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Non-Linear Seismic Analysis of Multi-Storey Building

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ABSTRACT

For structural design and assessment of reinforced concrete members, the non- linear analysis has become an important tool. To find the complex behavior of reinforced concrete model analytically in its non-linear zone is difficult. This analysis of the nonlinear response of RC structures to be carried out in a routine fashion.

Pushover method can be used to study the behavior of reinforced concrete structures. It helps in the investigation of the behavior of the structure under different loading conditions, its load -deflection behavior and the cracks pattern. In the present study, the non-linear response of RCC frame using SAP2000 under the loading has been carried out with the intention to observe the yielding of the members and the adequacy of the structural strength. The extent of damage experienced by the structure at the target displacement is considered representation of the damage that would be experienced by the building when subjected to design level ground shaking.

The pushover curve is generated by pushing the top node of structure to the limiting displacement for the structure and consequent base shear, cracks, yielding and hinge formation in the different members of the structure observed.

Keyword: Multi-Storey Building, Non-Linear Seismic Analysis, Pushover Method & SAP2000.

Introduction:

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.

Pushover analysis can be performed as force-controlled or displacement- controlled. In force controlled pushover procedure, full load combination is applied as specified, i.e., force controlled procedure should be used when the load is known (such as gravity loading). Also, in force-controlled pushover procedure some numerical problems that affect the accuracy of results occur since target displacement may be associated with a very small positive or even a negative lateral stiffness because of the development of mechanisms and P- delta effects.

Pushover analysis has been the preferred method for seismic performance evaluation of structures 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.

CONCEPT

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. A plot of total base shear versus top displacement in a structure is obtained by this analysis that would indicate a premature failure or weakness. All the beams and columns which reach yield or have experienced crushing and even fracture are identified. A plot of total base shear versus inter-story drift is also obtained. A pushover analysis is performed by subjecting a structure to a monotonically increasing pattern of lateral loads that shows the inertial forces which would be experienced by the structure when subjected to ground motion. Under incrementally increasing loads many structural elements may yield sequentially. Therefore, at each event, the structure experiences a decrease in stiffness. Using a nonlinear static pushover analysis, a representative non-linear force displacement relationship can be obtained.

BACKGROUND

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.

Although, pushover analysis has been shown to capture essential structural response characteristics under seismic action, the accuracy and the reliability of pushover analysis in predicting global and local seismic demands for all structures have been a subject of discussion and improved pushover procedures have been proposed to overcome the certain limitations of traditional pushover procedures. However, the improved procedures are mostly computationally demanding and conceptually complex that use of such procedures are impractical in engineering profession and codes. As traditional pushover analysis is widely used for design and seismic performance evaluation purposes, its limitations, weaknesses and the accuracy of its predictions in routine application should be identified by studying the factors affecting the pushover predictions. In other words, the applicability of pushover analysis in predicting seismic demands should be investigated for low, mid and high-rise structures by identifying certain issues such as modeling nonlinear member behavior, computational scheme of the procedure, variations in the predictions of various lateral load patterns utilized in traditional pushover analysis, efficiency of invariant lateral load patterns in representing higher mode effects and accurate estimation of target displacement at which seismic demand prediction of pushover procedure is performed.

DESCRIPTION OF STRUCTURE

In this report a RC framed building was taken for analysis: G+4. The RC frame model is subjected to earthquake located in seismic zone V. In the above model, the support condition was assumed to be fixed and soil condition was assumed as medium soil.

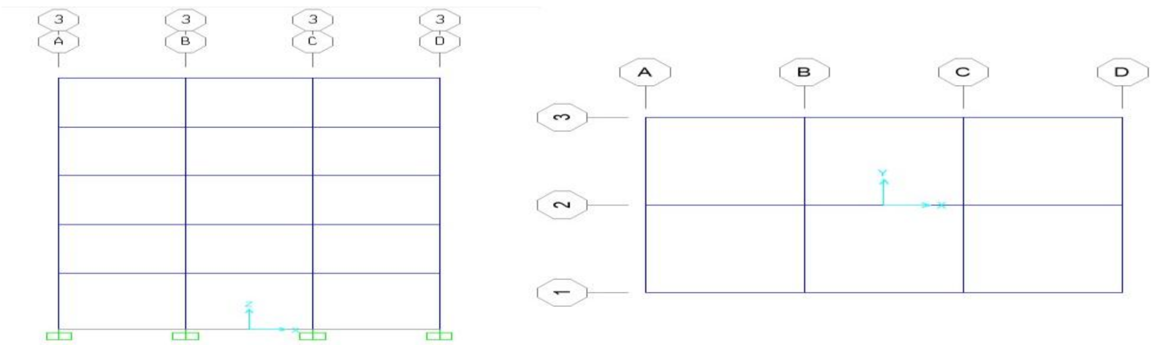

Fig: 1: Elevation and plan of RC framed building (G+4)

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The G+4 building having infill as membrane. All the slabs were considered as shell element of 130 mm thickness. All structural members were of M25 grade concrete and Fe 415 steel. The slabs were considered as rigid floor diaphragm. The model incorporates infill wall as a membrane element. The property of membrane element is such that it has only in-plane stiffness and out-planes stiffness is voids. The infill walls were provided below all the beams except the first floor beams. The thickness of wall was 230 mm. The geometrical properties of beams and columns and loading were same as considered in bare frame.

CALCULATION OF LATERAL FORCES AT EACH STOREY

Design seismic base shear is calculated according to the clause 6.2.4 of IS 1893 (Part I):2002. The design seismic base shear can be calculated from SAP 2000.

Nonlinear using Response Spectrum analysis as per IS 1893:2002. The total base shear is given by:

$$Vb = Ah\ W$$

$$Ah = Z\ I\ (Sa/g)/\ 2R$$

$$Qpi = Vb\ Wi\ hi^2 / \sum Wj \ \ldots\ldots\ldots\ldots (c)$$

RESULTS

Floor	Wi	Hi	$Wi*hi^2$	$Wi*hi^2$ / $\sum Wi*hi^2$	$Qip = Wi*hi*Vb$ / $\sum Wi*hi^2$	Vi
1-1	2400	4	38400	0.024	25	25
2-2	2400	7.5	135000	0.087	89.26	114.6
3-3	2400	11	209400	0.187	191.86	306.12
4-4	2400	14.5	504600	0.326	334.4	640.52
5-5	1800	18	583200	0.375	384.75	1026
TOTAL			**1551600**		**1026**	

PLASTIC HINGE FORMATION

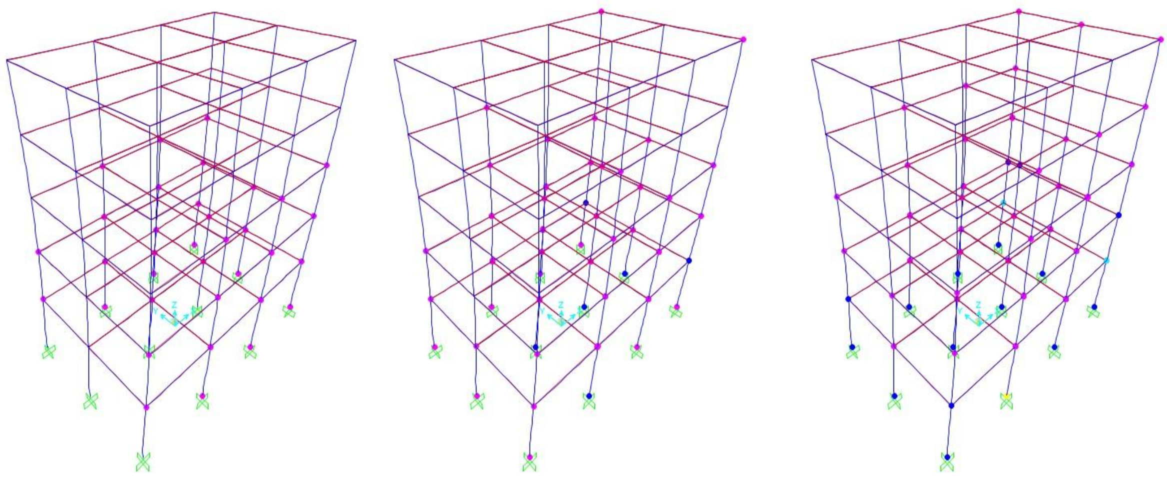

Fig: 2: Plastic hinge formation at different steps

The plastic hinges are formed from first to fourth floor only but from first to third floor plastic hinges are beyond the collapse prevention level which is in danger zone and somewhere life safety levels are also appeared.

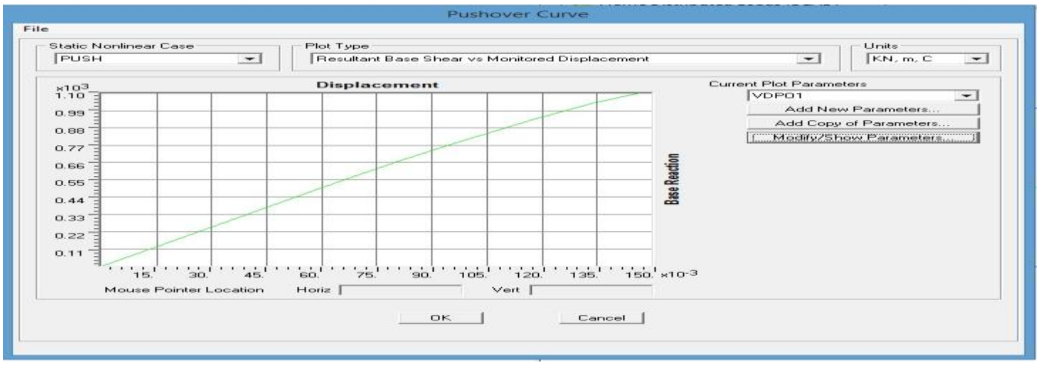

Fig: 3: Pushover analysis

In the above figure shows the Pushover curve is linear up to immediate occupancy level beyond that the is Non-linear up to collapse prevention level and the target displacement is $720X10^{-3}$ m, which is 4% of the total height of the building.

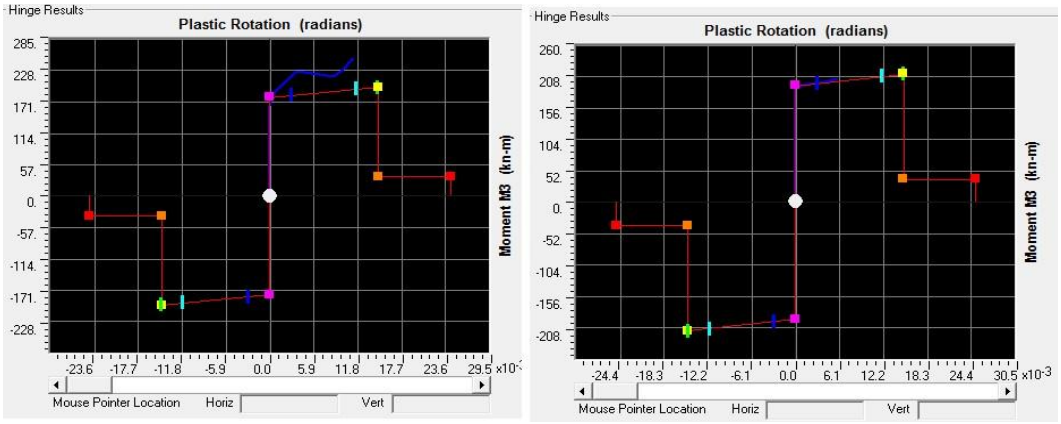

Fig: 4. Hinges path of different beams and columns

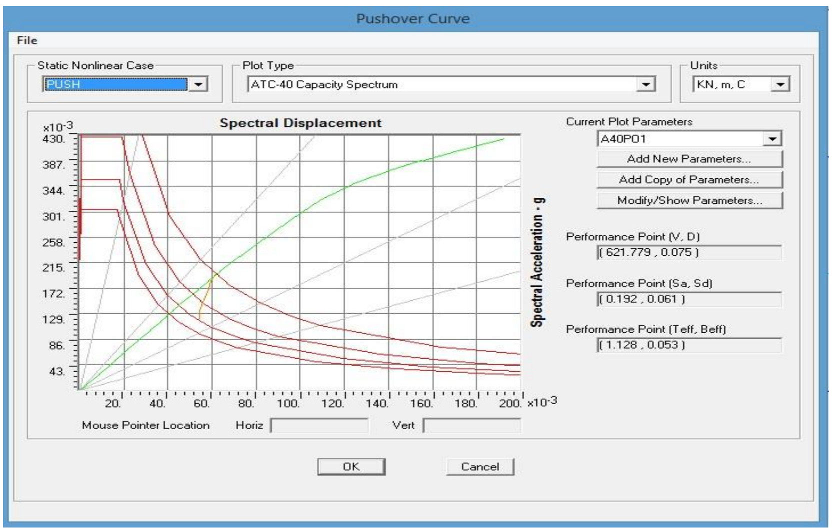

Fig: 5: ATC-40 Capacity Spectrum

In the above figure shows the Capacity curve and Demand curve are intersected in the life safety zone. This point of intersection is known as the Performance point. Based on this Performance point location the damage intensity to the building will be calculated. Above green line is Pushover curve is divided into three stages, i.e. immediate occupancy, life safety and collapse prevention. If this point is located in immediate occupancy the damage intensity is light. If the performance lies in life safety the damage intensity is moderate. Similarly if the performance point lies in the collapse prevention the damage intensity is severe.

Conclusion

Pushover analysis is a useful tool for accessing inelastic strength and deformation demands and for exposing design weakness. The pushover analysis is relatively a simple way to explore the non-linear behavior of the buildings. The behavior of the reinforced concrete buildings is adequate by indicating in terms of demand and capacity curves, and hinges are developed in beams.

After pushover analysis is complete, pushover curve is obtained. In this study both capacity and demand curves are intersected in between immediate occupancy and life safety zone. Such that building is subjected to moderate damage when subjected to pushover loads in Seismic Zone V.

For peak lateral load of 384.75 KN plastic hinges formation will start with beam ends and base column of lower stories then propagates and continue with the yielding of interior intermediate columns in the upper stories.

In this study, hence building is needed to be retrofitted immediately from first to fourth floor because of plastic hinges formation up to collapse prevention level.

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