Seismic Performance Evaluation of RCC Buildings with Different Structural Configurations

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Abstract

This paper explores the comparative study of building performances at its performance points with two different response reduction factors. RCC Building with Bare Frame, RCC Building with Shear Wall and RCC Building with Stiffness Asymmetry, these three types of buildings are used for obtaining better objective of the study. Pushover Analysis is performed in SAP2000 to get performance of the building.

1 INTRODUCTION

Amongst the natural hazards, earthquakes have the potential for causing the greatest damages. Since earthquake forces are random in nature & unpredictable, the engineering tools need to be sharpened for analyzing structures under the action of these forces. Pushover analysis which is an iterative procedure is used to get the performance point of the building which gives the lateral load carrying capacity of building and also provides information of hinges in building which declares the performance objective.

Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached. Pushover analysis consists of a series of sequential elastic analysis, superimposed to approximate a force-displacement curve of the overall structure. A two or three dimensional model which includes bilinear or trilinear load-deformation diagrams of all lateral force resisting elements is first created and gravity loads are applied initially. A predefined lateral load pattern which is distributed along the building height is then applied. The lateral forces are increased until some members yield. The structural model is modified to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield. The process is continued until a control displacement at the top of building reaches a certain level of deformation or structure becomes unstable. The roof displacement is plotted with base shear to get the global capacity

curve. These capacity curve is compared with demand curve and the intersection of both the curves is the Performance Point. By performance point, result will shows the hinges of building in each performance levels. From that result performance objective will be obtained and by changing the design it is possible to set performance objective of any building and that design is called a Performance Based Design (PBD).

In last decade, many researchers had focused on the application of the performance based design. Jose et al.,[A] has analyzed the finite element models with various complexity are used in different types of analysis using linear-static, multi-mode pushover, and non-linear dynamic analysis. In conclusion, performance based seismic design is common in local structural engineering practice, as well as in the awareness of the real estate developers in the Philippines. Dubal et al.,[H] deals with application of Performance based seismic design method for soft storey RC building frames (10 storeys). Push over analysis results show significance of PBSD method in frames having soft story at lower floor level compared to higher ones. And concluded that performance point of the frames (vertical irregularity of soft storey) designed by performance based seismic design (PBSD) method is enhanced than for all frames designed by conventional method.

Based on the brief literature review presented here, it is observed that comparison of performance of building by changing response reduction factor is not done yet. The objectives of the present study have been identified as follows:

- To carry out the performance based analysis to obtain performance levels of buildings for the future earthquake and also to understand its collapse mechanism in case of extensive damage.
- To obtain performance of building by changing response reduction factor in different types of buildings.

2   NUMERICAL STUDY

In Software SAP2000, Nonlinear is utilized to create 3D models and run all analyses using FEMA 356 and ATC 40. The software is able to predict the geometric nonlinear behaviour of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity. Three models have been analysed by using two response reduction factor which are 5 and 3, (1) RCC building with bare frame (2) RCC building with full shear wall (3) RCC building with stiffness asymmetry.

Plan dimension of structure: 15 x 15 m

- Nos. of bays in X-direction: 3
- Nos. of bays in Y-direction: 3
- Floor height: 3.5 m
- Slab thickness: 120 mm
- Size of columns:
    - CASE 1, 2 = 350 x 350 mm
    - CASE 3, 4 = 450 x 450 mm
    - CASE 5, 6 = 500 x 500 mm
- Floor finish load: 1 kN/m2
- Zone: V

- Size of beams:
    - CASE 1, 2 = 230 x 460 mm
    - CASE 3, 4 = 230 x 460 mm
    - CASE 5, 6 = 350 x 550 mm
- Thickness of masonry wall:
    - EXTERNAL = 230 mm
    - INTERNAL = 115 mm
- Live load: 3 kN/m2
- Seismic code: IS 1893 (Part 1) 2002
- Design code: IS 456:2000
- Response reduction factor:

o Ordinary RC moment-resisting
   force (OMRF) = 3

o Special RC moment-resisting
   force (SMRF) = 5

I.   RCC Building with Bare Frame (R=5)
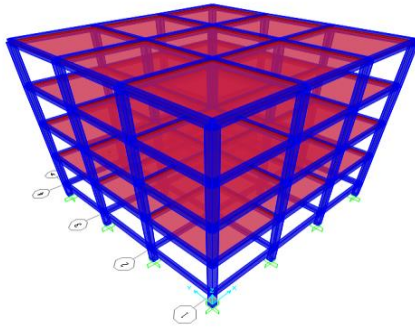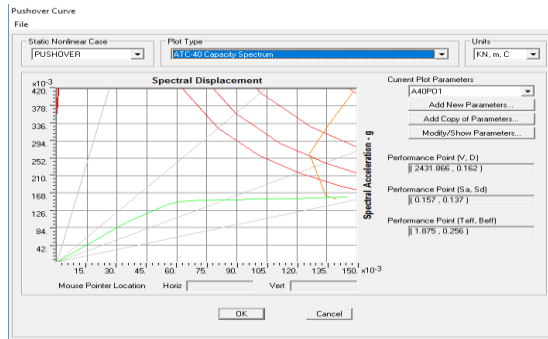

FIG.1: 3D view of RCC Building   FIG.2: Performance Point (R=5)

Figure 1 shows 3D view of RCC building with bare frame. The capacity spectrum curve obtained from nonlinear static analysis is shown in Figure 2. The ultimate lateral load carrying capacity of building at performance point is around 2431.86 kN and the corresponding roof displacement is 162 mm.

Step	Displacement	BaseForce	AtoB	BtoIO	IOtoLS	LStoCP	CPtoC	CtoD
	m	KN						
0	9.546E-17	0.000	400	0	0	0	0	0
1	0.043831	1388.243	399	1	0	0	0	0
2	0.070283	2042.103	350	50	0	0	0	0
3	0.076959	2136.019	325	75	0	0	0	0
4	0.089060	2206.164	304	96	0	0	0	0
5	0.154243	2409.676	280	64	41	15	0	0
6	0.171516	2460.083	273	69	14	42	0	2

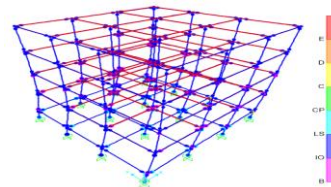FIG.3: Hinges of Performance Levels (CASE-1)   FIG.4: Deflected Shape of Building

At performance point, out of 400 assigned hinges, 273 hinges were in linear range, 69 were in B – IO (Immediate occupancy) range, 14 were in IO – LS (Life safety) range, 42 were in LS – CP (Collapse Prevention) and 2 were in C – D (Collapse). Thus the overall building performance is considered to be in Collapse.
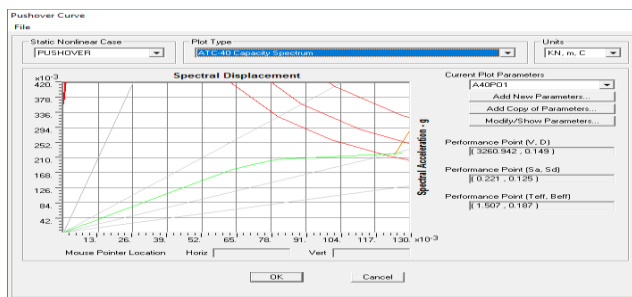
II.   RCC Building with Bare Frame (R=3)

FIG.5: Performance Point (R=3)

Step	Displacement m	BaseForce KN	AtoB	BtoIO	IOtoLS	LStoCP	CPtoC	CtoD
0	9.557E-17	0.000	400	0	0	0	0	0
1	0.062000	1963.683	400	0	0	0	0	0
2	0.079665	2523.180	396	4	0	0	0	0
3	0.097072	2910.895	372	28	0	0	0	0
4	0.101241	2963.078	364	32	4	0	0	0
5	0.151954	3278.893	332	36	14	16	0	2

FIG.6: Hinges of Performance Levels (CASE-2)

At performance point, the ultimate load carrying capacity of building is 3260.94 kN and the corresponding roof displacement is 149 mm. And it is observed that, out of 400 assigned hinges, 332 hinges were in linear range, 36 were in B – IO (Immediate occupancy) range, 14 were in IO – LS (Life safety) range, 16 were in LS – CP (Collapse Prevention) and 2 were in C – D (Collapse). Thus, the overall building performance is considered to be in Collapse.

By comparing both the cases 1 & 2, it is observed that, there 2 hinges of both the cases are in Collapse level but if that will be recovered by changing the design of that particular member then both the cases will comes in Collapse Prevention Level. As observed, performance of model having response reduction factor 3 is more preferable than model having response reduction factor 5, because Lateral Load Carrying Capacity increases thus Displacement decreases and also hinges at collapse prevention level is more in case 1.
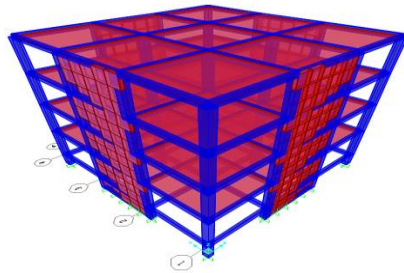
III. RCC Building with Shear Wall (R=5)

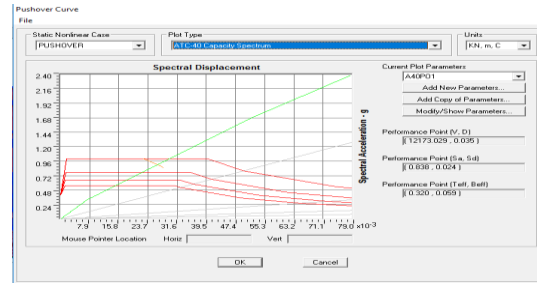FIG.7: 3D view of RCC Building with Shear Wall   FIG.8: Performance Point (R=5)

Step	Displacement m	BaseForce KN	AtoB	BtoIO	IOtoLS
0	-1.079E-17	0.000	408	0	0
1	0.010201	4663.021	407	1	0
2	0.074515	24248.724	240	168	0

FIG.9: Hinges of Performance Levels (CASE-3)

At performance point, lateral load carrying capacity of structure is 12173.029 kN with a displacement of 35 mm and also have developed 168 hinges in immediate occupancy level.

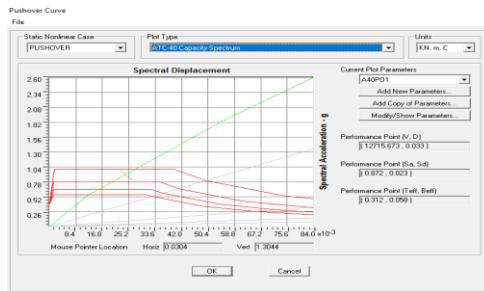## IV. RCC Building with Shear Wall (R=3)

Step	Displacement m	BaseForce KN	AtoB	BtoIO	IOtoLS
0	-1.079E-17	0.000	408	0	0
1	0.017166	7846.898	407	1	0
2	0.080748	27108.645	229	175	4

FIG.10: Performance Point (R=3)   FIG.11: Hinges of Performance Levels (CASE-4)

At performance point, lateral load carrying capacity of structure is 12175.673 kN with a displacement of 33 mm and also have developed 175 hinges in immediate occupancy level and 4 hinges in life safety.

By comparing cases 3 & 4, there were not much difference observed in lateral load carrying capacity and displacement, but it is observed that, Performance of case 3 is more preferable than case 4 because case 4 is in life safety level while case 3 is in immediate occupancy.

V.   RCC with Stiffness Asymmetry (R=5)

For stiffness asymmetry in cases 5 and 6, as per IS 1893 (part 1): 2002

$$K_i < 0.7\ K_{i+1}$$

For that, no shear walls are provided at ground and first floor and at second and third floor, four shear walls are provided of 5 m length and 200 mm thickness.
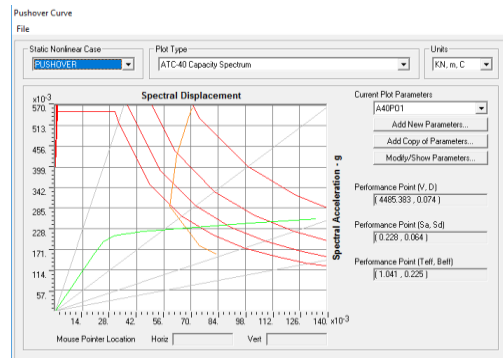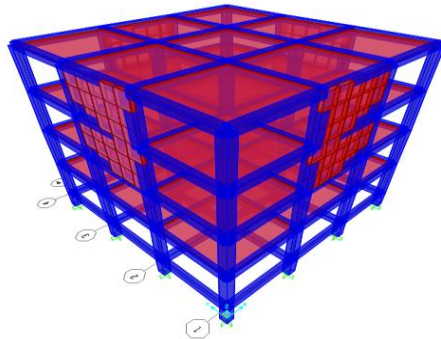

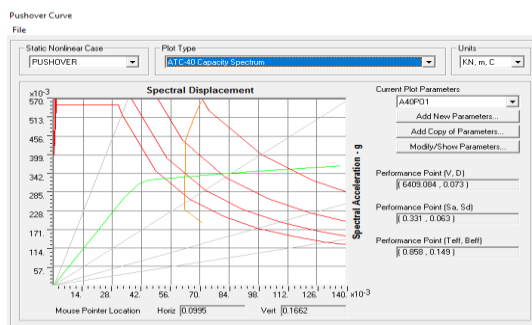FIG.12: 3D view of RCC Building with Stiffness Asymmetry   FIG.13: Performance Point (R=5)

At performance point, lateral load carrying capacity of structure is 4485.383 kN with a displacement of 74 mm and also have developed 84 hinges in immediate occupancy and 55 hinges in life safety.

Step	Displacement	BaseForce	AtoB	BtoIO	IOtoLS
	m	KN			
0	-5.074E-17	0.000	400	0	0
1	0.022488	2937.151	399	1	0
2	0.028569	3628.353	367	33	0
3	0.035527	3992.990	332	68	0
4	0.052440	4288.731	295	105	0
5	0.115218	4849.366	261	84	55

FIG.14: Hinges of Performance Levels (CASE-5)

VI.   RCC with Stiffness Asymmetry (R=3)

Step	Displacement	BaseForce	AtoB	BtoIO	IOtoLS
	m	KN			
0	-5.075E-17	0.000	400	0	0
1	0.038949	5087.207	398	2	0
2	0.047008	5869.791	358	42	0
3	0.053415	6150.298	331	69	0
4	0.108342	6878.782	286	64	50

FIG.15: Performance Point (R=3)   FIG.16: Hinges of Performance Levels (CASE-6)

At performance point, lateral load carrying capacity of structure is 6409.084 kN with a displacement of 73 mm and also have developed 64 hinges in immediate occupancy level and 50 hinges in life safety.

By comparing cases 5 & 6, it is observed that there is not much difference in hinges and displacement in structure. According to the result it is drawn that model 6 is preferable because of having more lateral load carrying capacity then case 5.

By comparing cases 3 & 5, it is observed that lateral load carrying capacity decreases highly in stiffness asymmetry and hinges increases because the performance level of the case 5 is life safety while performance level of case 3 is immediate occupancy.

3 CONCLUSIONS

Based on the analysis carried out in the present study, the following conclusions can be drawn:
- The seismic performance level as well as the hinge formation significantly depends on the response reduction factor.
- The lateral load resisting capacity of the building increases with the decrease in response reduction factor.

The building with stiffness asymmetry suffers more damage and more number of hinges towards collapse level as compared to the building with full shear wall.

4 REFERENCES

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