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Pushover Analysis on RCC Structure for Zone IV and Zone V

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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 examination we get to know that the structure will do well or not during seismic activities. If the performance points obtain from the examination are within collapse able range the structure will perform well. The Graph of pushover curve has been plot 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 development of plastic hinges in beams and columns throughout the structure.
Keywords*: pushover, sap2000 15, reinforced concrete, lateral displacement & plastic hinges.*

I. INTRODUCTION TO PUSHOVER

The term earthquake can be used to explain any kind seismic event which may be either natural or initiate by humans, which generates seismic waves. Earthquake generally occurs by split of geological faults but they can also occur due some natural as well as un natural behavior like volcanic activity, mine blasts, landslides and nuclear tests. A sudden discharge of energy in the earth's crust creates seismic wave which in the end results into earthquake. Pushover analysis is an fairly accurate method in which the structure is subjected to endlessly growing lateral forces with invariant height wise distribution until the target displacement is reached. Pushover analysis consists of chain 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 figure of all lateral force resisting elements is first created and gravity loads are applied primarily. An already recognized lateral load pattern which is distributed along the building height is then applied. The lateral forces are augmented until some members of the structure yields. Then changes are made in the structural model to lessen the stiffness of yielded members and lateral forces are again augmented until some other members yield. The process is carry on until a control displacement at the top of building reach a certain level of deformation or structure become unstable. The roof displacement is plot with base shear to obtain the global capacity curve.

Pushover analysis can be performed as force-controlled. In force-controlled pushover practice, full load combination is applied. Also, in force-controlled pushover method 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 assessment of structure by the major rehabilitation guidelines and codes because it is conceptually and computationally easy. Pushover analysis permit tracing the series of yielding and breakdown on member and structural level as well as the growth of overall capacity curve of the structure.

II. PUSHOVER ANALYSIS OF STRUCTURE

The present study is to evaluate G+10 multistory building subjected to earthquake forces in zone III and IV. The various aspects of pushover analysis and the precision of pushover analysis in forecasting seismic demands is investigated by a number of researchers. However, most of these researches made use of exclusively designed structures in the context of the study or specific forms of pushover practice. Firstly, the supremacy 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 15. Also, the effects and the exactness of various invariant lateral load patterns 'Uniform', 'Elastic First Mode', 'Code', 'FEMA-273' and 'Multi-Modal utilized in traditional pushover analysis to forecast the performance imposed on the structure due to arbitrarily 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 position are then evaluated 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 evaluated by performing an improved pushover

procedure named Modal Pushover Analysis (MPA) on case study frames. Pushover results are judge against with the 'exact' values of response parameters obtained from the experimental outcome to evaluate the accurateness of software.

III. 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.

IV. 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 IV. 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 IV.

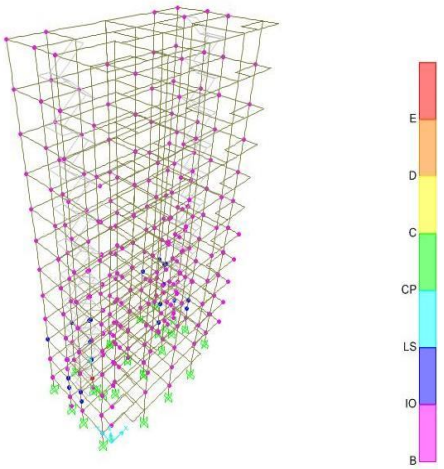

Fig1: Hinge formation diagram zone IV- PUSH X

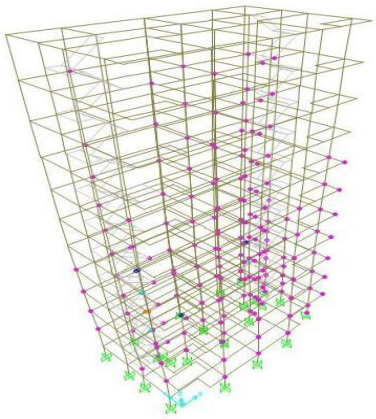

Fig2: Hinge formation diagram zone IV –PUSH Y

TABLE I

TABLE: Pushover Curve - PUSH X										
Step	Displacement	Base Force	A to B	B to IO	IO to LS	LS to CP	CP to C	C to D	D to E	Beyond E	Total
	m	KN									
0	0	0	1918	0	0	0	0	0	0	0	1918
1	0.000318	64.129	1916	2	0	0	0	0	0	0	1918
2	0.004061	355.625	1806	112	0	0	0	0	0	0	1918
3	0.008022	529.648	1707	199	10	2	0	0	0	0	1918
4	0.008214	535.197	1703	203	9	2	0	1	0	0	1918
5	0.007121	381.526	1690	213	5	5	0	1	4	0	1918

TABLE III

TABLE: Pushover Curve - PUSH Y											
Step	Displacement	Base Force	A to B	B to IO	IO to LS	LS to CP	CP to C	C to D	D to E	Beyond E	Total
	m	KN									
0	0.000076	0	1918	0	0	0	0	0	0	0	1918
1	0.011419	106.589	1915	3	0	0	0	0	0	0	1918
2	0.053542	378.91	1755	163	0	0	0	0	0	0	1918
3	0.143381	598.405	1515	388	15	0	0	0	0	0	1918
4	0.147243	620.952	1510	391	17	0	0	0	0	0	1918
5	0.169614	704.505	1476	412	25	4	0	0	1	0	1918
6	0.234422	883.816	1464	422	27	3	0	1	0	1	1918

TABLE IIIII

Step	T eff	B eff	Sd Capacity	Sa Capacity	Sd Demand	Sa Demand	Alpha	PFP hi
			m		m			
0	1.678145	0.05	0	0	0.041686	0.05959	1	1
1	1.678145	0.05	0.003426	0.004897	0.041686	0.05959	0.750316	-0.09296
2	1.841333	0.062821	0.023259	0.027616	0.043149	0.051232	0.737876	-0.1746
3	2.271613	0.158675	0.049635	0.038722	0.04024	0.031393	0.783768	-0.16161
4	2.28841	0.161213	0.050862	0.039099	0.040313	0.03099	0.784348	-0.1615

TABLE IVV

TABLE: Pushover Curve Demand Capacity - ATC40 - PUSH Y								
Step	T eff	B eff	Sd Capacity	Sa Capacity	Sd Demand	Sa Demand	Alpha	PFP hi
			m		m			
0	2.112359	0.05	0	0	0.052472	0.04734	1	1
1	2.112359	0.05	0.008857	0.007991	0.052472	0.04734	0.764318	1.297776
2	2.451266	0.08109	0.042144	0.028236	0.053579	0.035897	0.76895	1.27224
3	2.902434	0.150654	0.081296	0.038849	0.052344	0.025014	0.766349	1.268059
4	3.228446	0.188495	0.112341	0.04339	0.053758	0.020763	0.76384	1.276979
5	3.257782	0.191669	0.115216	0.043703	0.053911	0.020449	0.763206	1.278536
6	3.261298	0.192835	0.115241	0.043618	0.053847	0.020381	0.763192	1.278349
7	3.40846	0.204079	0.131624	0.04561	0.055084	0.019087	0.760186	1.284912
9	3.413583	0.205861	0.132118	0.045576	0.055059	0.018994	0.760262	1.285134
10	3.416107	0.205522	0.137716	0.046123	0.055447	0.01857	0.760014	1.284384

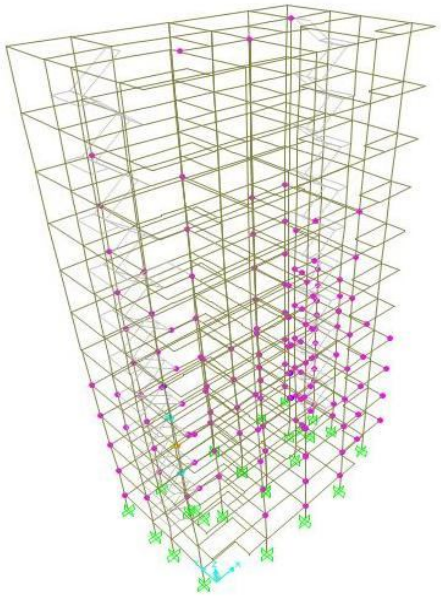

Fig3:- Hinge formation diagram zone V –PUSH X

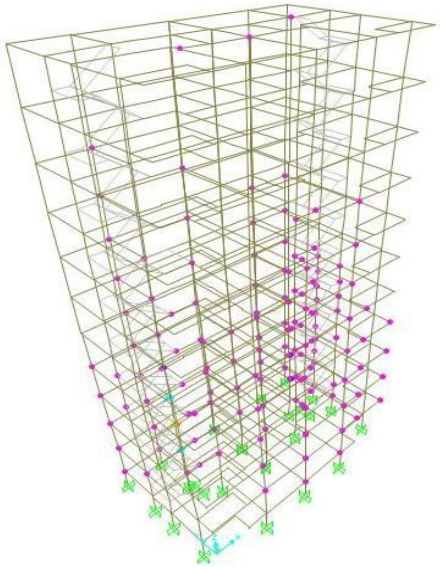

Fig4:- Hinge formation diagram zone V –PUSH Y

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 V. 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 V.

TABLE V

-TABLE: Pushover Curve - PUSH X											
Step	Displacement	Base Force	A to B	B to IO	IO to LS	LS to CP	CP to C	C to D	D to E	Beyond E	Total
	m	KN									
0	0	0	1918	0	0	0	0	0	0	0	1918
1	0.001246	250.956	1916	2	0	0	0	0	0	0	1918
2	0.00297	500.285	1882	36	0	0	0	0	0	0	1918
3	0.010204	962.771	1764	147	7	0	0	0	0	0	1918
4	0.010594	1005.77	1750	158	4	5	0	1	0	0	1918
5	0.008819	666.6	1750	158	4	4	0	1	1	0	1918

TABLE VI

TABLE: Pushover Curve - PUSH Y											
Step	Displacement	Base Force	A to B	B to IO	IO to LS	LS to CP	CP to C	C to D	D to E	Beyond E	Total
	m	KN									
0	0.000076	0	1918	0	0	0	0	0	0	0	1918
1	0.031917	296.666	1917	1	0	0	0	0	0	0	1918
2	0.093879	710.733	1767	151	0	0	0	0	0	0	1918
3	0.194306	1025.905	1564	331	23	0	0	0	0	0	1918
4	0.249202	1123.992	1497	345	65	9	0	2	0	0	1918

TABLE VII

TABLE: Pushover Curve Demand Capacity - ATC40 - PUSH X								
Step	T eff	B eff	Sd Capacity	Sa Capacity	Sd Demand	Sa Demand	Alpha	PFP hi
			m		m			
0	1.678145	0.05	0	0	0.041686	0.05959	1	1
1	1.678145	0.05	0.013407	0.019165	0.041686	0.05959	0.750316	-0.09296
2	1.703442	0.056176	0.02814	0.03904	0.041093	0.05701	0.734282	-0.10555
3	1.945942	0.104884	0.068437	0.072757	0.039444	0.041933	0.758245	-0.1491
4	1.996169	0.11904	0.074625	0.075392	0.038902	0.039302	0.764416	-0.14197

TABLE VIII

TABLE: Pushover Curve Demand Capacity - ATC40 - PUSH Y								
Step	T eff	B eff	Sd Capacity	Sa Capacity	Sd Demand	Sa Demand	Alpha	PFP hi
			m		m			
0	2.112359	0.05	0	0	0.052472	0.04734	1	1
1	2.112359	0.05	0.024652	0.022241	0.052472	0.04734	0.764318	1.297776
2	2.362894	0.085939	0.073562	0.05304	0.050801	0.036629	0.767827	1.277222
3	2.835519	0.151611	0.153875	0.077045	0.051026	0.025549	0.762999	1.263242
4	3.064219	0.178322	0.197018	0.084471	0.052073	0.022326	0.762458	1.26525

V. RESULTS FOR PUSHOVER CURVES AND DEMAND CAPACITY CURVES FOR ZONE IV AND ZONE IV

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

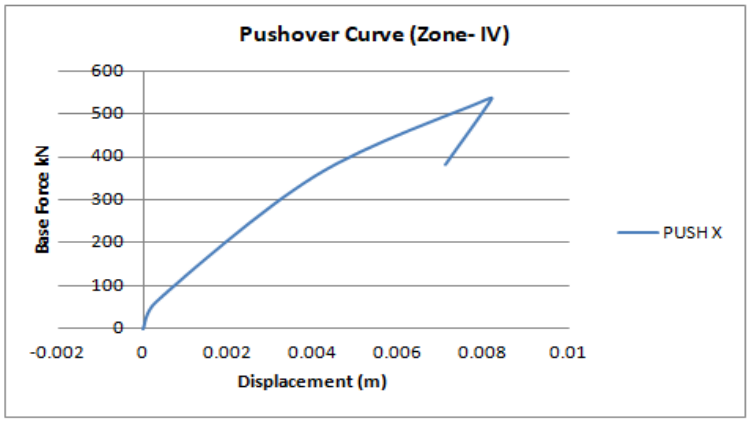

Chart 1:- pushover curve zone IV- Push-X

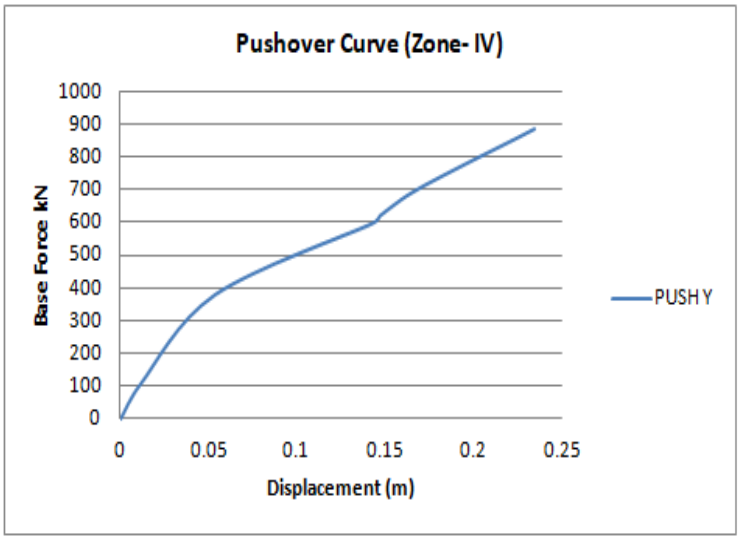

Chart 2:- pushover curve zone IV- Push-Y

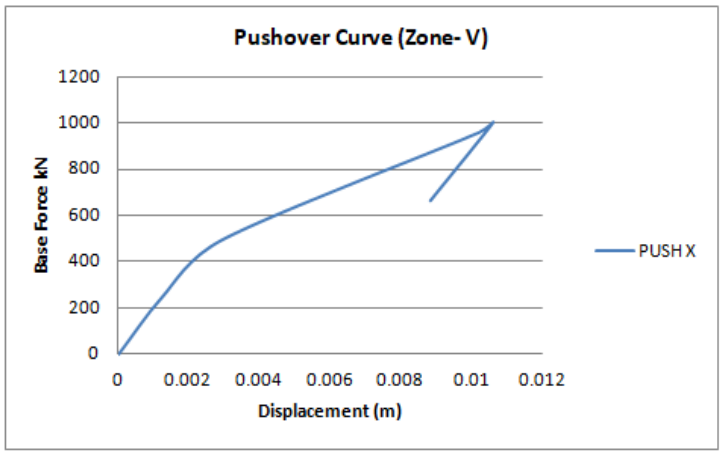

Chart 3:- pushover curve zone V- Push-X

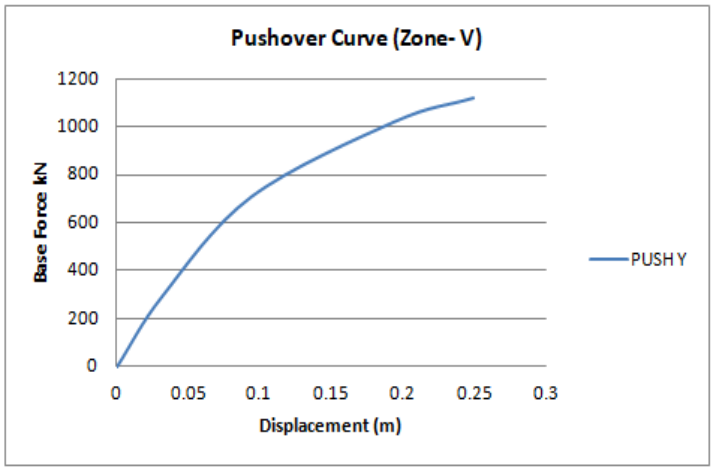

Chart 4:- pushover curve zone V- Push-Y

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

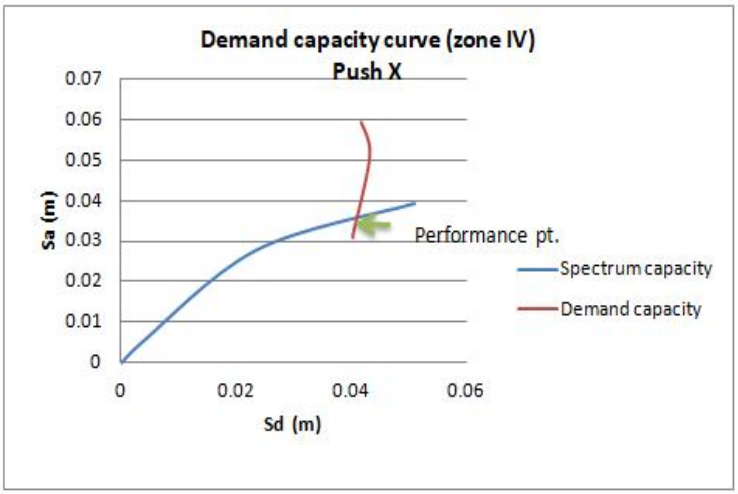

Chart 3: Demand capacity curve zone VI- Push-X

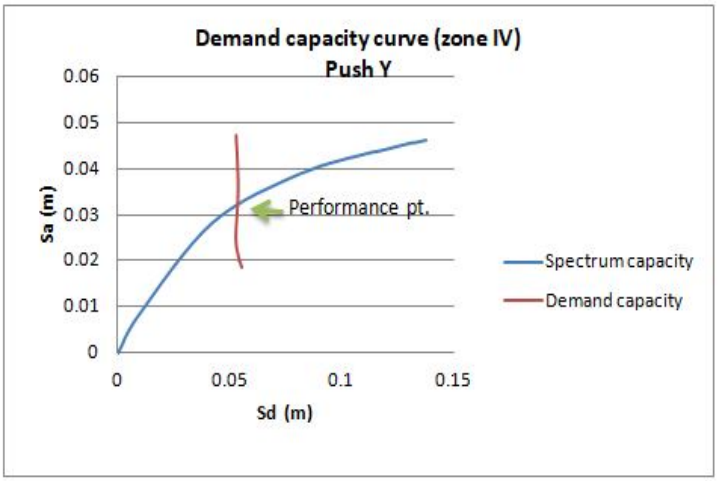

Chart 4: Demand capacity curve zone VI- Push-

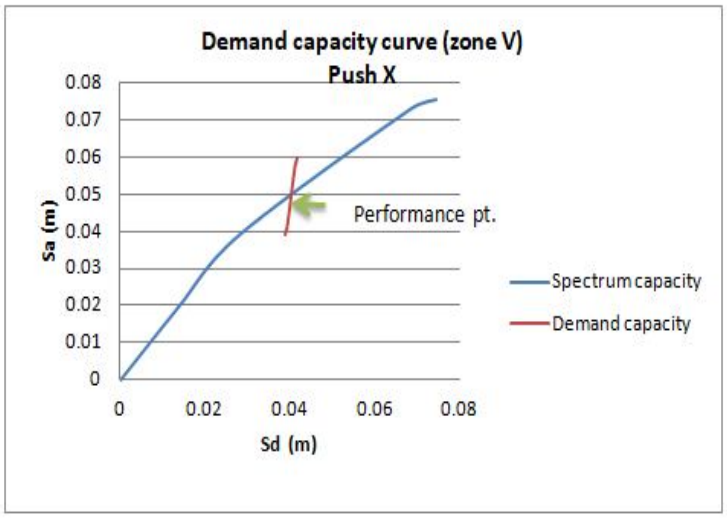

Chart 5: Demand capacity curve zone V- Push-X

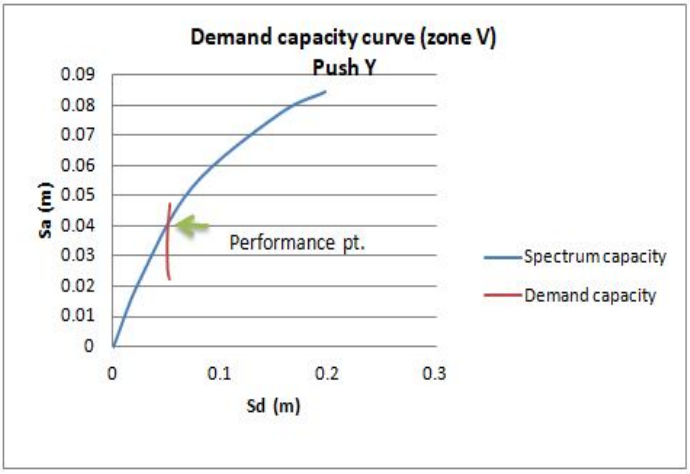

Chart 6: Demand capacity curve zone V- Push-Y

VI. COMPARISON OF PUSHOVER CURVES

The comparison of pushover curves for Push X and Push Y are plotted for seismic zone IV and V.

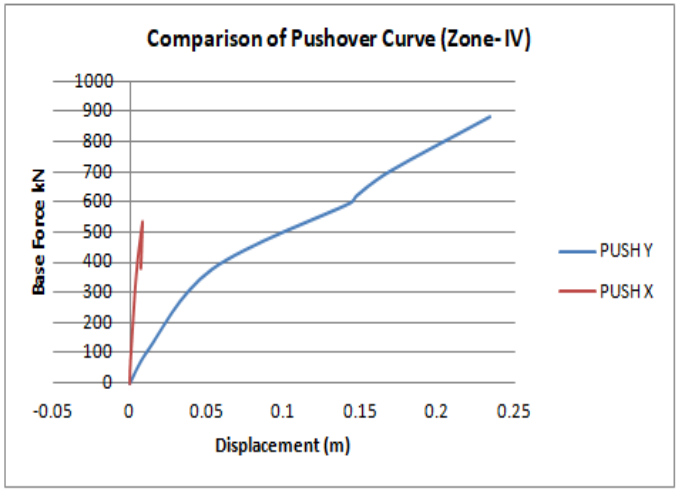

Chart 6: Comparison of Pushover Curve IV

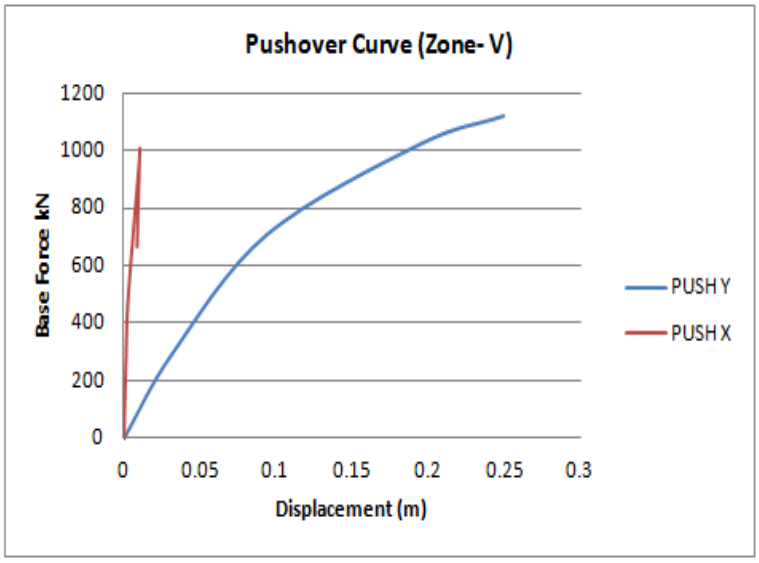

Chart 7: Comparison of Pushover Curve V

VII. 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

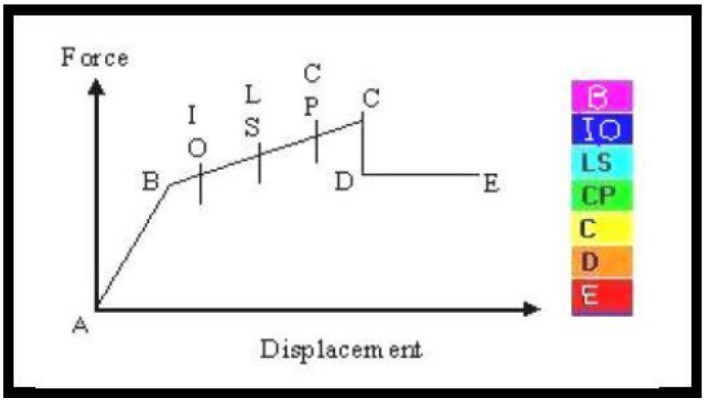

Chart 7: Load vs. Deformation

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

A. A to B -Elastic state, Point 'A' corresponds to the unloaded condition
B. Point 'B' corresponds to the onset of yielding. B to IO below immediate occupancy,
C. IO and LS – between immediate occupancies and life safety LS to CP-between life safety and collapse prevention
D. CP and C----- between collapse prevention and ultimate capacity Point C corresponds to ultimate capacity.
E. C and D- between ultimate capacity and residual strength Point D correspond to residual strength
F. D to E- between residual strength and collapse. Point E corresponds to collapse.

VIII. CONCLUSION

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

C. It is observed that the structural elements of the three upper floors have not entered in the plastic zone in contrast to some structural elements in the lower floors.

D. From the results obtained in x-direction and y- direction there are nearly 5 to 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.

E. It was found that the seismic performance of studied building is adequate according in X-X direction and in Y-Y direction because all elements were not reached the Immediate Occupancy (IO) level.

F. The main output of a pushover analysis is in terms of response demand versus capacity. If the demand curve intersects the capacity envelope near the elastic range, then the structure has a good resistance. If the demand curve intersects the capacity curve with little reserve of strength and deformation capacity, then it can be concluded that the structure will behave poorly during the imposed seismic excitation and need to be retrofitted to avoid future major damage or collapse.

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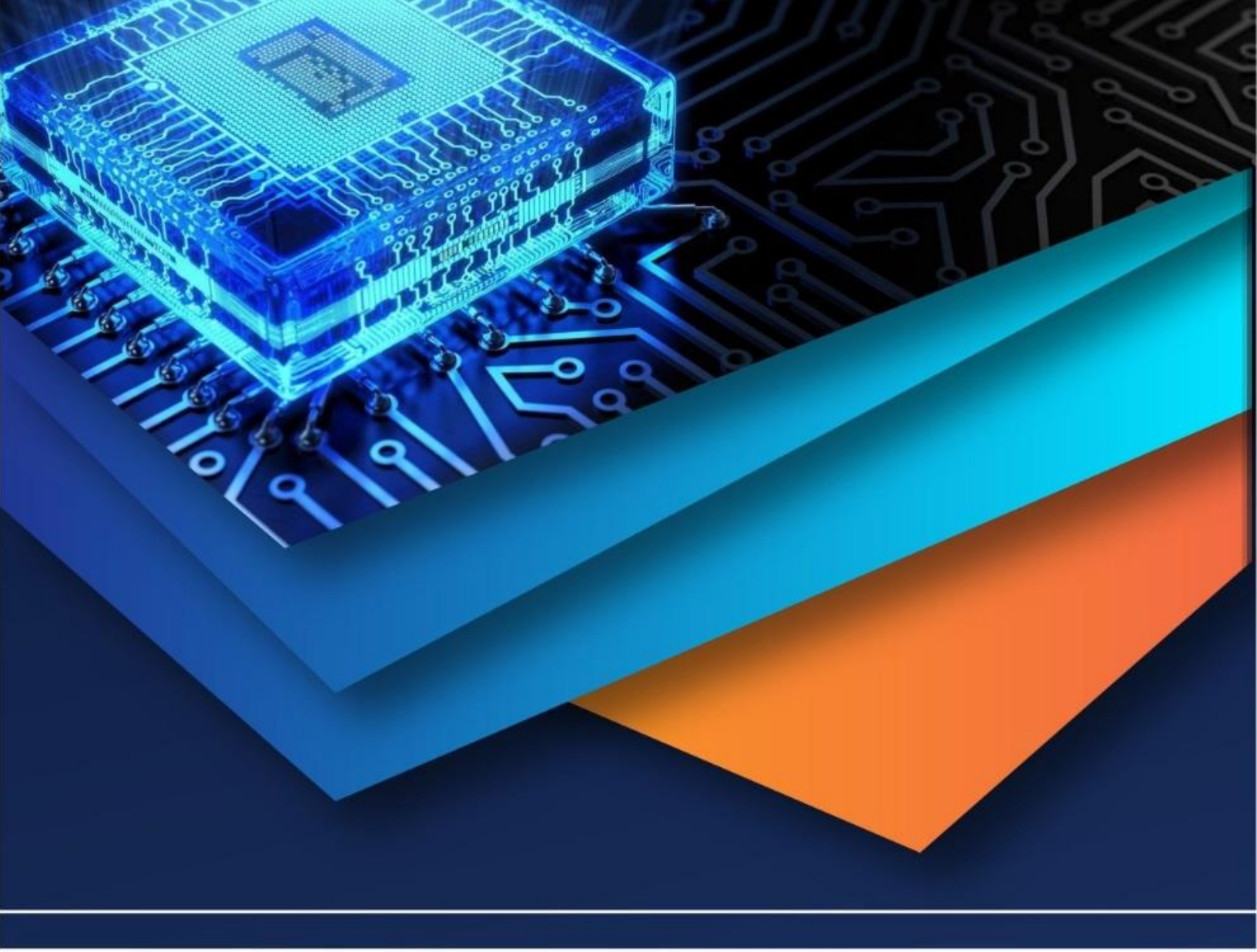

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