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PERFORMANCE- BASED SEISMIC DESIGN OF A BUILDING

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ABSTRACT

Performance-Based Design (PBD) is a comparatively new and powerful approach to structural engineering born from constant hard work to resolve the differences between the actual observed performance and the expected performance of structures. The main objective of present study is to find the performance of building under earthquake using performance based seismic design. In present study different set of reinforcement are made at different levels to study the performance of building due to the earth quake force and finally the best suitable combination of reinforcement is given i.e. economical effective and whose damage is limited in order to get the immediate occupancy level. The second to find the performance point of the building and to compare the seismic reaction of building in terms of base shear, storey drift, Spectral acceleration, storey displacement and spectral displacements. Then the resultant roof displacement will be compared with target displacement and if resultant displacement is lower than target displacement, then design will be performance based seismic design. And finally performance based design will be compared with code based design. The effect of shear wall, on Performance of building is also observed.

Keyword: Performance-Based Design,storey drift, Spectral acceleration, storey displacement

I. INTRODUCTION

Due to the effects of major earthquakes since 1980, it has accomplished that seismic risk has been high in urban areas are increasing much from socio economically acceptable levels. There must be more reliable seismic standard and codes then the presently available at this time. Performance base design is a tool for reducing damage by applying specific estimation of proper response parameter. It would only be possible by using more reliable analysis including all possible important factors involved in structure behavior.In present work, reinforced concrete frame structure in zone 4 will be designed according to Indian code 456:2000 by using Staad, Same RC frame structure will be designed by considering only gravity loads for getting initial reinforcement. Then it will be analyzed by sap 2000-14 by using push over analysis. It will be redesign by changing the main reinforcement of various frame elements. It will be analyzed again and again for getting the best possible combination of reinforcement that is economical, effective and whose damage is limited in order to get Immediate Occupancy level. This is termed as Performance Based seismic Design. The effect of shear wall, on Performance of building is also observed.

II. MODELLING AND ANALYSIS

In the present work, a four storey RC frame building situated in zone IV has been taken for the purpose of study. It will be designed by STAAD and analyzed by SAP by using Push over analysis to bring the building in immediate occupancy level.

2.1 Description of building

The plan area of building is 12 x 8 m with 3.5m as height of each typical storey. It consists of 2 bays of 6m each in X-direction and 2 bays of 4m each in Y-direction. Hence, the building is symmetrical about both the axis. The total height of the building is 14m. The building is considered as a Special Moment resisting frame. The plan of building, front elevation and 3D view is shown in fig. 2.1, fig. 2.2 and fig 2.3

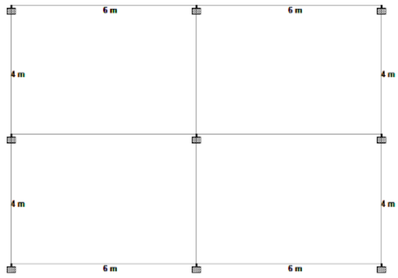

Figure 2.1 Plan of building

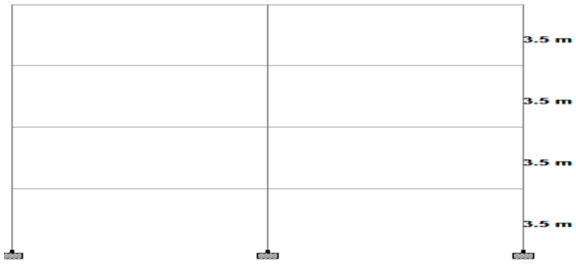

Figure 2.2 Elevation of building

2.2Properties of element

2.2.1 Material properties

- Concrete – M 30
- Steel –HYSD reinforced of grade FE 415 confirming to IS: 1786.

2.2.2 Sectional properties

I. Size of beam -250 x 450 mm
II. Size of column -350 x 350 mm
III. Thickness of slab -150 mm

After calculating seismic base shear, lateral force are calculated by using the formula given by IS 1893;2002. Storey wise lateral load distribution is given in table 2.1. And figure 2.4 shows lateral load distribution on building.

Table 2.1 Lateral load distribution at different storey height

STOREY LEVEL	W_i	h_i	$W_i h_i^2$	V_b	$\frac{(w_i)(h_i^2)}{\sum(w_i)(h_i^2)}$	Lateral force at i level for EL in direction (kN)	
						x	**z**
4	902.56	14.0	176901.76	308	0.422	130	130
3	1411.56	10.5	155624.49	308	0.37	114	114
2	1411.56	7	69166.44	308	0.16	50	50
1	1411.56	3	17291.61	308	0.04	13	13
$\sum$			418984.3			307	307

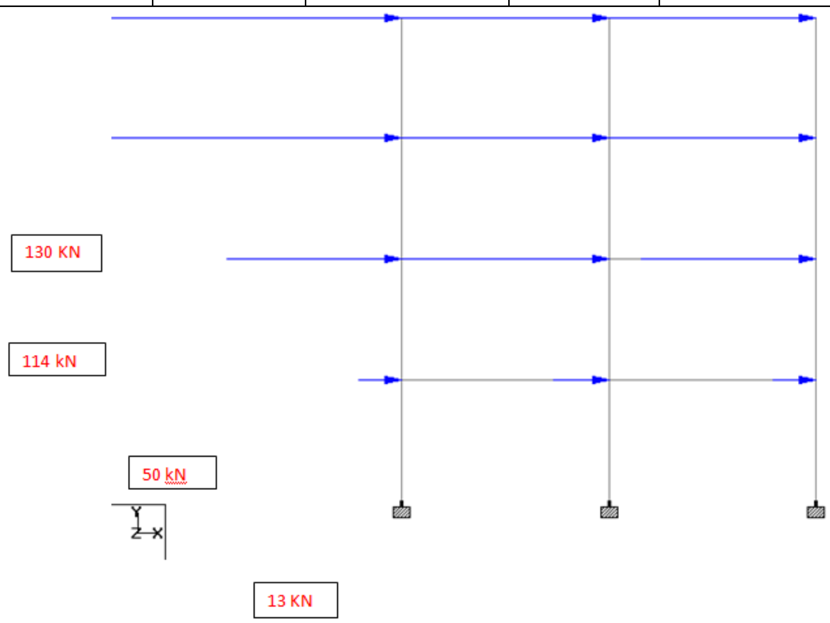

Figure 2.4 lateral load on frame structure

2.3 Assumption

I. Materialis "isotropic, homogeneous and linearly elastic".
II. Supports at the columns are fixed.
III. In the case of bending, tensile strength is ignored.
IV. Structure is analysed, assuming the foundation is fixed.
V. In pushover analysis, plastic hinges are assigned at the end of member. In beam M3 hinges are provide and in column PMM hinges are provided-
M3 < bending moment hinges>
PMM <axial force and bi axial moment hinges>
VI. Maximum target displacement is 2.5 % of the total height of building.

2.4 Reinforcement of structure

Reinforcement obtained from STAAD is given in table 2.2

Table 2.2Reinforcement of element

Sr.no.	Storey	Corner column	Mid column	Interior column	Beam	
					Top	Bottom
1	G.F	452.39	803.84	1256.4	1570	785
2	F.F	452.39	803.84	803.84	1406	785
3	S.F	803.84	803.84	803.84	1471	785
4	T.F	1256.4	803.84	1256.4	1130.4	785

2.5 Step by step procedure of pushover analysis in SAP2000

1) First we have to create a 3d frame model.
2) After we have to define material using define command by modifying the properties of M30 and Fe415.
3) Then we have to define frame sectional properties.
4) After that we have to assign push over hinges. In sap 2000 they have default properties of hinges based on FEMA 273 for steel and ATC 40 for concrete members. In this work we define M3 hinges at both end of beams and PMM hinges at both end of column.
5) Then we define the load pattern of push over analysis.
6) The first pushover load case is to run gravity load condition. This is force controlled; it pushed to a defined force level. It starts from a zero initial condition and the Gravity load case is combination of (DL+25LL).
7) Then we define push load case which is displacement controlled, which can be pushed to a specified displacement. It starts from the state where the of gravity load case end.
8) After analysis we got the pushover curve and its table explaining the performance of structure.
9) Then we got the capacity spectrum curve and its table was generated.
10) Model showing deformed shape indicating formation of hinges during push over analysis and showing which hinges lies in which acceptances criteria.

2.6 Cases observed in present work

I. Effect of change in reinforcement on the roof displacement at different storey level is studied.
II. Effect of change in reinforcement on the base force at different storey level is studied.
III. Different combination of reinforcement is provided at each storey level and its effect on the performance of building is observed.
IV. Shear wall is provided ant its effect on the roof displacement and base force is observed.
V. After that performance based is done by increasing the reinforcement of element at different storey level by iteration method or hit and trial method.

2.7 Analysis result

2.12 Effect of change in reinforcement on roof displacement and base force are given in table 2.4 and table 2.5 and its results are discussed below.

I. It has been observed that by increasing the reinforcement in the beams of ground floor, there is a decrease in the roof displacement.
II. In case of first storey beams, if we increase the reinforcement there will be decrease in the roof displacement.
III. There is no effect on roof displacement, if we increasing reinforcement on second and third storey beams.
IV. It has been observed that when the reinforcement in beams of ground storey is increased then base force ranges from -7.56 to 6.8 %.
V. It has been observed that when the reinforcement in beams of first storey is increased then base force ranges from -5.56% to 7%.
VI. There is no effect on base force, on increasing reinforcement of second and third storey beam.
VII. It has been observed that there is decrease in roof displacement when the reinforcement of ground and first storey columns is increased.
VIII. There is no change in roof displacement by increasing the reinforcement of second and third storey columns.
IX. There is large increase in base force when reinforcement of ground and first storey column is increased.
X. It has been observed that there is no effect on base force, on increasing reinforcement of second and third storey columns.
XI. It has been found that there is a decrease in 70% of roof displacement, if we provide shear walls in the building.
XII. There is increase in base force of 8.96% when the shear wall is provided.

2.8 Performance based seismic design

For Performance based seismic design, we are increasing the reinforcement of various element of structure, so that after performing nonlinear pushover analysis the building lies in immediate occupancy level. We are using hit and trial method for the analysis. We are using table 2.3 given by FEMA for performance based seismic design.

It means drift ratio of the building after analysis is 0.7% of the total height of the building.

Table 2.3 Different performance level of building

Performance level	**Operational**	**Immediate occupancy**	**Life safety**	**Collapse prevention**
Drift ratio($\frac{\delta}{h}$)	**0.37**	**0.7**	**2.5**	**5**

(NEHRP seismic rehabilitations guidelines <ATC 2000> FEMA 356)

Total height of building is 14 m.

Therefore roof displacement

- Immediate occupancy-.(0.7×14)= 98mm
- Life safety level-(2.5×14)= 350mm

Our Target displacement (δ -Lateral roof displacement) should be less than 98mm.

Roof displacement of basic structure building is 224.8mm

Roof displacement of performance based design is 83.3mm

This is less than the target displacement.

After that different form of coded design are compare in table 4.4 at each storey level. And it has been observed that in performance based seismic design, there is a decrease in reinforcement in some members of the structure when compared to building designed by IS 1893:2002.

Different graphs are drawn indicating the performance of structure. Graph given in figure 2.5 indicate roof displacement of normal design is more than performance based design. If we apply shear wall on building it roof displacement decreases appreciably as indicated by figure 2.6 and 2.7 and all three performance of building at different retrofitting are compared in figure 2.8 and it was found that roof displacement is minimum in case of shear wall.

Table 2.4 Effects of change in reinforcement on roof displacement

Cases	Element	Reinforcement Increase in %	Roof displacement	Roof displacement (Change in %)
			224.927	
Case 1	Beam G.F	5 %	211.302	-6.05%
Case 2	Beam G.F	8 %	206.709	-8.09%
Case 3	Beam G.F	15%	202.709	-9.87%
Case 4	Beam F.F	8 %	204.200	-9.21%
Case 5	Beam F.F	15 %	205.200	-8.77%
Case 6	Beam F.F	20%	204.200	-9.21%
Case 7	Beam S.F	5%	224.927	NO CHANGE
Case 8	Beam S.F	10%	224.927	NO CHANGE
Case 9	Beam S.F	20%	224.927	NO CHANGE
Case 10	Beam T.F	5%	224.927	NO CHANGE
Case 11	Beam T.F	20%	224.927	NO CHANGE
Case 12	Column GF & FF	12%	193.589	-13.93&
Case 13	Column GF & FF	36%	182.658	-18.75%

Case 14	Column SF & TF	12%	224.927	NO CHANGE
Case 15	Column SF & TF	36%	224.927	NO CHANGE
Case 16	Shear wall		55	75%

Table 2.5 Effects of change in reinforcement on base force

Cases	Element	Reinforcement Increase in %	Base force	Base force (Change in %)
			904.349	
Case 1	Beam G.F	5 %	835.931	-7.56%
Case 2	Beam G.F	8 %	856.281	-5.31%
Case 3	Beam G.F	15%	966.864	6.8%
Case 4	Beam F.F	8 %	853.704	- 5.56%
Case 5	Beam F.F	15 %	863.527	- 4.5%
Case 6	Beam F.F	20%	968.464	7%
Case 7	Beam S.F	5%	904.349	NO CHANGE
Case 8	Beam S.F	10%	904.349	NO CHANGE
Case 9	Beam S.F	20%	904.349	NO CHANGE
Case 10	Beam T.F	5%	904.349	NO CHANGE
Case 11	Beam T.F	20%	904.349	NO CHANGE
Case 12	Column GF & FF	12%	954.058	5.53%
Case 13	Column GF & FF	36%	1147.107	26.88%
Case 14	Column SF & TF	12%	904.349	NO CHANGE
Case 15	Column SF & TF	36%	904.349	NO CHANGE
Case 16	Shear wall		985.557	8.96%

Table 2.6 Showing reinforcement (mm^2) of beam and columns for different forms of designs.

Structure element	IS 456:2000		Performance based seismic design		IS 1893:2002	
	Top	Bottom	Top	Bottom	Top	Bottom
Beam G.F	1570	785	2511	785	1570	785
Beam F.F	1406	785	1884	785	1471	785
Beam S.F	1130	785	803	785	1471	785
Beam T.F	1130	785	803	785	1130	785
Corner Column G.F	452.39		1884		1256.4	
Corner Column F.F	452.39		1884		1256.4	
Corner Column S.F	803.4		803.4		1256.4	

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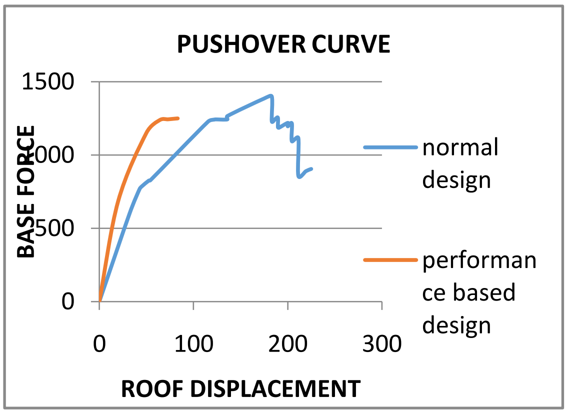
Corner Column T.F	1256.4	803.4	1256.4
Mid Column G.F	803.4	1884	1256.4
Mid Column F.F	803.4	1884	1256.4
Mid Column S.F	803.4	803.4	1256.4
Mid Column T.F	803.4	803.4	1256.4
Interior Column G.F	1256.4	1884	1256.4
Interior Column F.F	803.4	1256.4	1256.4
Interior Column S.F	803.4	803.4	1256.4
Interior Column T.F	1256.4	803.4	1256.4



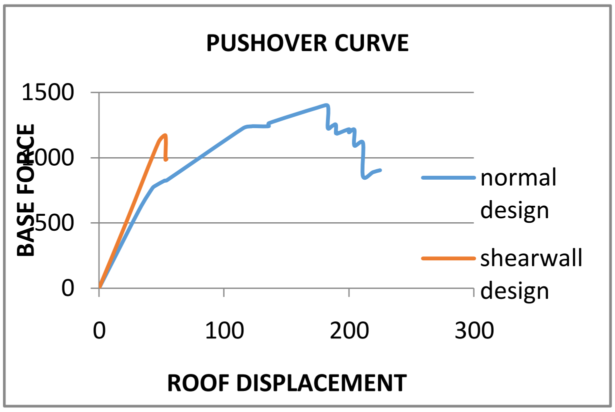
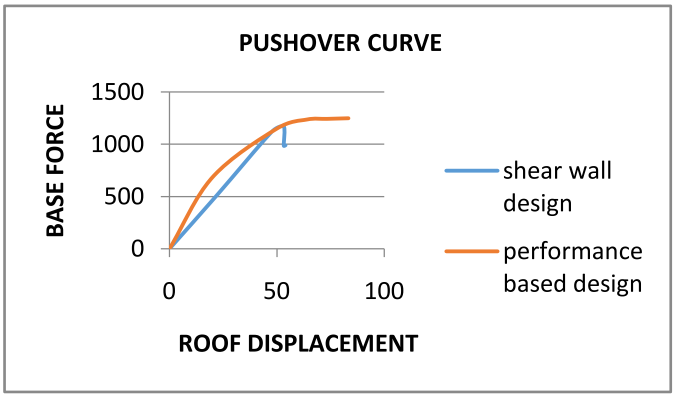


Fig.2.5 Difference in performance of building

Fig. 2.6 Performance with and without shear wall



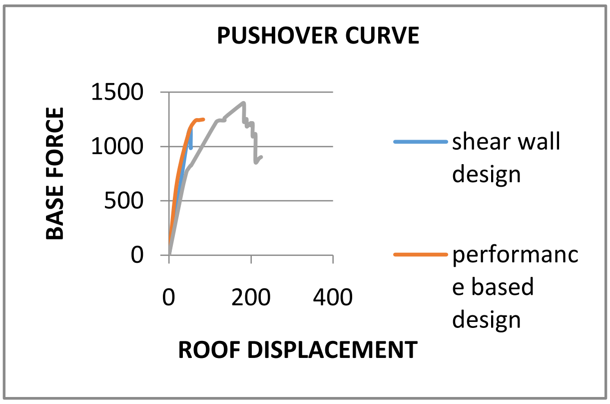


Figure 2.7 Performance of building

Figure 2.8 Difference in performance of building

3.1 Conclusion and Recommendation

In the present study, a four storey frame building performance has been analysed using Pushover analysis. Pushover performance had been carried out by SAP2000 (nonlinear software tool). The effect of different combination of reinforcement has been seen and its effect on the performance of building is observed. The shear wall on the building is studied and its effect on the performance is also observed.

The main conclusion are summarized below;

I. It has been observed that on increasing the reinforcement of ground storey beam, structure performance also improved.

II. On increasing the reinforcement of first storey beam, structure performance increases up to some limit then after its performance remain same. And it is observed that, there is no effect in performance of building on increasing the reinforcement of second and third floor.

III. Roof displacement decreases on increasing reinforcement of ground floor beam and first floor beam but there is no variation of roof displacement in cases of second and third storey.

IV. There is a variation in base force on increasing the reinforcement of ground storey and first storey beam. While there is no variation in base force is found on changing the reinforcement of second and third storey beams.

V. It has been observed that there is appreciable change in roof displacement on increasing reinforcement of ground and first storey columns while there is no change in roof displacement if we increase the reinforcement of second and third storey columns.

VI. There is large increase in base force when reinforcement of ground and first storey column is increased but there is no change in base force when reinforcement of second and third storey is increased.

VII. It has been observed that, by providing shear wall there is an appreciable decrease in roof displacement of the building.

VIII. There is an increase in base force by on providing shear wall in the building.

IX. After doing all the arrangement it has been observed the building is coming in acceptance criteria of immediate occupancy for various level of earthquake in zone four.

X. It has been observed that in performance based seismic design, there is a decrease in reinforcement in some members of the structure when compared to building designed by IS 1893:2002.

XI. It has been observed that for the building to be in immediate occupancy level, reinforcement of ground and first storey floor has been increased but reinforcement of second and third floor members had been reduced as compared to reinforcement designed by of IS1893:2002.

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