PERFORMANCE BASED SEISMIC DESIGN OF RCC BUILDING

Mr. Chetan Ingale[1], Prof. M.R.Nalamwar[2]

[1,2] Civil Engineering Department, Jagadambha college of Engineering and Technology, Yavatmal, 445105, (M.S.) India.

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Abstract: Every Civil Engineering structure or building is inimitable in nature unlike other engineering products which are constructed in a massive scale using the same technique repeatedly. The present Project is an attempt to understand Performance Based Design Approach. The performance-based seismic design approach enables us to design new structures more efficiently and to assess existing structures more realistically. The promise of performance-based seismic engineering is to construct structures with expected seismic performance. Performance based seismic design precisely evaluates how building is likely to perform in given possible earthquake threat. In performance based design identifying and assessing performance capacity of structure in an important part of design process, and guide the many decisions that must be made. Present study based on performance based seismic design and non-linear analysis of multi-storey RCC building. Performance based seismic design is an iterative process, begins with choice of performance objective followed by preliminary design, an evaluation whether or not the design meets the performance objective and finally redesign and reassessment, until desired performance level is achieved. In this project work we have carried out performance based seismic design of multi-storey (G+5) RCC building. Once design is complete, non-linear analysis is carried out to study seismic performance of building and found out whether selected objective is satisfied or not. In this work (G+5) RCC building is designed as per IS code (IS 1893 (Part 1): 2002, IS 456: 2000) for zone 5, 4 and 3 for Maximum Considered Earthquake (MCE) and Design based Earthquake (DBE) and a nonlinear static analysis is carried out using auto plastic hinges. After the building is designed it is imported to ETABS platform in order to carry out Pushover Analysis. The Displacement controlled Pushover Analysis was carried out and the Pushover Curve were obtained for the building as per guidelines mentioned in ATC 40. The Capacity Spectrum, Storey Displacement, Storey Drift, Demand Spectrum and Performance point of the building was found using the analysis carried out in ETABS 2015. These results were compared for each zone from which we can find out how the building will perform in different zones. From the Performance point it was found that the Building designed as per Indian standards was found to be well above Life safety performance level considering Designed Based Earthquake.

Keywords: Performance based seismic design, Performance objective, Capacity, Demand.

1. Introduction

The concept of performance based design evolved when designers started realizing that conventional code design method was not always the most appropriate method. Different structures have different performance requirements and it is not appropriate that the same prescriptive criteria be used for designing different structures. According to the code guidelines base shear is calculated on the basis of Importance factor (“I”), Zone factor (“Z”) and Average response acceleration coefficient (S_a /g). Calculated base shear is distributed to floor levels which depend on amount of mass present at storey level and its height. After the analysis for lateral forces gives design forces and moments and combined with forces and moments due to dead load and live loads according to load combinations stated in IS 1893(Part 1) : 2002 according to that we stabilize the structure by using IS 456:2000 followed by pushover analysis. Performance based seismic design suggest how a building will perform for given seismic hazard. Performance based design begins with the selection of performance objective then preliminary design and check whether the building meets the performance objective if not than redesign and reassessment if required.

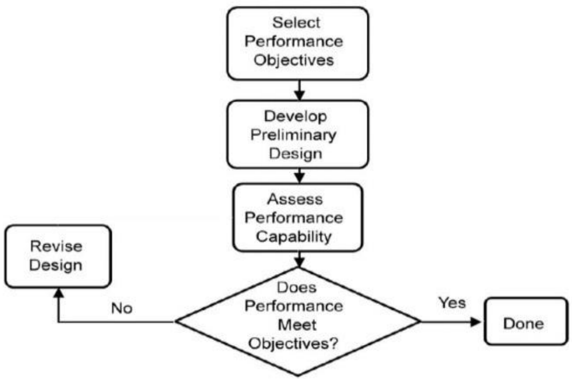

Fig.1 Performance based seismic design

Performance levels: In general, performance requirement can be categorized into four classes as operational (functioning fully after earthquake), immediate occupancy (slightly damaged but any minor repair could be done without disrupting the function of the building), immediate occupancy (slightly damaged but any minor repair could be done without disrupting the function of the building), life safety (damaged but reparable although the building may need to be evacuated for repair), collapse prevention (does not collapse although the building may be severely damaged requiring demolition.

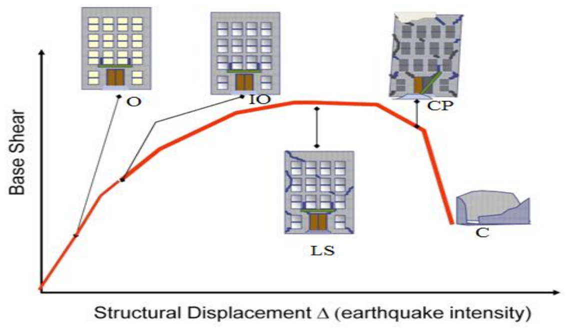

Fig: 2 Performance level

Performance objective: A desired level of seismic performance of the building (performance level) which describes maximum allowable structure or non structural damage for a specified level of seismic hazard. Seismic hazard and damage state are the two essential parts of a performance objective. Seismic performance is describe by designating the maximum allowable damage situation (performance level) for an known seismic hazard (earthquake ground motion).

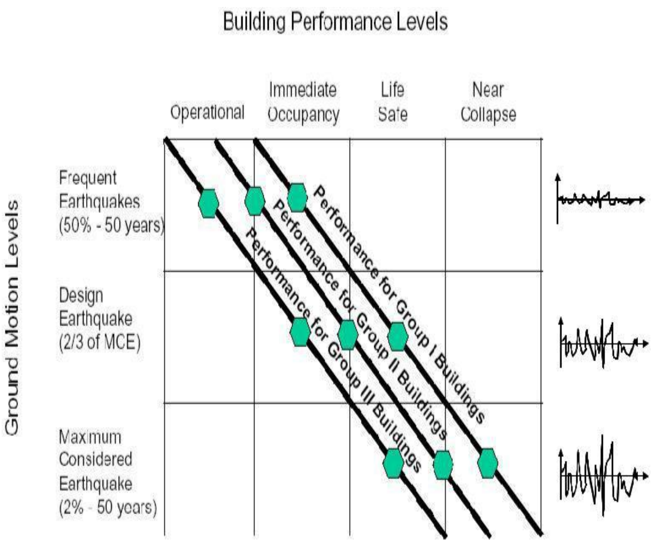

Fig: 3 Performance objectives

Seismic hazard: Seismic hazard at a site due to ground shaking are classified in three earthquake hazard levels

- The Serviceability Earthquake (SE)
- The Design Earthquake (DE)/ Design Based Earthquake
- The Maximum Earthquake (ME)/ Maximum Considered Earthquake

The Serviceability Earthquake (SE): Serviceability Earthquake is defined as the level of ground shaking that has a 50 percent chance of being exceeded in a 50 years period. This level of earthquake ground shaking is on average about 0.5 times the level of ground shaking of the design earthquake.

The Design Earthquake (DE) / Design Based Earthquake (DBE): The design earthquake is defined probabilistically as the level of ground shaking that has a 10 % chance of being exceeded in a 50 year period.

The Maximum Earthquake (ME) / Maximum Considered Earthquake (MCE): The maximum earthquake is defined deterministically as the maximum level of earthquake ground shaking which may ever be expected at the building site within the known geological framework. In seismic zone 3 and 4 this intensity of ground shaking may be calculated as the level of earthquake ground motion that has a 5% probability of being exceeded in 50 years time period. This level of ground shaking is typically about 1.25 to 1.5 times the level of ground shaking of the design earthquake.

Capacity: The expected ultimate strength (in flexure, shear, or axial loading) of a structural component excluding the reduction (Φ) factors commonly used in design of concrete members. The capacity usually refers to the strength at the yield point of the element or structure's capacity curve. For deformation-controlled components, capacity beyond the elastic limit generally includes the effects of strain hardening.

Capacity Curve: The plot of the total lateral force *V*, of a structure against the lateral deflection *d* of the roof of the structure. This is often referred to as the "pushover" curve.

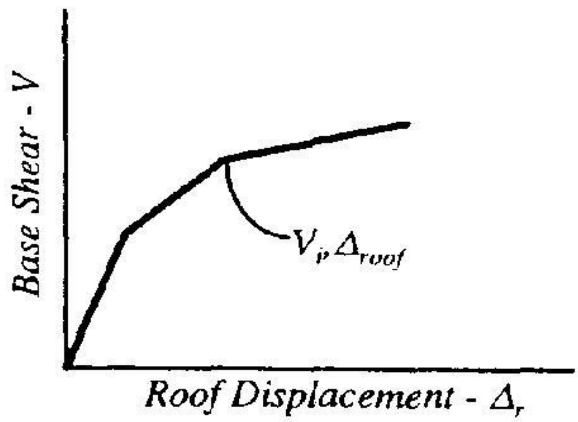

Fig: 4 Capacity curve

Demand (displacement): A representation of the earthquake ground motion or shaking that the building is subjected to. In nonlinear static analysis procedures demand is represented by an estimation of the displacements or deformations that the structure is predicted to experience.

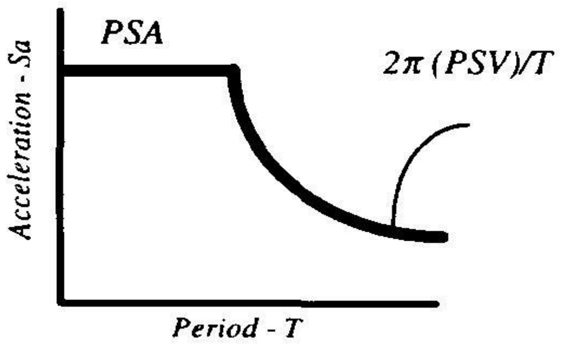

Fig: 5 Demand Curve

Performance: It is an intersection point of Capacity curve and Demand curve. The performance of building is depending upon the performance of structural and nonstructural components. From the performance point the performance of the structure is checked against performance levels mentioned above.

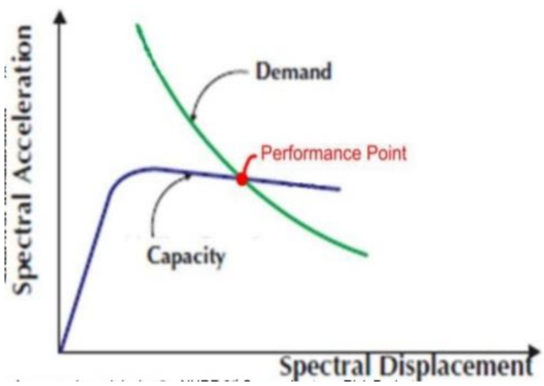

Fig:6 Capacity spectrum curve Performance point

2. METHODOLOGY

2.1 Basis of the procedure

In Nonlinear static procedure/Pushover analysis, the basic demand and capacity parameters from the analysis is the lateral displacement of the building. Capacity curve is the capacity of the building for particular force distribution and displacement i.e. base shear v/s roof displacement. If the building displaces laterally, its response must lie on this capacity curve. A point on the curve defines a specific damage state for the structure. By correlating this capacity curve to the seismic demand generated by a specific earthquake or ground shaking intensity, a point can be found on the capacity curve that estimates the maximum displacement of the building the earthquake will cause. This point defines the performance point or target displacement. Location of performance point on the capacity curve is related to the performance levels, which indicates whether or not the design meets the performance objectives, and finally redesign and reassessment, if required, until the desired performance objective is achieved.

In this present work, G+5 storied reinforced concrete frame building situated in zone 3, 4 and 5 maximum considered earthquake and design based earthquake is considered for this study. The number of bays and size is shown in Fig 7. The total height of the building is 18m. Slab thickness is considered as 120mm. Beam and column size is 500mm x 600 mm. The building is considered as Special RC moment-resisting frame (SMRF) with response reduction factor as 5.0. This building is considered as an educational building as per that Importance factor is considered as 1.5. Load combinations are taken as per IS 456: 2000 and IS 1893(part 1): 2002. Dead load on slab is taken as 5 Kn/m^2. Live load on slab is taken as 4 Kn/m^2 not considered on roof. Outer beams consist dead load of 12.5 kn/m and interior beams consist dead load of 8.1 kn/m. Capacity spectrum method is carried out as per guidelines mentioned in ATC 40.

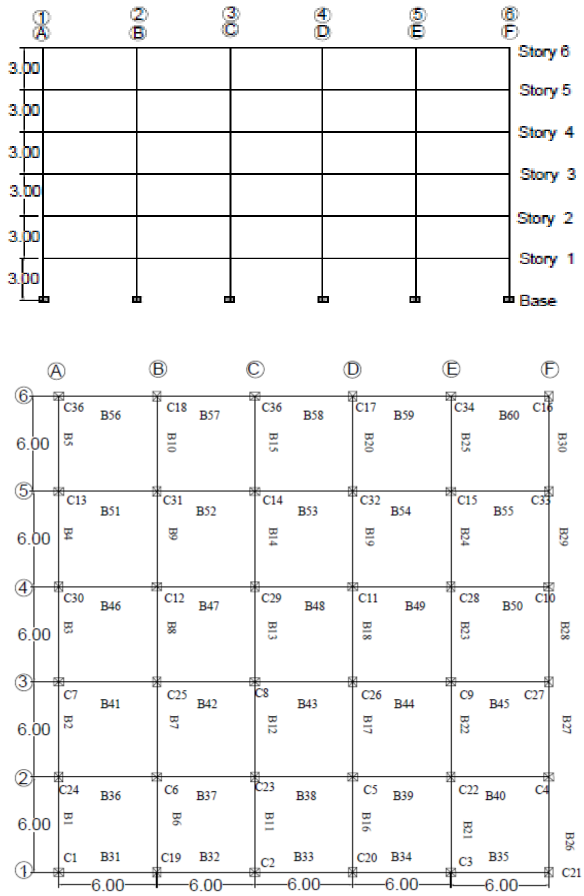

Fig: 7 Building Plan and Elevation

2.2 Pushover Analysis using ETABS

1] Create the basic computer model. Assign sectional properties, material properties and place columns, beams and supports to the structure, apply gravity load i.e. dead load and live load on the structure. Run analysis and find shear force and bending moments for the applied load and check whether structure is safe or not according to IS 456:2000.
2] Add lateral forces and allocate load combination as per IS 1893 (Part 1): 2002 and check whether structure is safe or not.
3] Add Response Spectrum function and assign Response spectrum load cases, and find out max storey displacement, max storey drift from Response spectrum method.
4] Add Time history function and assign Time history load cases, find out peak acceleration, velocity and displacement of the structure's response to a ground motion.
5] Define and modify Pushover load cases. In ETABS more than one pushover load case can be run in the same analysis. Pushover load cases can be force controlled i.e. pushed to a certain defined force level, or they can be displacement controlled, i.e. pushed to a specified displacement controlled. ETABS contains several built-in hinges that are based on average values from ATC- 40 for concrete members. M3 hinges have been defined at both the ends of all the beams and PMM hinges have been defined at both the column ends.
6] Assign pushover hinge properties to beams and columns by selecting all the frame members at particular hinge location, run pushover analysis.
7] The capacity curve and capacity spectrum curve is obtained. The performance point for a given set of values is defined by intersection of the capacity curve and the single demand spectrum curve. Observe plastic hinge formation sequence.

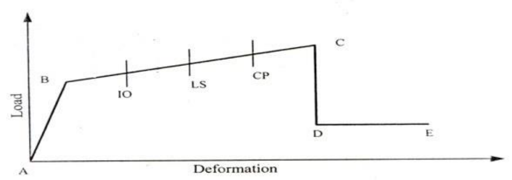

Fig: 8 Load-Deformation Curve

1 Point 'A' corresponds to the unloaded condition.
2 Point 'B' corresponds to the onset of yielding.
3 Point 'C' corresponds to the ultimate strength.
4 Point 'D' corresponds to the residual strength.
5 Point 'E' corresponds to the maximum deformation capacity with the residual strength.

3. Observation

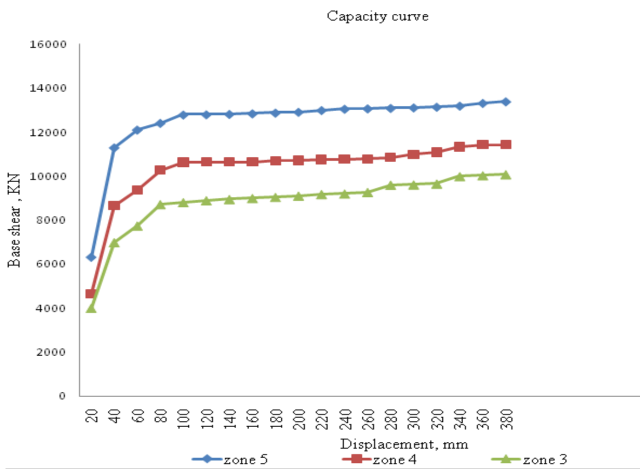

Fig:9 Comparison of Capacity Curve Zone 5, 4 and 3 Maximum Considered Earthquake

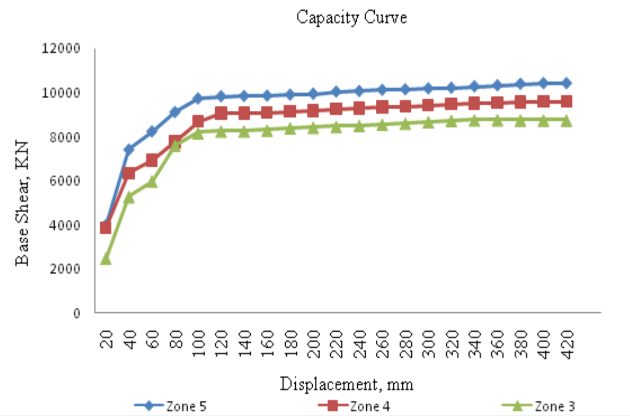

Fig: 10 Comparison of Capacity Curve Zone 5, 4 and 3 Design Based Earthquake

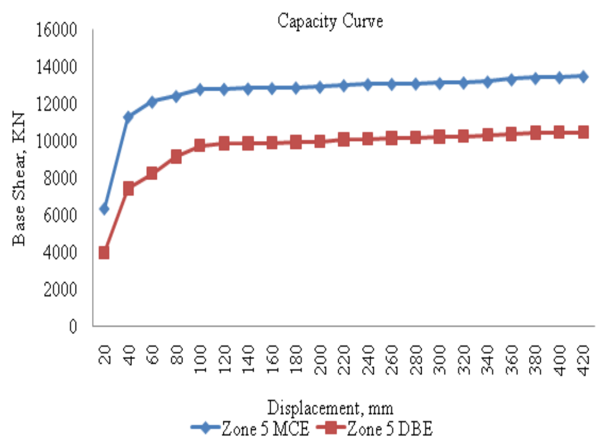

Fig: 11Comparison of Capacity Curve Zone 5 Design Based Earthquake and Maximum Considered Earthquake

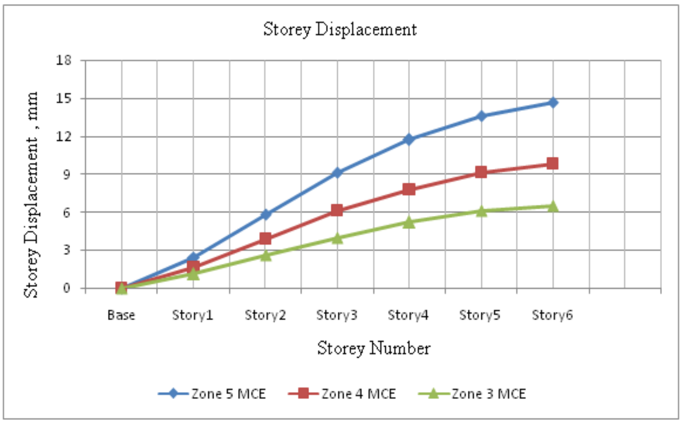

Fig: 12 Comparison of Storey Displacement Zone 5, 4 and 3 Maximum Considered Earthquake

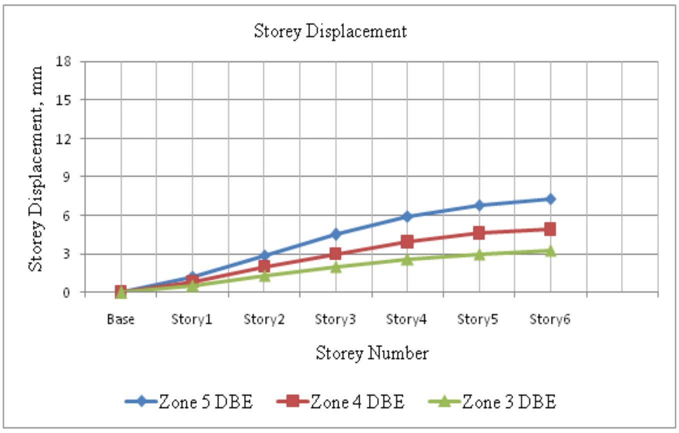

Fig: 13 Comparison of Storey Displacement Zone 5, 4 and 3 Design Based Earthquake

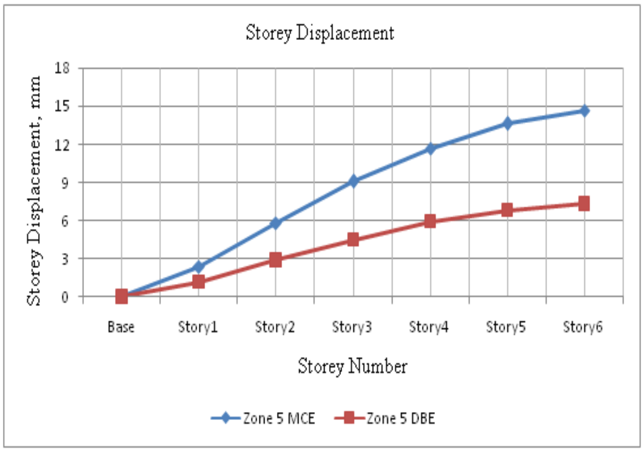

Fig: 14 Comparison of Storey Displacement Zone 5 Design Based Earthquake and Maximum Considered Earthquake

4.RESULTS

Table:1 Results obtained from storey displacement

Target roof displacement ratio's at various performance level				
Performance level	Operational	Immediate occupancy	Life safety	Collapse prevention
Lateral drift ratio=(δ/h)	0.37	0.7	2.5	5
Zone 3 DBE	0.17			
Zone 3 MCE	0.36			
Zone 4 DBE	0.33			
Zone 4 MCE		0.70		
Zone 5 DBE	0.40			
Zone 5 MCE		0.82		

Table:2 Results obtained from storey drift.

Performance Limit ATC40 Table no 11.2				
Inter story Drift Limit		Immediate Occupancy	Damage Control	Life Safety
Maximum Total Drift		0.01	0.01 – 0.02	0.02
Maximum Inelastic Drift		0.005	0.005 – 0.015	No Limit
Results obtained				
Inter story Drift Limit ZONE 3 RESP X	MCE			0.022
	DBE		0.010	
Inter story Drift Limit ZONE 4 RESP X	MCE			0.028
	DBE		0.016	
Inter story Drift Limit ZONE 5 RESPX	MCE			0.040
	DBE			0.024

Table:3 Results obtained from capacity spectrum curve.

Plastic hinge formation results						
	A-B	B-C	C-D	D-E	>E	Total hinges
	A-IO	IO-LS	LS-CP	>CP		
Zone 3DBE	1796	418	78	12		2304
Zone 3MCE	1908	392	4	0		2304
Zone 4DBE	2268	36	0	0		2304
Zone 4MCE	2000	296	0	8		2304
Zone 5DBE	1856	404	22	22		2304
Zone 5MCE	1918	378	0	8		2304

6. CONCLUSIONS

From the results it is concluded that storey displacement and storey drift both goes on increasing with increase of zone and are greater in MCE than DBE.

Base shear increases and displacement decreases as the zone increases hence load carrying capacity increases as the zone decreases.

By using performance based design we can find actual performance from practical point of building for applied zone, lower zone and farther zone.

Plastic hinges formed in columns and beams are within immediate occupancy and life safety, as they are designed with "strong column and weak beam concept".

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