Pushover Analysis On G+10 Reinforced Concrete Structure for zone II and Zone III Ad Per IS 1893 (2002)

Mohammad Azaz M.tech scholar: Structural Engineering G.H.R.A.E.T, Nagpur Maharashtra, India

Anshul R. Nikhade , Asst Prof.Mtech Structural Engineering G.H.R.A.E.T, Nagpur Maharashtra , India

---*****---

Abstract— this paper emphasizes on pushover analysis on reinforced concrete structure. In which G+10 building was subjected to push in x and push in y direction. Analysis was done in sap2000 15. Based on the performance point obtain from the analysis we get to know that the structure will perform well or not during seismic activities. If the performance points obtain from the analysis are within collapse able range the structure will perform well. The Graph of pushover curve has been plotted in terms of base shear - roof displacement .The slope of pushover curve gradually changes with increase of the lateral displacement of the building. This is due to the progressive formation of plastic hinges in beams and columns throughout the structure.

1. INTRODUCTION TO PUSHOVER

The term earthquake can be used to describe any kind seismic event which may be either natural or initiated by humans, which generates seismic waves. Earthquake generally occurs by rupture of geological faults but they can also occur due some natural as well as un natural activities like volcanic activity, mine blasts, landslides and nuclear tests. A sudden release of energy in the earth's crust creates seismic wave which ultimately results into earthquake. Pushover analysis is an approximate method in which the structure is subjected to continuously increasing lateral forces with invariant height wise distribution until the target displacement is reached. Pushover analysis consists of series of sequential elastic analysis, superimposed to approximate a force-displacement curve of the overall structure. Two or three dimensional model which includes bilinear or tri-linear load-deformation diagrams of all lateral force resisting elements is first created and gravity loads are applied initially. An already known lateral load pattern which is distributed along the building height is then applied. The lateral forces are increased until some members of the structure yields. Then changes are made n the structural model to reduce the stiffness of yielded members and lateral forces are again increased until some other members yield. The process is continue until a control displacement at the top of building reaches a certain level of deformation or structure become unstable. The roof displacement is plotted with base shear to get the global capacity curve.

Pushover analysis can be performed as force-controlled. In force-controlled pushover procedure, full load combination is applied. Also, in force-controlled pushover procedure some numerical problems that affects the accuracy of the results which occur since target displacement may be associated with minute positive or negative lateral stiffness because of the development of mechanisms and p-delta effects.

Pushover analysis has been preferred method for seismic performance evaluation of structure by the major rehabilitation guidelines and codes because it is conceptually and computationally simple. Pushover analysis allows tracing the sequence of yielding and failure on member and structural level as well as the progress of overall capacity curve of the structure.

2. PUSHOVER ANALYSIS OF STRUCTURE

The present study is to evaluate G+10 multistory building subjected to earthquake forces in zone II and III. The various aspects of pushover analysis and the accuracy of pushover analysis in predicting seismic demands is investigated by several researchers. However, most of these researches made use of specifically designed structures in the context of the study or specific forms of pushover procedure. Firstly, the superiority of pushover analysis over elastic procedures in evaluating the seismic performance of a structure is discussed by identifying the advantages and limitations of the procedure. Then, pushover analyses are performed on case study frames using SAP2000. Also, the effects and the accuracy of various invariant lateral load patterns 'Uniform', 'Elastic First Mode', 'Code', 'FEMA-273' and 'Multi-Modal utilized in traditional pushover analysis to predict the behavior imposed on the structure due to randomly selected individual ground motions causing elastic and various levels of nonlinear response are evaluated. For this purpose, six deformation levels represented a speak roof displacements the capacity curve of the frames are firstly predetermined and the response parameters such as story displacements, inter-story drift ratios, story shears and plastic hinge locations are then estimated from the results of pushover analyses for any lateral load pattern at the considered deformation level. Story displacements, inter-story drift ratios and plastic hinge locations are also estimated by performing an improved pushover procedure named Modal Pushover Analysis (MPA) on case study frames. Pushover predictions are compared with the 'exact' values of response parameters obtained from the experimental results to assess the accuracy of software.

2.1 Performance Based Design for Nonlinear Static Pushover Analysis

Create a model on the software of G+10 building. Assign different properties to material and fix the acceptance criteria for pushover hinges. The program consists of several default hinge properties that are based on ATC-40 for concrete members and FEMA-365 for steel members. Locate the pushover hinges by selecting numbers of frame and assign them one or more hinge properties. Then define the pushover load cases.

3. RESULTS

The figure 1 and figure 2 shows the hinges formation in the structure when subjected to pushover analysis in x and y direction in zone II. Table 1 and 2 displacement – base force data in x and y direction. Table 3 and 4 shows demand capacity data for push in x and y direction for zone II.

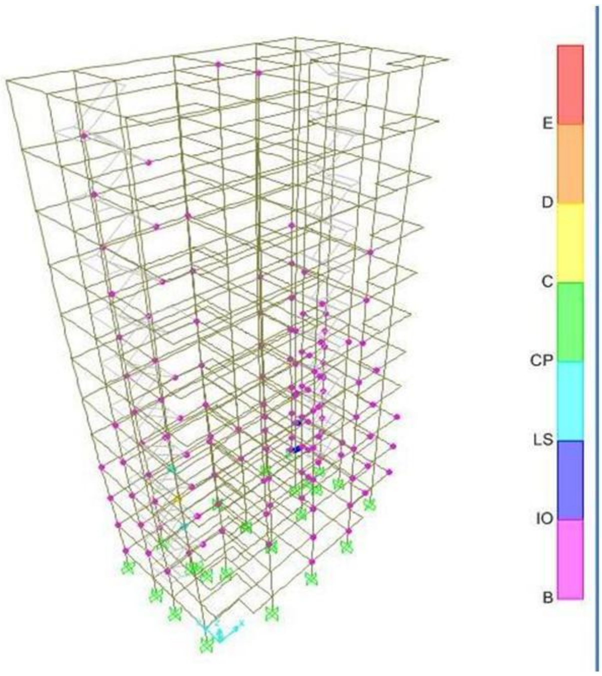

Fig1: Hinge formation diagram zone II- PUSH X

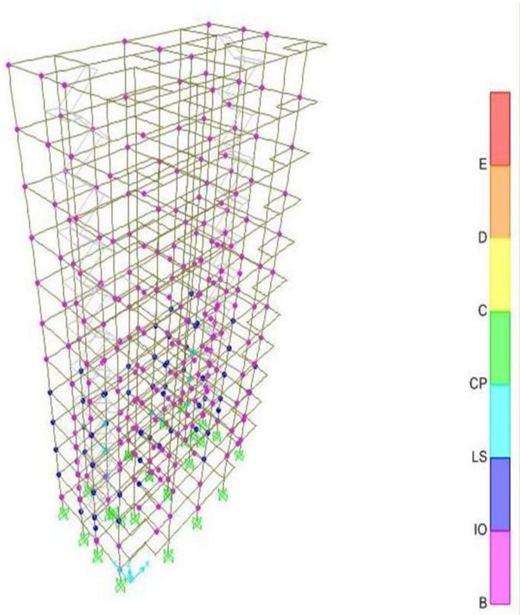

Fig2: Hinge formation diagram zone II –PUSH

Table- 1: Pushover Curve - PUSH X											
Step	Displacement	Base Force	AtoB	BtoIO	IOtoLS	LStoCP	CPtoC	CtoD	DtoE	BeyondE	Total
	m	KN									
0	0.000076	0	1920	0	0	0	0	0	0	0	1920
1	0.000944	174.866	1919	1	0	0	0	0	0	0	1920
2	0.009051	849.94	1758	151	4	6	0	1	0	0	1920
3	0.007549	559.924	1758	151	4	5	0	1	1	0	1920

Table-: 2 Pushover Curve - PUSH Y											
Step	Displacement	BaseForce	AtoB	BtoIO	IOtoLS	LStoCP	CPtoC	CtoD	DtoE	BeyondE	Total
	m	KN									
0	0.000076	0	1918	0	0	0	0	0	0	0	1918
1	0.008196	76.701	1916	2	0	0	0	0	0	0	1918
2	0.055409	404.757	1780	138	0	0	0	0	0	0	1918
3	0.155638	717.011	1608	304	6	0	0	0	0	0	1918
4	0.224466	846.105	1506	332	68	10	0	2	0	0	1918
5	0.179452	584.943	1500	338	67	11	0	0	2	0	1918

Table-:3 Pushover Curve Demand Capacity - ATC40 - PUSH X								
Step	**Teff**	**Beff**	**SdCapacity**	**SaCapacity**	**SdDemand**	**SaDemand**	**Alpha**	**PFPhi**
			m		m			
0	1.678145	0.05	0	0	0.041686	0.05959	1	1
1	1.678145	0.05	0.009342	0.013354	0.041686	0.05959	0.750316	0.09296
2	1.993191	0.076176	0.062559	0.063391	0.044336	0.044926	0.768275	0.14347

Table-:4 Pushover Curve Demand Capacity - ATC40 - PUSH Y								
Step	**Teff**	**Beff**	**SdCapacity**	**SaCapacity**	**SdDemand**	**SaDemand**	**Alpha**	**PFPhi**
			m		m			
0	2.112359	0.05	0	0	0.052472	0.04734	1	1
1	2.112359	0.05	0.006374	0.00575	0.052472	0.04734	0.764318	1.297776
2	2.410292	0.068895	0.043473	0.030124	0.055108	0.038187	0.769901	1.276316
3	3.020864	0.139968	0.122793	0.054169	0.055851	0.024638	0.758463	1.268096
4	3.329212	0.166784	0.176306	0.064036	0.05795	0.021048	0.75711	1.273586

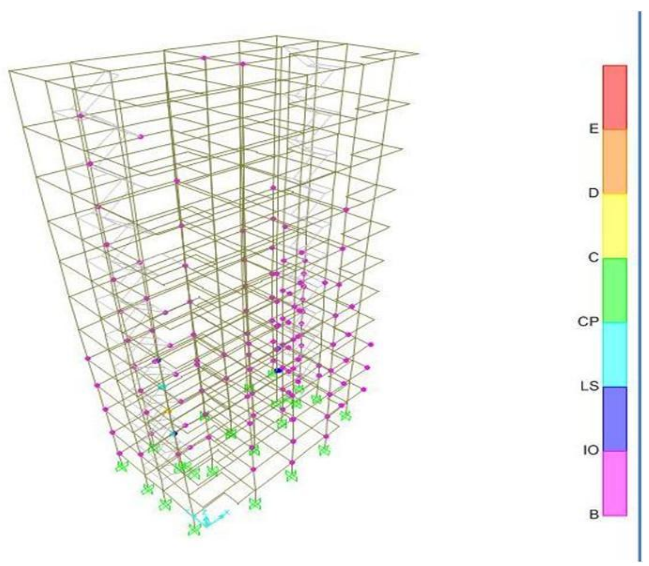

Fig3:- Hinge formation diagram zone III –PUSH X

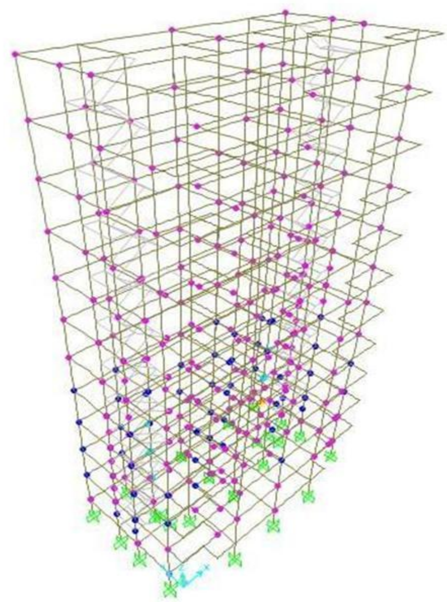

Fig4:- Hinge formation diagram zone III –PUSH Y

The figure 3 and figure 4 shows the hinges formation in the structure when subjected to pushover analysis in x and y direction in zone III. Table 5 and 6 displacement – base force data in x and y direction. Table 7 and 8 shows demand capacity data for push in x and y direction for zone III.

Table-5 : Pushover Curve - PUSH X											
Step	**Displacement**	**BaseForce**	**AtoB**	**BtoIO**	**IOtoLS**	**LStoCP**	**CPtoC**	**CtoD**	**DtoE**	**BeyondE**	**Total**
	m	KN									
0	0	0	1918	0	0	0	0	0	0	0	1918
1	0.00087	175.105	1917	1	0	0	0	0	0	0	1918
2	0.003489	483.178	1875	43	0	0	0	0	0	0	1918
3	0.00845	857.646	1765	141	6	5	0	1	0	0	1918
4	0.006953	569.368	1765	141	6	4	0	1	1	0	1918

Table-6: Pushover Curve - PUSH Y											
Step	**Displacement**	**BaseForce**	**AtoB**	**BtoIO**	**IOtoLS**	**LStoCP**	**CPtoC**	**CtoD**	**DtoE**	**BeyondE**	**Total**
	m	KN									
0	0.000076	0	1918	0	0	0	0	0	0	0	1918
1	0.010443	97.544	1916	2	0	0	0	0	0	0	1918
2	0.057571	430.485	1784	134	0	0	0	0	0	0	1918
3	0.158062	747.001	1607	305	6	0	0	0	0	0	1918
4	0.223784	872.299	1509	335	64	9	0	1	0	0	1918
5	0.135697	166.102	1503	341	64	8	0	1	1	0	1918

Table7:- Pushover Curve Demand Capacity - ATC40 - PUSH X								
Step	**Teff**	**Beff**	**SdCapacity**	**SaCapacity**	**SdDemand**	**SaDemand**	**Alpha**	**PFPhi**
			m		m			
0	1.678145	0.05	0	0	0.041686	0.05959	1	1
1	1.678145	0.05	0.009355	0.013373	0.041686	0.05959	0.750316	0.09296
2	1.726997	0.058449	0.027913	0.037676	0.041239	0.055662	0.73486	0.12499
3	1.998943	0.116285	0.063164	0.063636	0.039245	0.039538	0.772257	0.13378

TABLE NO.3.10: Pushover Curve Demand Capacity - ATC40 - PUSH Y								
Step	**Teff**	**Beff**	**SdCapacity**	**SaCapacity**	**SdDemand**	**SaDemand**	**Alpha**	**PFPhi**
			m		m			
0	2.112359	0.05	0	0	0.052472	0.04734	1	1
1	2.112359	0.05	0.008106	0.007313	0.052472	0.04734	0.764318	1.297776
2	2.370276	0.070124	0.04454	0.031915	0.053935	0.038647	0.772904	1.294266
3	2.975867	0.142448	0.123982	0.05636	0.054697	0.024864	0.759467	1.275489
4	3.270602	0.16876	0.17515	0.065916	0.056692	0.021336	0.758284	1.278104

3.1. Results for Pushover curves and Demand capacity curves for zone II and zone III

The graphs of displacement versus base shear are plotted for push in x and y direction for zone II and III.

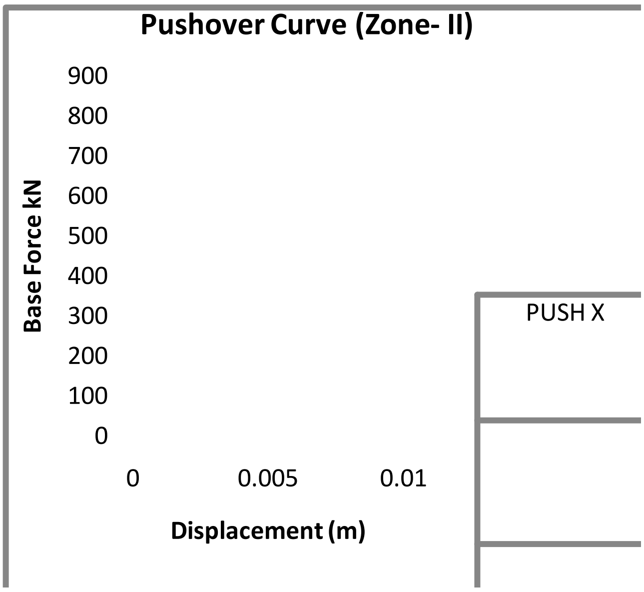

Chart 1:- pushover curve zone II- Push-X

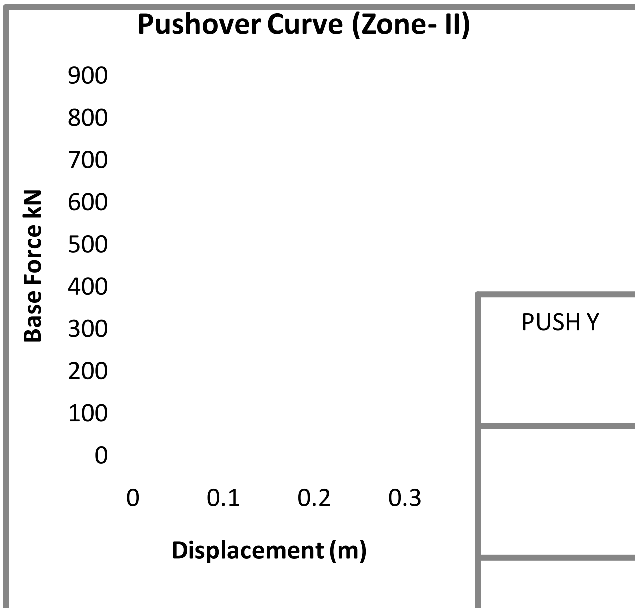

Chart 2:- pushover curve zone II- Push-Y

The graphs of demand capacity versus spectrum capacity are plotted in for push in x and y direction for zone II and zone III.

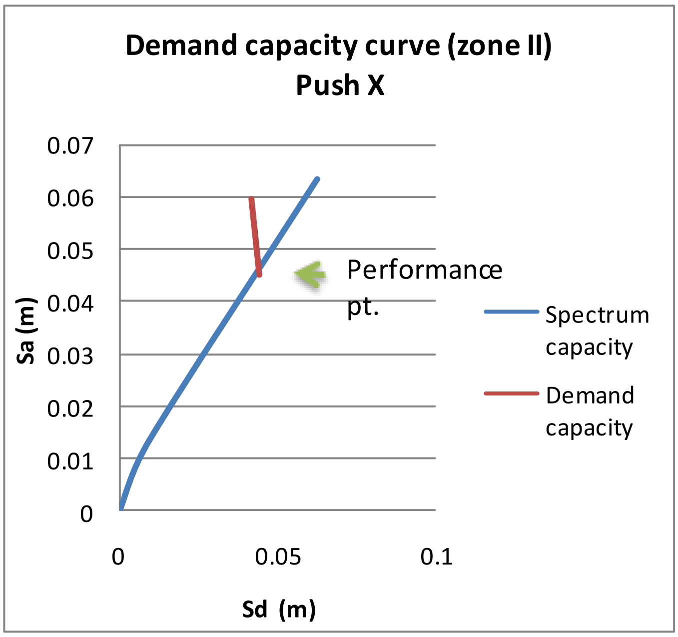

Chart 3: Demand capacity curve zone II- Push-X

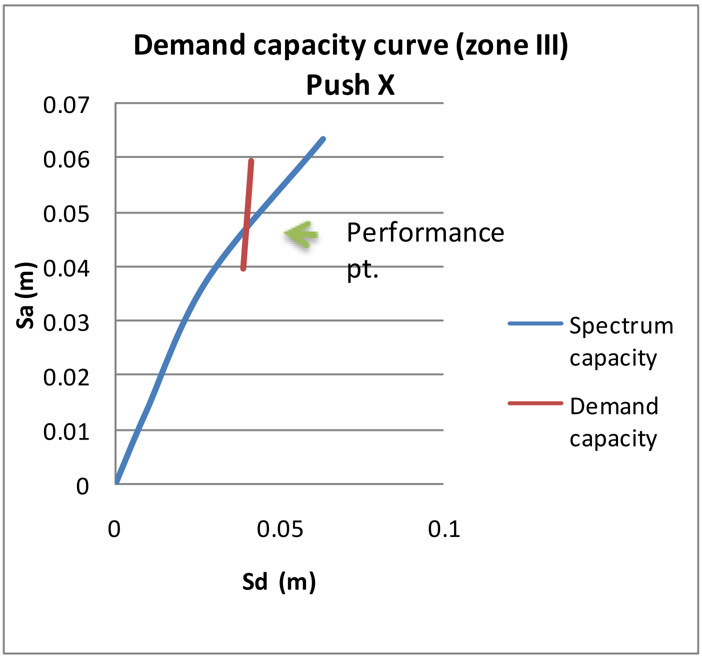

Chart 5: Demand capacity curve zone III- Push-X

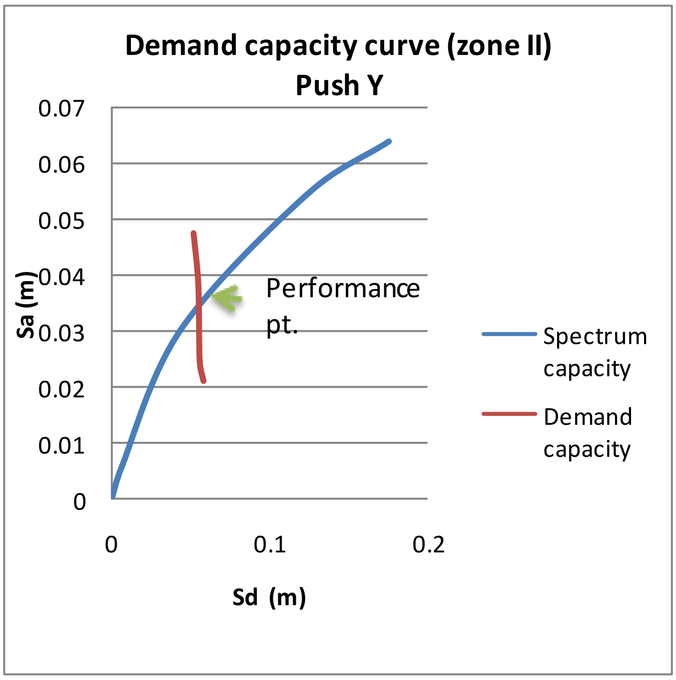

Chart 4: Demand capacity curve zone II- Push-Y

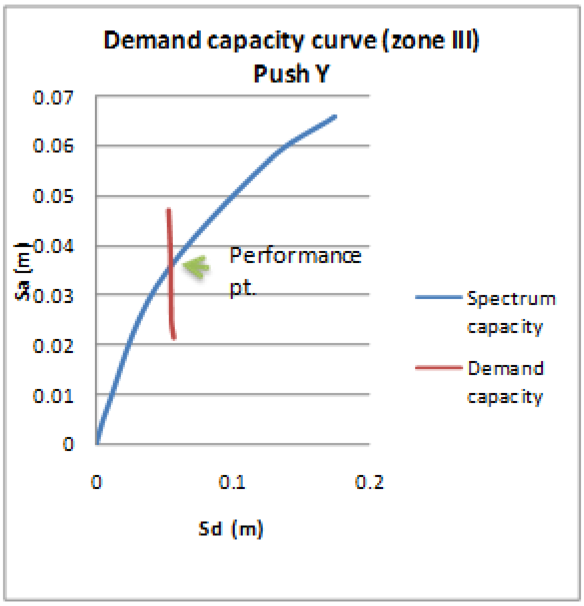

Chart 5: Demand capacity curve zone III- Push-Y

3.2 Comparison of pushover curves

The comparison of pushover curves for Push X and Push Y are plotted for seismic zone II and III.

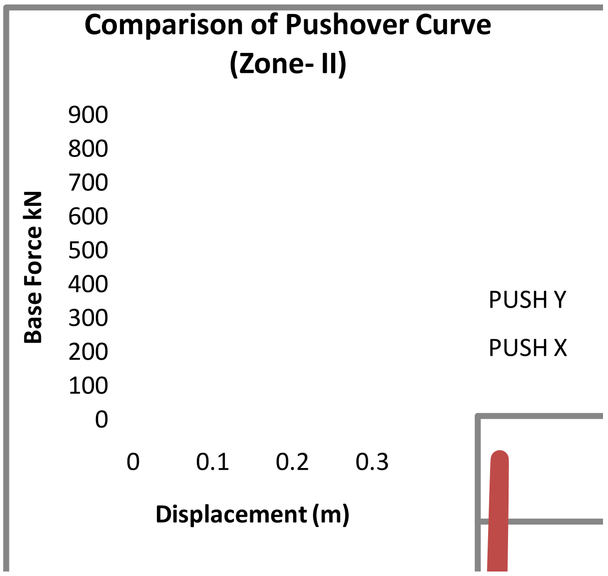

Chart 6: Comparison of Pushover Curve II

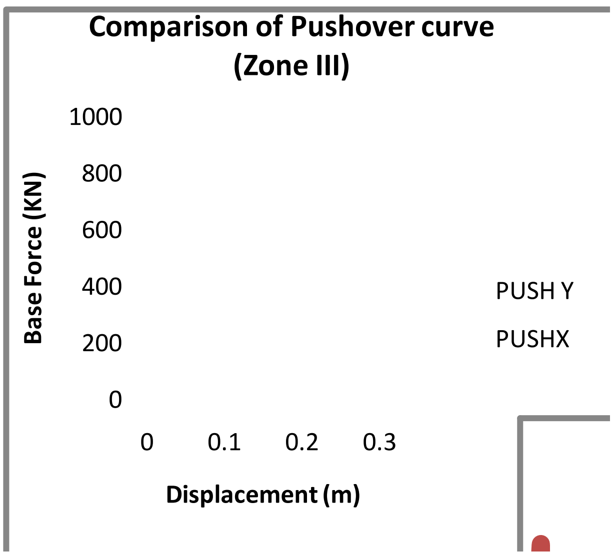

Chart 7: Comparison of Pushover Curve III

3.3 PERFORMANCE LEVEL OF STRUCTURE AND RANGE OF PLASTIC HINGES FORMATION IN THE STRUCTURE:-

The performance of the building depends on many factors one of the major factor are the structural and non-structural elements. The structure is subjected to roof displacement and the performance of structure is shown below by plotting the force versus deformation. Five letters A, B,C.D and E are generally used to define force deflection behavior of the hinge and these point are given as

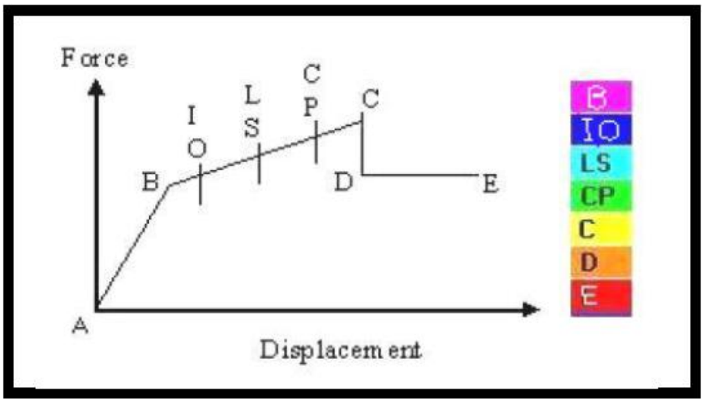

Chart 7: Load vs. Deformation

The performance level (IO, LS and CP) a structural element is represented in load versus deformation curve as shown below,

1. A to B -Elastic state,

Point 'A' corresponds to the unloaded condition

2. Point 'B' corresponds to the onset of yielding.

B to IO below immediate occupancy,

3. IO and LS – between immediate occupancies and life safety

LS to CP-between life safety and collapse prevention

4. CP and C----- between collapse prevention and ultimate capacity

Point C correspond to ultimate capacity.

5. C and D- between ultimate capacity and residual strength

Point D correspond to residual strength

6. D to E- between residual strength and collapse. Point E corresponds to collapse.

4. CONCLUSION

1. The pushover analysis is a useful tool for assessing the inelastic strength and Deformation demands and for exposing design weakness. The pushover analysis is relatively simple way to explore the non-linear behavior of the structure

2. Pushover analysis was carried out separately in the X and Y directions. The resulting pushover curves, in terms of Base Shear – Roof Displacement (V-Δ), are given in for X and Y directions separately. The slope of the pushover curves is gradually changed with increase of the lateral displacement of the building. This is due to the progressive formation of plastic hinges in beams and columns throughout the structure.

3. From the results obtained in x-direction and y- direction there are nearly 6 elements exceeding the limit level between life safety (LS) and collapse prevention(CP), as shown in Table. This means that the building not requires retrofitting.

REFERENCES

[1] Agarwal A. (2012): Seismic Evaluation of Institute Building, Bachelor of Technology Thesis, National Institute of Technology Rourkela.

[2] Agarwal P., Shrikhande M. (2004): Earthquake Resistant Design of Structures, PHI Publication.

[3] Bodige N., Ramancharla P. K. (2012): Pushover Analysis of RC Bare Frame: Performance Comparison between Ductile and Non-ductile Detailing, Report No: IIIT/TR/2012/-1, Urban Safety of Mega Cities in Asia (USMCA)

[4] Faella C., Martinelli E., Nigro E. (2002): Steel and concrete composite beams with flexible shear connection: "exact" analytical expression of the stiffness matrix and applications, Computers & Structures - COMPUT STRUCT, vol. 80, no. 11, pp. 1001-1009, 2002

[5] Fardis M. N. (2009): Seismic Design, Assessment and Retrofitting of Concrete Buildings, Springer Publication.

[6] Griffith M. C., Pinto A. V. (2000):"Seismic Retrofit of RC Buildings - A Review and Case Study", University of Adelaide, Adelaide, Australia and European Commission, Joint Research Centre, Ispra Italy.

[7] Goel R. K. (2008): Evaluation of Current Nonlinear Static Procedures for Reinforced Concrete Buildings, The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.

[8] Kadid A., Boumrkik A. (2008): Pushover Analysis of Reinforced Concrete Frame Structures, Asian Journal of Civil Engineering (Building and Housing) Vol. 9, No. 1(2008) Pages 75-83

[9] Krawinkler H., Seneviratna G.D.P.K. (1998): Pros and Cons of a Pushover Analysis of Seismic Performance Evaluation, Engineering Structures, Vol.20, 452-464.

[10] Lawson R.S., Reinhorn A.M., Lobo R.F. (1994): Nonlinear Static Pushover Analysis -Why, When and How? Proceedings of the 5th US National Conference on Earthquake Engineering Chicago, Vol. 1, 283-292.

[11] Monavari B., Massumi A., Kazem, A (2012): Estimation of Displacement Demand in RC Frames and Comparing with Target Displacement Provided by FEMA-356, 15th World Conference on Earthquake Engineering, 24th to 28th September, 2012, Lisbon, Portugal.

[12] Mouzzoun M., Moustachi O., Taleb A. (2013): Seismic Damage Prediction of Reinforced Concrete Buildings Using Pushover Analysis, International Journal of Computational Engineering Research (ijceronline.com) Vol. 3 Issue. 1, January 2013.

[13] Mouzzoun M., Moustachi O., Taleb A., Jalal S. (2013): Seismic performance assessment of reinforced concrete buildings using pushover analysis, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE); ISSN: 2278-1684 Volume 5, Issue 1 (Jan. - Feb.2013), PP 44-49.

[14] Mwafy A. M., Elnashai A. S. (2001): Static Pushover versus Dynamic Analysis of RC Buildings, Engineering Structures, Vol. 23, 407-424.

[15] Otani S. (2000): Seismic Vulnerability Assessment of Reinforced Concrete Buildings ,Faculty of Engineering, University of Tokyo, Series B, Vol., XLVII, October 2000, pp. 528.

[16] Pillai S. U., Menon D. (2009): Reinforced Concrete Design, TMH Publication.

[17] Poluraju P., NageswaraRao P. V. S. (2011): Pushover analysis of reinforced concreteframe structure using SAP 2000, International Journal of Earth Sciences and Engineering ,ISSN 0974-5904, Volume 04, No 06 SPL, pp. 684-690.

[18] Rai, Durgesh C. (2005): "Seismic Evaluation and Strengthening of Existing Buildings "IIT Kanpur and Gujarat State Disaster Mitigation Authority.

[19] Sarkar S. (2010): Design of Earth-quake Resistant Multi-storied RCC Building on a Sloping Ground, Bachelor of Technology Thesis, National Institute of Technology Rourkela.