Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 5, Issue 5; April-June, 2018, pp. 285-288

http://www.krishisanskriti.org/Publication.html

Seismic Performance of Indian Code ATC-40 Designed RC Buildings

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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. In present study is an effort to understand performance based seismic design approach. The two building model are considered having symmetric rectangular and square plan building. Both the buildings are analyzed by software SAP2000 vs.14. The pushover analysis in that capacity spectrum method is used by SAP2000 vs.14 and then capacity curve is finding out and performance point is calculated by considering plot type as ATC-40 from that the capacity spectrum is intersect with demand spectrum and performance point is calculated in this case software uses the Procedure- B of ATC-40 [5]. The capacity curve obtained by SAP2000 vs.14 analysis is used for further analytical and graphical method because for the same building model capacity curves become same. The analytical method (i.e. Procedure- A) is performed for that procedure the excel programming sheet is made by inserting formulae in logical manner from that sheet performance point of building is calculated. For the same building model the graphical method (i.e. Procedure- C) is applied in that the capacity curve consider is same which is obtained by software. The demand curve is reduces from 5 percent damped response spectra to calculated reduced damped spectra and it represent graphically and the performance point is calculated by graphical iterations. In this way the performance point of the building is calculated by three methods and which method is advantageous for researchers with limitations and scope of each procedure are discus.*

1. INTRODUCTION

Severe earthquakes occur relatively infrequently. Although it is technically possible to design and construct buildings for these earthquake events, it is generally considered uneconomical and unnecessary to do so. The seismic design is performed with the an-ticipation that the severe earthquake would cause some damage, and design a seismic philosophy on this basis has been developed over the years. The goal of the seismic de-sign is to limit the damage in a building to an acceptable 1eveI. The buildings designed with that goal in mind should be able to resist minor levels of earthquake ground motion without damage, resist moderate levels of earthquake ground motion without structural damage, but possibly with some non-structural damage, and resist major levels of earthquake ground motion without collapse, but with some structural as well as non-structural damage.

Capacity Curve: The plot of the total lateral force V, of a structure against the lateral deflection d of the roof of the structure.

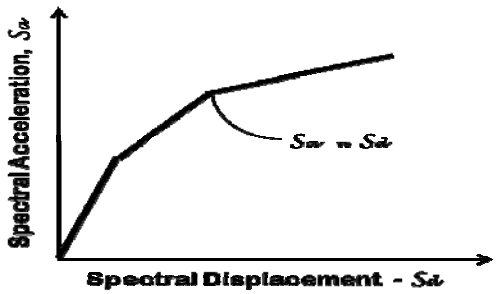


Fig. 1. Capacity Curve

Demand curve: The plot of spectral acceleration (Sa) Vs. Time Period(T).

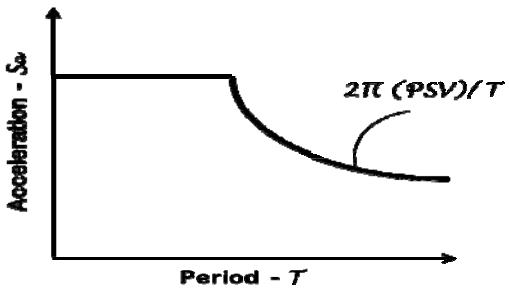


Fig. 2. Demand curve

Performance Point and Levels: It is an intersection point of Capacity curve and Demand curve. From performance point the performance of the structure is checked against performance level as mention below.

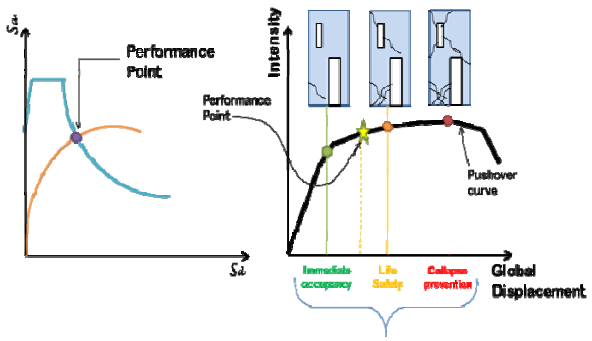


Fig. 3: Performance point and levels

2. METHODOLOGY

2.1 Description of Building

In the present work, rectangular G+5 and square G+3 storied RC building with story height 3m and 3.75m respectively in zone 3 considered for this study. The column and beam size for rectangular building is 0.35×0.35 and 0.25×0.35 and for square building is 0.35×0.35 and 0.4×0.5 in m. Slab Thickness is 0.12 m

Live load on all floors is 4 kN/m^2. Live load on roof is 1.5 kN/m^2. Floor finish is 2 kN/m^2. Water proofing on roof with open access on roof is 2 kN/m^2. Density of concrete is 25 kN/m^3. Zone factor for zone IV is 0.24 (As per IS 1893 part I: 2002). Importance factor of buildings is 1.5 (As per IS 1893 part I: 2002). Response reduction factor is 5 (As per IS 1893 part I: 2002). Structural behavior Type- B.

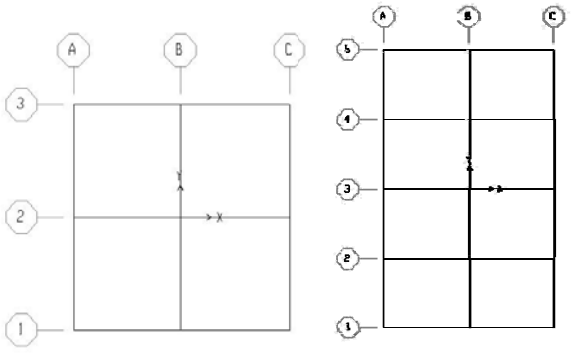


Fig. 4: Plan of the 6 Storey Rectangular Building and 4 Storey Square Building respectively.

2.2 Procedure: For finding the performance point procedures of ATC-40 are used that include Procedure- A, Procedure- B and Procedure- C. Procedure- A is analytical method, Procedure- B is software based method and Procedure- C is graphical method. The generalized steps of all these procedures are used from ATC-40 for this study.

Computational Model (i.e. Procedure- B)

Model in which result in a working computer software SAP2000 vs.14.

Analytical Model (i.e. Procedure- A)

Model in which results obtained by arranging formulae in logical manner and developing excel sheet program.

Analytical Model (i.e. procedure- C)

Model in which results obtained by plotting graph on graph sheet by hand.

3. OBSERVATION

3.1 Computational Analysis (i.e. Procedure- B)

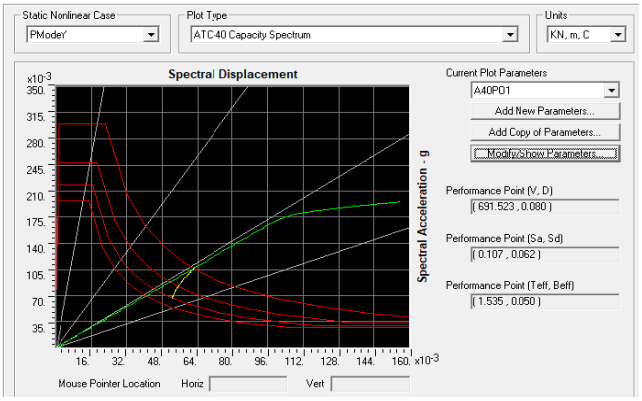


Figure 5: Capacity- Demand Spectrum for Rectangular Building

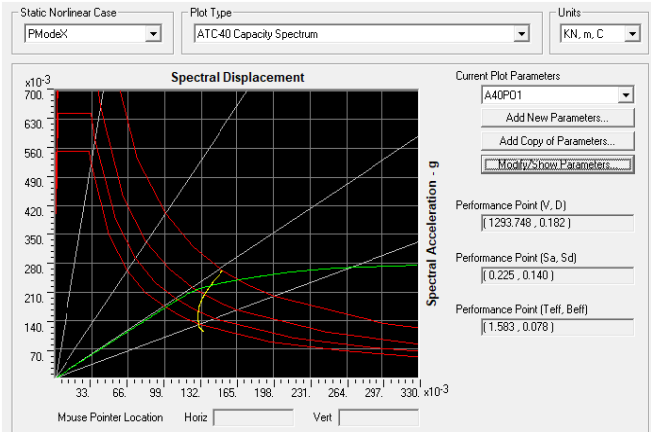


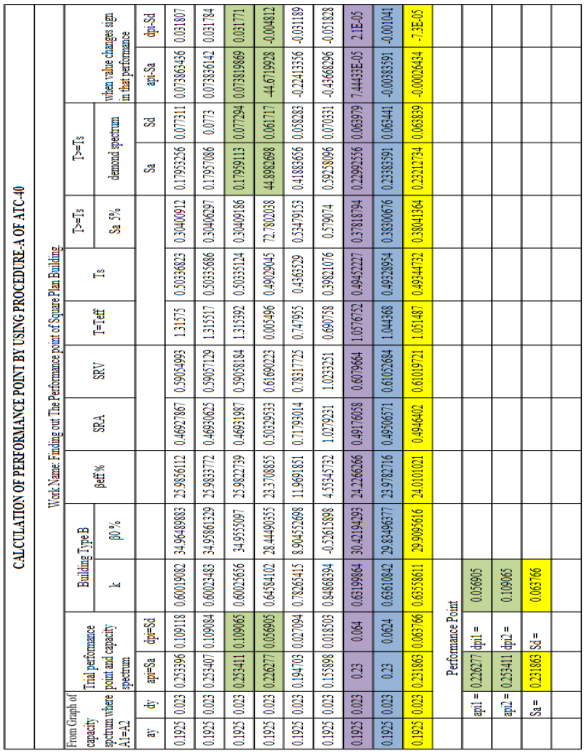
Figure 4.2.2.4: Capacity- Demand Spectrum for Square Building

3.2 Analytical Analysis (i.e. Procedure- A)

Table 1: Procedure- A Excel sheet of Rectangular Building

CALCULATION OF PERFORMANCE POINT BY USING PROCEDURE-A OF ATC-40																																
Work Name: Finding out The Performance point of Rectangular Plan Building																																
From Graph of capacity spectrum where A1=A2		Trial performance point and capacity spectrum			Building Type B										T>=Ts		T<=Ts		when value changes sign in that performance														
					k	β0 %	βeff %	SRA	SRV	T=Teff	Ts	Sa .5%	demond spectrum		apn-Sa	dpn-Sd																	
ay	dy	apn=Sa	dpn=Sd										Sa	Sd																		
0.162	0.015	0.200435	0.150099		0.528829	45.1572	28.80042	0.4354	0.564305	1.740305	0.51842	0.229084	0.129702	0.09771	0.070733	0.052387																
0.162	0.015	0.196861	0.126657		0.530799	44.8757	28.82001	0.436072	0.564825	1.608723	0.5181	0.24871	0.14048	0.09038	0.056381	0.036275																
0.162	0.015	0.193489	0.099386		0.538807	43.7192	28.56015	0.438977	0.567076	1.437009	0.51672	0.278336	0.157849	0.08108	0.03564	0.018307																
0.162	0.015	0.18897	0.079766		0.546524	42.6299	28.29025	0.441932	0.569365	1.30268	0.51534	0.310706	0.174829	0.0738	0.014144	0.005969																
0.162	0.015	0.176974	0.058666		0.55867	40.8951	27.84687	0.447409	0.57336	1.116406	0.51297	0.358529	0.205431	0.06369	-0.02846	-0.00882																
0.162	0.015	0.174775	0.037871		0.600252	33.81335	25.56715	0.474486	0.594584	0.933338	0.50124	0.428857	0.25482	0.05522	-0.00805	-0.01735																
0.162	0.015	0.166207	0.021719		0.718314	18.10939	17.99711	0.587102	0.681826	0.724804	0.46454	0.551873	0.376282	0.04917	-0.21007	-0.02745																
0.162	0.015	0.158774	0.017381		0.774841	10.0204	12.76425	0.697301	0.767196	0.663396	0.44009	0.60296	0.462587	0.05064	-0.30381	-0.03326																
0.162	0.015	0.152309	0.014978		0.817277	3.95949	8.236002	0.837835	0.876066	0.628766	0.41825	0.636171	0.557324	0.05481	-0.40502	-0.03983																
0.162	0.015	0.142183	0.012324		0.842354	0.3779	5.318329	0.978119	0.984742	0.611712	0.40271	0.6539	0.643925	0.05994	-0.50174	-0.0467																
0.162	0.015	0.184	0.07		0.547098	42.4337	29.24932	0.442487	0.569795	1.236703	0.51508	0.323244	0.184295	0.07011	-0.00029	-0.00011																
0.162	0.015	0.182	0.0712		0.541972	43.2801	28.45656	0.440143	0.567939	1.254092	0.51618	0.318896	0.18116	0.07087	0.00084	0.000329																
0.162	0.015	0.184988	0.069716		0.550381	42.0789	28.15947	0.443509	0.570387	1.230909	0.51461	0.324906	0.18542	0.06988	-0.00043	-0.00016																
Performance Point																																
		am1 =	0.176974	dpn1 =	0.054866																											
		am2 =	0.18897	dpn2 =	0.079766																											
		Sa =	0.184988	Sd =	0.069716																											

Table 2: Procedure- A Excel sheet of Square Building



3.3 Graphical Analysis (i.e. Procedure- C)

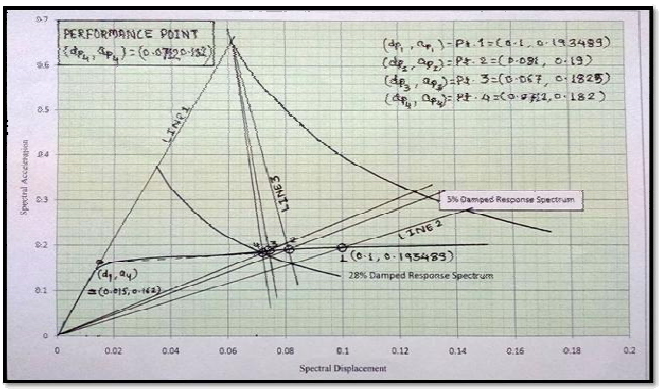


Figure 7: Performance Point by Graphical Iteration for Procedure- C

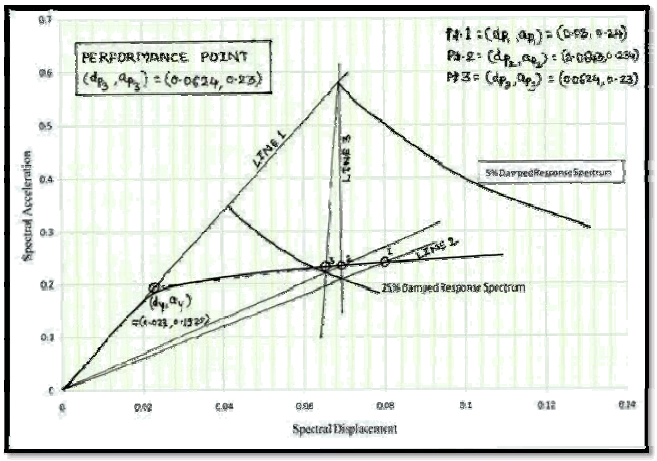


Figure 8: Performance Point by Graphical Iteration for Procedure- C of Square Building

4. RESULTS

Table 4.12: Performance point by Procedure- A, B and by Procedure- C

	Rectangular building		Square building	
Performance point	**Sa**	**Sd**	**Sa**	**Sd**
Procedure- B	0.107g	0.062m	0.23 g	0.140 m
Procedure- A	0.1849g	0.0697 m	0.2318g	0.0637 m
Procedure- C	0.182g	0.0712 m	0.23 g	0.0624 m

5. CONCLUSION

The following conclusions were made by this study:

1. The results obtained by Procedure- B (i.e. by software analysis) and by Procedure-A are nearly equivalent with difference of results is less than 1% but results obtained

by Procedure- B and by Procedure- C are of 2.5% shows that Procedure-A and Procedure- B gives same results. Hence the conventional software package based on Procedure- B is found to be performing satisfactorily.

2. A very small difference is found in the results obtained from SAP2000 vs.14 and Excel Sheet program of Procedure- A (i.e. less than 1%). This is due to the fact that SAP2000 vs.14 is based on Procedure- B. In Procedure- B, a simplifying assumption is made. That is post yield slope remains constant is made. This assumption is concluded to be the source of this difference.
3. The results of all Procedures are nearly same so that validate the results of one method with other two methods. Because all the procedure gives results in the range of 2.5%.
4. By checking the accuracy of calculated performance points with Excel Program Sheet it is clear to say that Procedure- B and Procedure- A is more accurate and the order of accuracy is Procedure-B > Procedure- A > Procedure- C.
5. For better understanding capacity spectrum method required to study minimum two procedures. So that helps the researchers to raise the confidence about results.
6. The Excel Sheet Program made for Procedure- A reduces the too much complications, calculations, iterations and interpolation work so it save the time of user and this program is validate by other two procedures for both the building.
7. In this study, capacity and demand curve intersected in between immediate occupancy and life safety, and hence building experienced moderate damage.

6. ACKNOWLEDGEMENTS

I earnestly wish my gratitude to my Guide Dr**.** Uttam B. Kalwane of Civil Engineering department and for his valuable guidance and continuous encouragement that he extended to me without whom my Dissertation could not have completed successfully. I would also like to thank him for his timely and useful suggestion, which enabled me to complete this Dissertation by enriching my knowledge, which will in turn enable me to do better in research and development field in future.I also express my thanks to Prof. Vaibhav Chavan Head of Civil Department & all my staff members of Civil Engineering Department who helped me directly or indirectly to complete my seminar successfully.

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