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Performance Based Seismic Design of Reinforced Concrete Building

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Abstract—*The basic concept of Performance Based Seismic Design is to provide engineers with the capability to design buildings that have a predictable and reliable performance in earthquakes. Performance based Seismic design is an elastic design methodology done on the probable performance of the building under input ground motions. The present study is an effort to understand Performance Based Design Approach. In this a ten storey unsymmetrical building is design using E-Tab and the performance based seismic design is performed by using a simple computer-based pushover analysis technique using E-Tab, a product of Computers and Structures International. The procedure compares the capacity of the structures (in the form of pushover curve) of a MDOF system with the demand of the structure. The method is formulated in acceleration displacement format. The graphical interaction of the two curves approximates the performance point of the structure. The proposed method is illustrated by finding the seismic performance point for a ten storey reinforced concrete framed building located in Zone-IV, unsymmetrical in plan (designed according to IS 456:2002). An extensive parametric study is conducted to investigate the effect of many important parameters on the Performance point. The parameter includes effect of input ground motion on performance point, size of column, beams individually. The results of analysis are compared in terms of base shear and storey displacements.*

Keywords*: Performance based seismic design, elastic response spectrum, shear wall, pushover analysis.*

1. NDRODUCTION

Among the natural hazards, earthquakes have the potential for causing the greatest damages. Since earthquake forces are random in nature and unpredictable, the engineering tools needs to be sharpened for analyzing structures under the action of these forces. Performance based design is gaining a new dimension in the seismic design philosophy wherein the near field ground motion (usually acceleration) is to be considered. Earthquake loads are to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damage is expected but it should be regulated. In this context pushover analysis which is an iterative procedure shall be looked upon as an alternative for the orthodox analysis procedures.

This study focuses on pushover analysis of multi-storey RC framed buildings subjecting them to monotonically increasing lateral forces with an invariant height wise distribution until the present performance level (target displacement) is reached. The promise of performance-based seismic engineering (PBSE) is to produce structures with predictable seismic performance. To turn this promise into a reality, a comprehensive and well coordinated effort by professionals from several disciplines is required.

The recent advent of performance based design has brought the non-linear static pushover analysis procedure to the forefront. Pushover analysis is a static, nonlinear procedure in which the magnitude of the structural loading is incrementally increased in accordance with a certain predefined pattern. With the increase in the magnitude of the loading, weak links and failure modes of the structure are identified. The loading is monotonic with the effects of the cyclic behavior and load reversals being estimated by using a modified monotonic force-deformation criteria and with damping approximations. Static pushover analysis is an attempt by the structural engineering profession to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design.

2. LITERATURE SURVEY

A brief review of the earlier works on PBSD is presented below in order to highlight the need for the present work. Detailed review of relevant literature is separately in the next chapter. Performance based design of building has been practiced since early in the twentieth century, England, New Zealand, and Australia had performance based building codes in place for decades [1]. The Inter-Jurisdictional Regulatory Collaboration Committee (IRCC) is an international group representing the lead building regulatory organizations of 10 countries formed to facilitate international discussion of performance based regulatory systems with a focus on identifying public policies, regulatory infrastructure, education, and technology issues related to implementing and managing these systems.

In 1989, the FEMA-funded project was launched to develop formal engineering guidelines for retrofit of existing buildings began (ATC, 1989), it was recommended that the rules and guidelines be sufficiently flexible to accommodate a much wider variety of local or even building specific seismic risk reduction policies than has been traditional for new building construction. The initial design document, [2] NEHRP Guidelines for the Seismic Rehabilitation of Existing Buildings, FEMA 273, therefore contained a range of formal performance objectives that corresponded to specified levels of seismic shaking. The performance levels were generalized with descriptions of overall damage states with titles of Operational, Immediate Occupancy, Life Safety, and Collapse Prevention. These levels were intended to identify limiting performance states important to a broad range of stakeholders by measuring: the ability to the building after the event; the traditional protection of life safety provided by building codes; and in the worst case, the avoidance of collapse.

Following the Northridge event, the Structural Engineers Associated of California (SEAOC, 1995) developed a PBSD process, known as Vision 2000 [3], which was more generalized than that contained in FEMA 273 but used similarly defined performance objectives.

Over the 10-year period after publication of FEMA 273, its procedures were reviewed and refined and eventually published in 2006 as an American Society of Civil Engineers (ASCE) national standard-Seismic Rehabilitation of Existing Buildings, ASCE 41. Although intended for rehabilitation of existing buildings, the performance objectives and accompanying technical data in ASCE 41 responded to the general interest in PBSD and have been used for the design of new buildings to achieve higher or more reliable performance objectives than perceived available from prescriptive code provisions. ASCE 41 is considered to represent the first generation of performance-based seismic design procedures.

3. MODELLING APPROACH

A 3-D model of ten storey RCC building has been created using E-Tab to undertake the non linear analysis. Beams and columns are modeled as nonlinear frame elements with lumped plasticity at the start and the end of each element. E-Tab provides default-hinge properties and recommends PMM hinges for columns and M3 hinges for beams as described in FEMA-356.

4. SEISMIC INPUT

The elastic response spectra with PGA levels of 0.2g is used as per IS Code 1893:2002. The elastic response spectra are changed to inelastic response spectra which are taken as seismic input.

5. PUSH OVER ANALYSIS

In pushover analysis, a static horizontal profile, usually proportional to the design force profiles specified in the codes, is applied to the structure. The force profile is then incremented in small steps and the structure is analyzed at each step. A s the loads are increased, the building undergoes yielding at a few locations. Every time such yielding takes place, the structural properties are modified approximately to reflect the yielding. The analysis is continued till the structure collapses, or the building reaches certain level of lateral displacement.

6. SIMULATION AND RESULTS

To illustrate the PBD procedure for finding the performance point, a ten storey unsymmetrical concrete frame is taken as an example. The properties of the concrete frame are shown in Table1. The frame is designed according to IS 456:2000 (with the superimposed vertical loads) using E-Tab. The frame is subjected to inelastic response spectrum as per IS code 1893-2002 for 5% damping (for medium soil). The pushover analysis is performed on the RC building (designed according to IS 456:2000) and reanalyzing by changing the size of columns and beams simultaneously. The pushover analysis has been carried out using E-Tab, products of Computers and Structures International.

A ten storey building frame located in Zone IV has been analyzed, size of different structural elements, i.e. beams and columns.

7. EFFECT OF CHANGE IN VARIOUS PARAMETERS ON THE PERFORMANCE OF THE BUILDING.

7.1 Effect of change of size of the columns and beams simultaneously.

7.2 Effect of providing shear wall on performance point.

Table 1: Properties of ten storeys RC frame

1	Size of Beams	300*550mm^2
2	Size of Columns	600*600mm^2
3	Thickness of Slab	150mm
4	Bay Width	6.0 m
5	Storey Height	3.0 m
6	Grade of concrete	M-30
7	Grade of Steel	Fe500
8	Shear wall	200mm

Table 2: Natural frequencies and Time periods

Mode Shapes	Period (sec)	Frequency (cycle/sec)
1	1.677	0.596
2	1.634	0.612
3	1.534	0.652
4	0.531	1.882

5	0.52	1.925
6	0.486	2.06
7	0.291	3.44
8	0.286	3.496

Table 3: Description of various cases

S. No	Case	Description of cases
1	A	Basic Structure
2	B	10% Inc. in columns size
3	C	20% inc. in columns size
4	D	10% dec. in columns size
5	E	20% dec in columns size
6	F	10% inc in Beams size
7	G	20% inc in Beams size
8	H	10% dec in Beams size
9	I	20% dec in Beams size
10	J	10% inc in columns and beams size
11	K	20% inc in columns and beams size
12	L	10% dec. in columns and beams size
13	M	20% dec. in columns and beams size

Table 4: Effect of change of size of beams and columns of the frame on performance point for PGA level 0.2g

S.N.	Case	Roof Displacement (mm)	% change in Roof Displacement	Base Shear (KN)	%change in Base Shear
1	A	0.095	-	2.0932	-
2	J	0.087	8.42	2.3792	-13.663
3	K	0.080	15.79	2.7023	-29.098
4	L	0.103	-8.42	1.8436	11.924
5	M	0.112	-17.89	1.6308	22.090

Table 5: Effect on performance point by changing the size of column and beam for PGA level 0.2g

S.N.	Case	Spectral Acceleration (Sa)	% change in Sa	Spectral Displacement (Sd)	% change in Sd
1	A	0.006876	-	0.003729	-
2	J	0.007486	-8.87	0.003426	8.125
3	K	0.008129	-18.22	0.003154	15.419
4	L	0.00631	8.231	0.004064	-8.984
5	M	0.005801	15.634	0.00442	-18.530

8. CONCLUSIONS

Based on the present study, the following conclusion can be drawn:

1. Pushover analysis is an elegant tool to visualize the performance level of a building under a given earthquake. It provides valuable information for the performance based seismic design of building frame.
2. Since frequencies are wide apart, thus for pushover analysis higher modes are neglected.
3. As the size increases, the roof displacement decreases whereas base shear increases.
4. As the size decreases, the roof displacement increases whereas base shear decreases.
5. As the size increases, the performance level of a building increases.
6. As the size decreases, the performance level of a building decreases.
7. By providing shear wall performance point of the building increases.

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