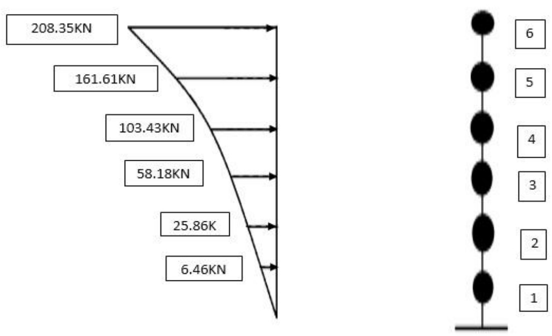
$$\sum_{i=1}^{n} W_j {h_j}^2 = 5204578.75$$

$$Q_i = V_B \frac{W_i {h_i}^2}{\sum_{i=1}^{n} W_j {h_j}^2}$$

Hence, Q_6 = (563.916 × 2136. 625 × 30^2) /5204578.75 = 208.35 kN

Similarly, Q_5 = 161.61 kN Q_4 = 103.43 kN

Q_3 = 58.18 kN Q_2 = 25.86 kN Q_1 = 6.46 kN



5.Results

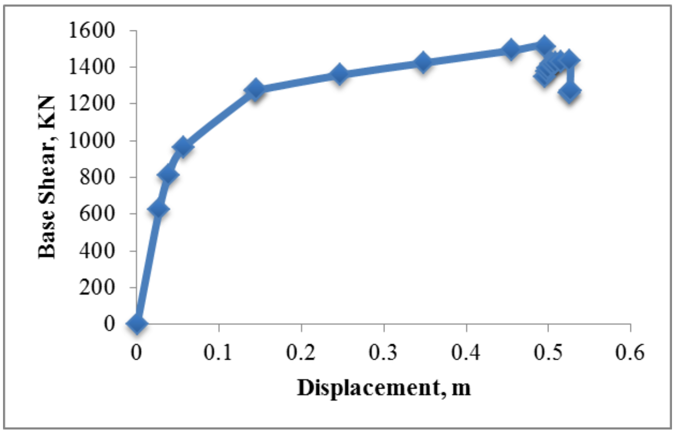


Fig:4 Pushover curve of a building

5.1 Results According to ATC-40 (1996)

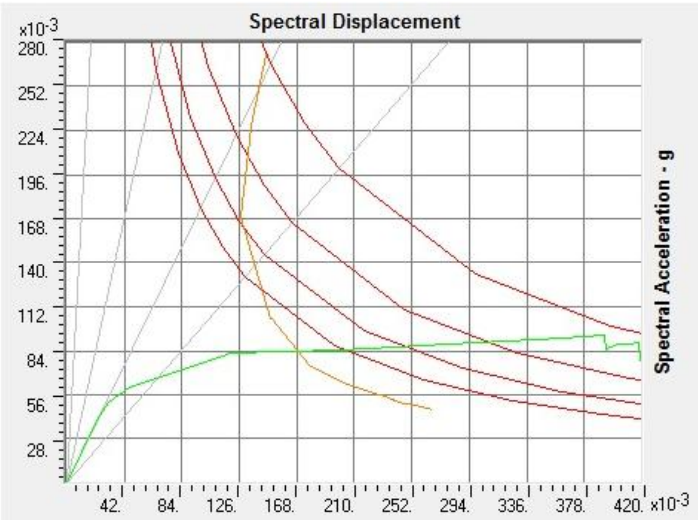


Fig: 5 Capacity spectrum curve

Performance point is the intersection of capacity and demand spectra.
V, D = 1321.666, 0.204
S_a, S_d = 0.084, 0.165
T_{eff}, B_{eff} = 2.793, 0.253
The performance point of the structure can be now determined by using the pushover curves obtained. The performance point is the point where the capacity and demand of the structure are equal. The performance point is determined automatically by SAP 2000, using the procedure c mentioned in ATC-40(1996).
The point at which the capacity curve intersects the reduced demand curve represents the performance point at which capacity and demand is equal. As displacement increase, the period of the structure lengthens and reduces demand. Hence, optimum point should have a higher capacity for a lesser displacement. Figure 5.2 shows that performance point is at T_{eff}= 2.793 sec which is close value of T_{eff} at step no. 5. Hence, it is required to see the hinge formations at step no. 5. From Figure 5.3, it also becomes clear that hinges formed in beams and columns are below immediate occupation level. Hence, structure is very safe to use.

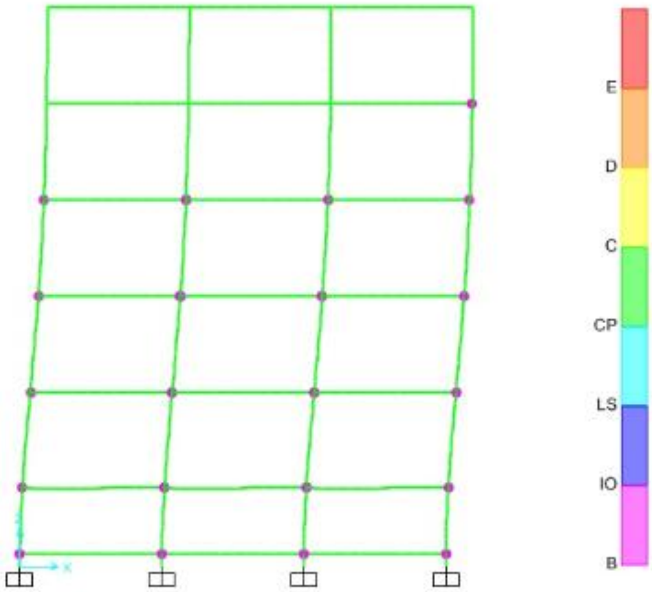


Fig: 6 Step 5 hinge mechanism in x-z direction

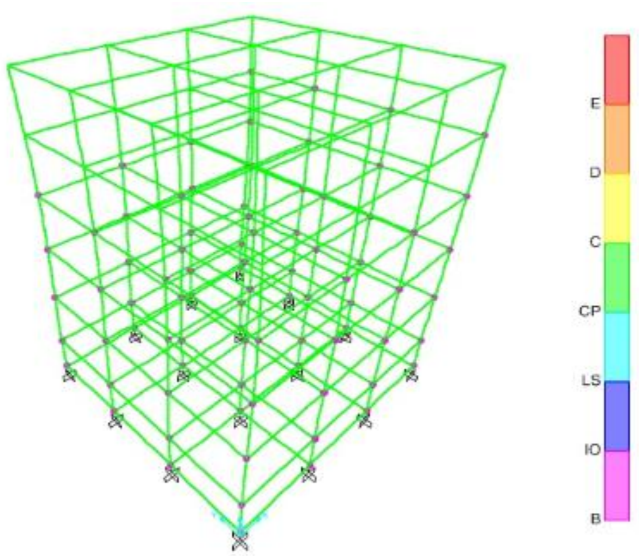


Fig: 7 Step 5 hinge mechanism in 3-D view

5.2 Results According to FEMA 356 (Coefficient Method)

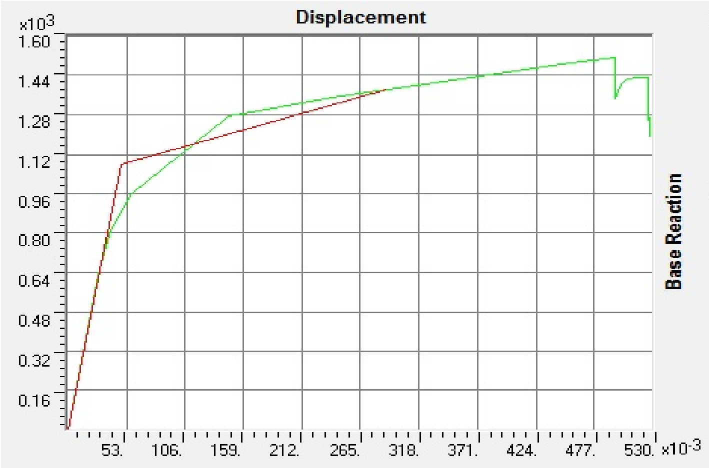


Fig.:8 Displacement coefficient curve

Table 5.3 Tabular data for capacity spectrum curve

Step	Displacement, (m)	Base Force,(kN)
0	0	0
1	0.027195	626.645
2	0.038493	812.892
3	0.056859	962.396
4	0.143651	1269.985
5	0.145789	1274.359
6	0.246559	1356.466
7	0.348705	1422.632
8	0.455601	1490.032
9	0.496137	1510.566
10	0.496147	1345.599
11	0.498092	1378.051
12	0.499579	1393.537
13	0.503786	1415.954
14	0.504936	1419.58
15	0.508075	1424.37
16	0.515478	1429.752
17	0.525908	1434.414
18	0.525918	1257.718
19	0.527204	1268.99

6. CONCLUSIONS

Building designed found to have a performance as follows:

- Under DBE, damage must be limited to Grade 2 (slight structural damage, moderate non-structural damage) in order to enable Immediate Occupancy after DBE.
- Under MCE, damage must be limited to Grade 3 (moderate structural damage, heavy non-structural damage) in order to ensure collapse prevention after MCE
- Pushover Analysis is an elegant tool to visualize the performance level of a building under a given earthquake
- The results in this study show that Indian Standard is very conservative in its approach.
- Performance increases on increasing reinforcement of columns only resulting into an appreciable decrease in the maximum roof displacement for symmetrical building. Decrease in roof displacement is maximum interior column and for corner and mid-face columns it is comparable
- Performance of the building decreases when the sectional sizes of beams and columns are reduced while keeping same reinforcement

ACKNOWLEDGEMENT

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