Pushover Analysis of Steel Frames By Considering Grade Variation And Sequence of Hinge Formation

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Abstract- *Analysis of steel structures is difficult to understand in non linear zone. The assessment of structural members of non linear analysis became an important tool to know the seismic evaluation of the structures. The evaluation of performance of the structure to design for its ground motions various cases are considered such as 15% variation in steel and its hinge behavior pattern. There are many researchers who did their research on effect of plastic hinge properties in nonlinear analysis. But a minimal attention and study has been done on understanding the sequence of hinge formation and their effects on the structure. This project attempts to show the results of pushover analyses of steel structures of various models that are adopted to understand the behavior of hinge formations and their patterns and its effect. Nonlinear responses of various two dimensional models with varying correction for steel and concrete are considered and the pushover curves of all the models are understood. All the models are analyzed for pushover analysis by using software **SAP 2000** and hinges formed in the models are observed with their order and location.*

Keywords- Hinge pattern, Plastic hinge, Pushover curve, SAP2000.

I. INTRODUCTION

Nonlinear static analysis, or pushover analysis, has been developed over the past twenty years and has become the preferred analysis procedure for design and seismic performance evaluation purposes as the procedure is relatively simple and considers post- elastic behavior. However, the procedure involves certain approximations and simplifications that some amount of variation is always expected to exist in seismic demand prediction of pushover analysis

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.

To understand the pushover analysis in SAP2000 we should know the element description of SAP2000. A frame element is modelled as a line element having linearly elastic properties and nonlinear force-displacement characteristics of individual frame elements are modelled as hinges represented by a series of straight line segments. Generalized force-displacement characteristic of a non-degrading frame element (or hinge properties) in SAP2000.

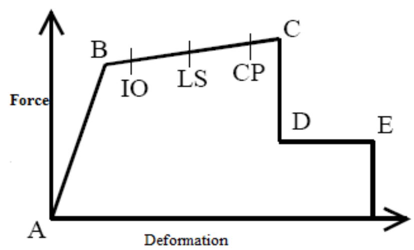

Fig-1: Force-Deformation

Point A corresponds to unloaded condition and point B represents yielding of the element. The ordinate at C corresponds to nominal strength and abscissa at C corresponds to the deformation at which significant strength degradation begins. The drop from C to D represents the initial failure of the element and resistance to lateral loads beyond point C is usually unreliable. The residual resistance from D to E allows the frame elements to sustain gravity loads. Beyond point E, the maximum deformation capacity, gravity load can no longer be sustained. Hinges can be assigned at any number of locations (potential yielding points) along the span of the frame element as well as element ends. Uncoupled moment (M2 andM3), torsion (T), axial force (P) and shear (V2 and

V3) force-displacement relations can be defined. As the column axial load changes under lateral loading, there is also a coupledP-M2-M3 (PMM) hinge which yields based on the interaction of axial force and bending moments at the hinge location. Also, more than one type of hinge can be assigned at the same location of a frame element. There are three types of hinge properties in SAP2000. They are default hinge properties, user-defined hinge properties and generated hinge properties. Default hinge properties could not be modified and they are section dependent. When default hinge properties are used, the program combines its built-in default criteria with the defined section properties for each element to generate the final hinge properties. The built-in default hinge properties for steel and concrete members are based on ATC-40 and FEMA-273 criteria. Only default hinge properties and user-defined hinge properties can be assigned to frame elements. User defined hinges are used in this research.

The main objectives of the study are

1. To investigate the nonlinear response and the sequence of hinge formations for steel frames
2. To determine the hinge pattern behavior for various varying strengths of steel.
3. To analyze the change in displacements from pushover curve for various grades of steel and concrete in RC frames and Steel frames.
4. To study the behavior of frames for different geometry of steel models.
5. To know the formation of first plastic hinge where the non linearity of the structure starts for various steel grades considering 15% grade variation.

II. MODELLING

A simplified model of three bay one storey, three bay two storey, three bay three storey and three bay four storey frames are considered and on considering the 15% variation in the strength of steel hence and these models are again analyzed for various steel grade strengths such as 353MPa, 415MPa, 477MPa and lets call these as Fe353, Fe415 and Fe477.

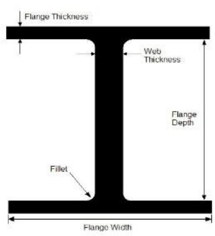

Fig-2: I section

The bay width is 4m and height of each storey is considered as 3.2m and the sections for the steel frames id ISBH- 300 with the dimensions of height 300mm, flange width 250mm, flange thickness 10.6mm and web thickness 7.6mm for beams and columns

Cases	No of models	Grade of Steel
1	4	Fe353
2	4	Fe415
3	4	Fe477

Table-1: Models

The static non linear responses are observed from pushover curves which are obtained from each and every model which gives us load vs displacement curves. The pushover curves are merged in one graph for each and every set of model cases. i.e one model of one bay one storey of five cases are put into one graph to know the relative change in displacement. The behavior of hinge and their pattern for the 1^{st} three modes are observed and displacement results are marked.

III. RESULTS AND CONCLUSION

From the various graphs and results it is observed that with the variation in the strength of the material, number of storeys, number of bays the displacement varies in the similar pattern in their respective structures. The consideration of 15% difference in the steel grade by considering the on site errors. Hence by considering Fe415 steel and adding and subtracting the considerable errors of 15% to the grade with change in strengths to 353MPa and 477 MPa.

Fe353		Fe415		Fe477	
displacement	base force	displacement	base force	displacement	base force
0	0	0	0	0	0
0.027661	897.591	0.032518	1055.195	0.037373	1212.784
0.031227	968.844	0.036707	1138.882	0.042185	1308.929
0.037194	1028.383	0.043713	1208.79	0.050239	1389.291
0.061527	1146.571	0.072265	1347.345	0.082998	1548.212
0.157048	1314.689	0.184625	1545.047	0.212199	1775.517
0.157063	922.197	0.184652	1082.345	0.212228	1243.23
0.157581	932.048	0.185345	1095.507	0.213031	1258.507
0.1585	940.386	0.18613	1102.626	0.213863	1266.05
0.15852	870.296	0.186134	1061.241	0.213864	1218.825
0.159759	881.53	0.186446	1064.066	0.214297	1223.168
0.159777	497.128	0.186437	1023.122	0.214317	1176.511
0.159797	465.071	0.187737	1034.886	0.215649	1188.593
0.180213	634.586	0.187763	537.237	0.215667	660.216
0.181116	636.847	0.212686	743.952	0.215687	616.81
0.194828	646.567	0.229914	756.203	0.244468	855.653
0.194848	279.026	0.229934	323.213	0.264274	869.739
0.206021	312.57	0.242106	359.766	0.264293	363.569
0.397621	355.26	0.243337	361.719	0.278941	407.571
		0.443337	406.282	0.478941	452.028
		0.467358	411.637	0.537689	465.098
		0.467378	9.784	0.516161	23.2
		0.467378	11.961		
		0.667378	11.962		
		0.867378	11.963		
		1.067378	11.964		
		1.267378	11.965		
		1.467378	11.966		
		1.667378	11.967		
		1.867378	11.969		
		1.99997	11.969		

Table-2: 3 Bay 1 Storey Displacement-Base shear

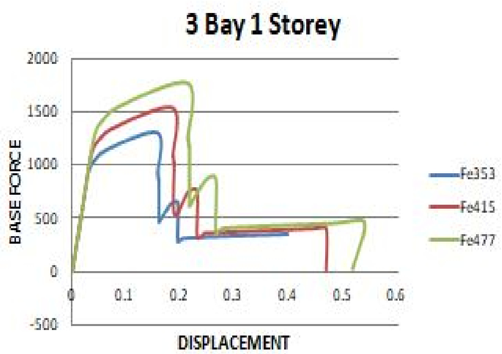

Fig 3: 3 Bay 1 Storey Pushover curve

Fe353		Fe415		Fe477	
displacement	base force	displacement	base force	displacement	base force
0	0	0	0	0	0
0.051726	748.461	0.060807	879.863	0.069886	1011.247
0.056106	795.125	0.065918	934.315	0.075715	1073.328
0.072054	893.226	0.084677	1050.426	0.097313	1207.045
0.096827	971.473	0.113223	1142.42	0.129895	1312.119
0.188245	1094.467	0.229729	1311.593	0.251277	1474.876
0.191478	1095.34	0.20901	926.396	0.25647	1478.502
0.168724	710.139			0.258176	1476.144
				0.220451	865.835

Table-3: 3 Bay 2 Storey Displacement-Base shear

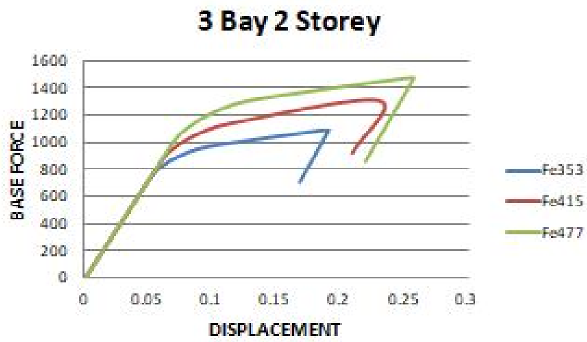

Fig 4: 3 Bay 2 Storey Pushover curve

Fe353		Fe415		Fe477	
displacement	base force	displacement	base force	displacement	base force
0	0	0	0	0	0
0.075794	689.609	0.089099	810.665	0.102401	931.7
0.081895	734.073	0.096199	862.402	0.110473	990.516
0.105166	833.29	0.123419	977.06	0.14151	1118.788
0.13818	887.6	0.143487	1012.068	0.160825	1128.515
0.139588	880.254	0.144246	1003.216	0.119468	674.867
0.140314	878.093	0.144247	1003.195		
0.140702	876.363	0.144204	995.772		
0.140717	874.48				
0.11552	586.16				

Table-4: 3 Bay 3 Storey Displacement-Base shear

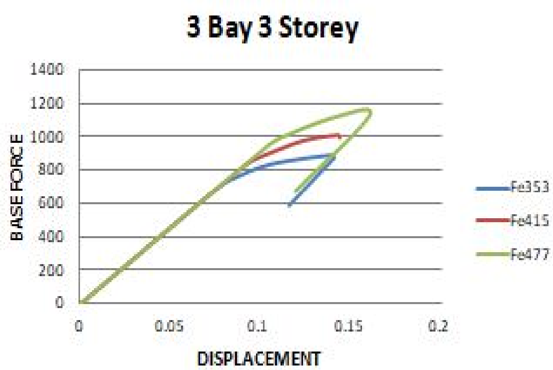

Fig-5: 3 Bay 3 Storey Pushover curve

Fe353		Fe415		Fe477	
displacement	base force	displacement	base force	displacement	base force
0	0	0	0	0	0
0.100554	662.631	0.118204	778.946	0.135851	895.238
0.12151	754.681	0.134793	855.696	0.164305	1020.297
0.129326	774.611	0.125972	788.28	0.18711	1086.545
0.130682	776.174	0.224304	1050	0.224304	1150.6
0.224304	950	0.370201	1185	0.370201	1285.216
0.370201	1084	0.445624	1230	0.445624	1330.866
0.445624	1130	0.328963	390	0.328963	489.454
0.328963	289				

Table-5: 3 Bay 4 Storey Displacement-Base shear

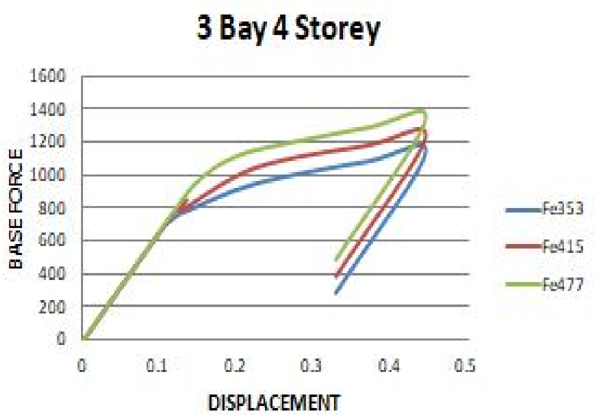

Fig-6: 3 Bay 4 Storey Pushover curve

3.2. Hinge pattern

Hinge pattern behavior in the various models. The numbers for the hinges represent the formation of hinge in each step i.e in the order of 1-2-3-4-5 the hinges are formed in the multiple steps. For example in the fig-6 i.e three bay one storey frame many hinges are formed in multiple steps. The understanding of the sequence of hinges is by numbering them in order.

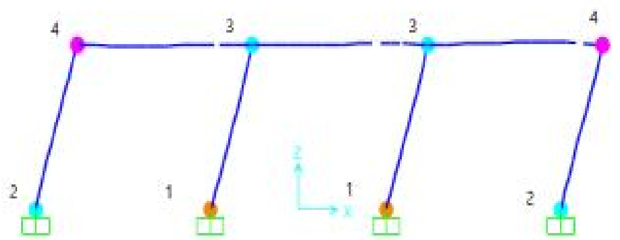

Fig-7: 3 Bay 1 Storey Hinge pattern

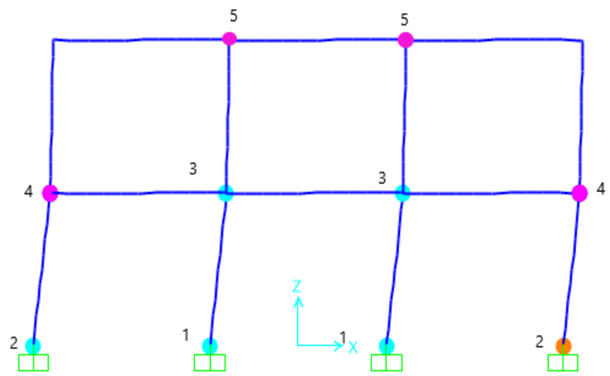

Fig-8: 3 Bay 2 Storey Hinge pattern

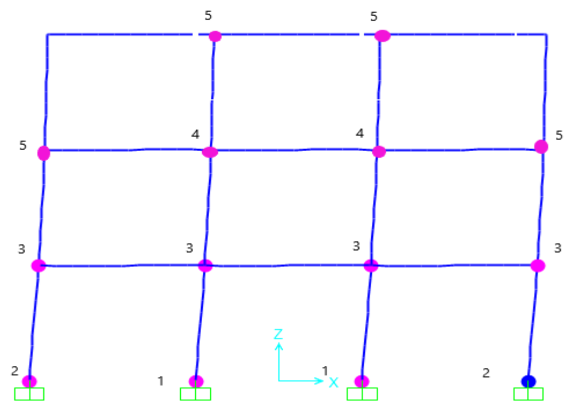

Fig-9: 3 Bay 3 Storey Hinge pattern

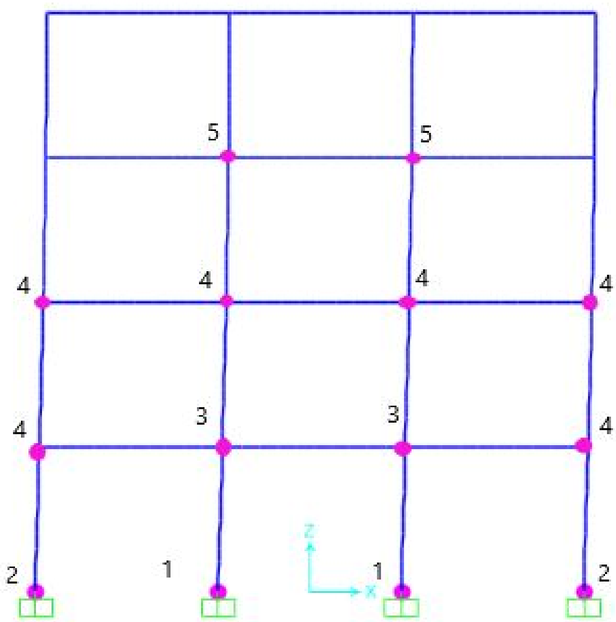

Fig-10: 3 Bay 4 Storey Hinge pattern

IV. CONCLUSION

The main objective of the study is to understand the sequence of hinge formations for various grades of concrete

1. The location of plastic hinge can vary according to the geometrical properties of structural components.
2. The gap between the successive hinges will have the major effect on structural behavior.
3. The order of sequence of hinge formation controls the deformation characteristics of the structure.
4. With the change in height and material of the structures the non linear behaviour will change from one structure to another.
5. The formation of first plastic hinge in various grades of steel structures were observed i.e it is the point where non linearity is started.

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