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STUDY OF PROGRESSIVE COLLAPSE ON MULTI-STORIED STEEL STRUCTURE

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Abstract - Progressive collapse is a catastrophic chain reaction of failure initiated by loss of vertical bearing load element of the structure resulting in damage of a part of the structure or entire structure. In the current study, it is intended to investigate the progressive collapse potential of multi-storied steel structure according to IS 1893:2002. The buildings include regular and irregular plans of total 5 models with column removed at three different locations at first storey in order to study consequences and check safety of adjacent members. Pushover Analysis is also conducted for all the models. The seismic response of steel structure in terms of performance point and the effect of earthquake forces on multi storey building with the help of pushover analysis is carried out in this paper. Modelling and Analysis of the buildings are performed using ETABS 2017.

Key Words: Progressive collapse, DCR ratio, Pushover Analysis, Performance point, Hinge Formation

1.INTRODUCTION

During recent times, attention has need been paid in order to probe a progressive collapse among all the owners of the building in each and every part of the entire world. This is the case due to the fact that a larger building's collapse is a lot more dangerous occurrence, potentially resulting in a substantial number of causalities and fatal injuries for the occupants as well as major property loss. The progressive collapse of structures is commenced when the primary component(s), usually columns, is eliminated. When a column is suddenly removed as a result of a vehicle collision, explosion, terrorist attacks, earthquake and other natural and artificial hazards, gravity loads (Dead Load and Live Load) get transmitted to adjoining columns in the structure.

Progressive Collapse: Progressive collapse is a catastrophic chain reaction of failure initiated by loss of vertical bearing load element of the structure resulting in damage of a part of the structure or entire structure. Experts were first alerted to progressive collapse by the partial collapse of Ronan Point, a 22-story apartment building in London, UK, in 1968. After the event of 11th September, 2001 terrorist attack more researchers around the world have refocused on the causes of progressive collapse.

Pushover Analysis or Nonlinear Static method: Pushover analysis is a static procedure that uses a simplified nonlinear technique to estimate seismic structural deformations. Structures redesign themselves during earthquakes. As individual components of a structure yield or fail, the dynamic forces on the building are shifted to other components.

Methods of pushover analysis

Generally, pushover analysis is classified into two types.

i. Force controlled: In force-controlled analysis, the building is subjected to lateral loads and the displacements are determined. In this method, the magnitude of the load to be applied is known and it is expected that the building is able to support those loads. In this method, loads are applied in an incremental order from zero to full magnitude.

ii. Displacement controlled: In this method, a target displacement has been given at the beginning and forces in the lateral direction are determined. It is divided into a number of steps and then it is applied incrementally.

2.MODELLING AND ANALYSIS

In the present study, 5 models (A, B, C, D, E) are considered, which are created using ETABS software, wherein in each model, 3 cases of column removal at first storey at different locations are taken. Model A is regular square shaped, Model B is L shaped, Model C is C shaped, Model D is T shaped & Model E is U shaped. The structure is 15 - storeyed, 6 bays along X-dir. and 6 bays along Y- dir. The floors are modelled as rigid deck section.

Structure		Steel Framed Structure
No. of storeys		15
	First storey	4 m.
	Upper storeys	4 m
Type of building usage		Commercial (Assumption)
Foundation Type		Isolated footing, Fixed Support
Seismic zone		Z-2
Assumed Dead Load Intensities		
Floor finishes		1.50 kN/m^2
Live Load Intensities		
Floor		4.0 kN/m^2
Partition Wall Load		1.0 kN/m^2
Glazing Load (25mm Thk.) – Periphery Only		= 0.025x4x25 = 2.5 kN/m

Member Properties	
Column	ISWB600-2 Built-up
Beam	ISMB 500
Deck Slab	150mm Thk.
Wall	250mm Thk.

Step by step procedure for analysis

Step1: First the steel structure is modelled in ETABS 2017 as per IS 800:2007 and IS 1893:2002 and the output results are obtained from pushover curve i.e., base shear and displacement without removing any column.

Step2: A vertical column is removed from the first storey at three different locations, and the pushover analysis is carried out with loading combination as per latest GSA guidelines.

Step 3: Results are extracted for each model with 3 different column removal cases and comparison is made for 5 different models.

Step 4: Further, DCR ratio is also compared among the models. If the DCR for any member exceeds allowable limit, the member is considered a failure.

It is important to check both stages (before and after column removal) of 5 models.

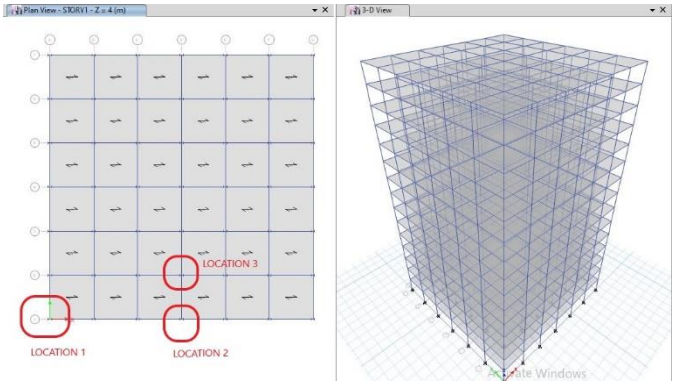


Fig 1. Sample plan view and 3D view of Model A building with 3 locations where the columns are removed

3.RESULTS

3.1 Pushover Analysis: The Pushover analysis is carried out and the performance point of the models is extracted from the graphs generated. It is the intersection of demand vs capacity curve of the structure. For all 5 models, with 3 cases of column removal, totally for 20 models the results are extracted and compared.

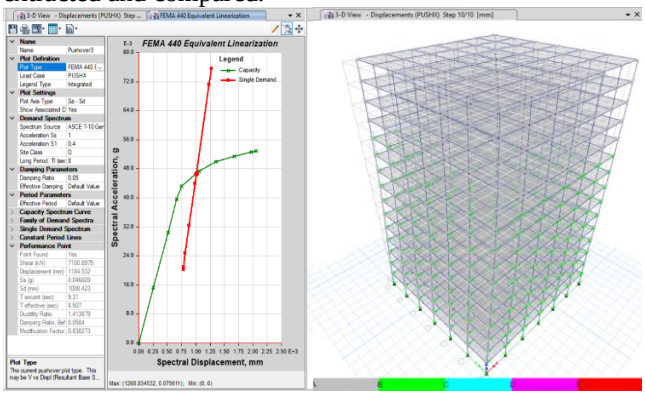
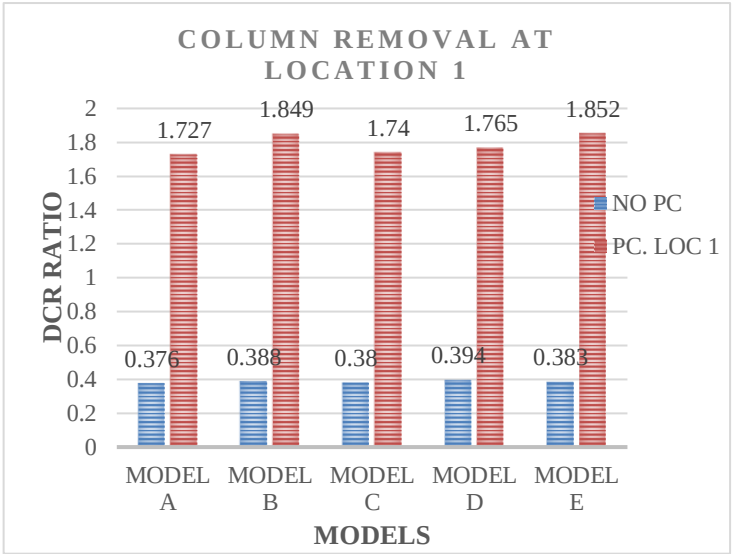


Fig 2. Sample of performance point for PUSHX condition with base shear and displacement values, Hinge Formation

3.2 DCR for Beams

The DCR – Demand Capacity Ratio of beams at column removal location is extracted. The sample table & graph shows the DCR values of beams before and after removal of column with percentage variation for column removal at Location 1.

DCR Ratios adjacent beam	Model A	Model B	Model C	Model D	Model E
No Pc	0.376	0.388	0.38	0.394	0.383
Pc. Loc 1	1.727	1.849	1.74	1.765	1.852
% Variation	459.31%	476.55%	457.89%	447.97%	483.55%

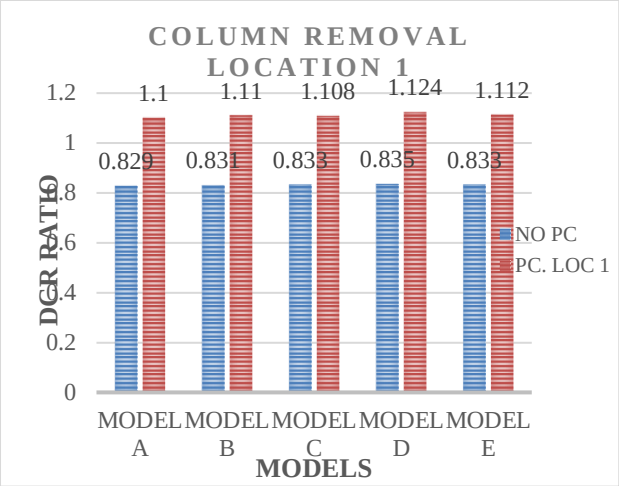


In a similar manner, DCR ratios for other two locations are extracted and compared.

3.3 DCR for Columns

The DCR – Demand Capacity Ratio of adjacent column during removal of column at various locations are extracted. The sample table & graph shows the DCR of adjacent column before and after removal of column with percentage variation for column removal at Location 1.

DCR Ratios adjacent column	Model A	Model B	Model C	Model D	Model E
No Pc	0.829	0.831	0.833	0.835	0.833
Pc. Loc 1	1.1	1.11	1.108	1.124	1.112
% Variation	24.64%	25.14%	24.82%	25.71%	25.09%



In a similar manner, DCR ratios for other two locations are extracted and compared.

4.CONCLUSIONS

1. It was found from the Pushover analysis that; the Model A is having maximum lateral force carrying capacity than other models. In the order of maximum to minimum, it can be arranged as: Model A, Model C, Model E, Model B and Model D. It was also found that the column removed at corner location 1 was critical compared to column removed at locations 2 & 3.
2. Beam fails for all cases of column removal. However, the DCR ratio is highest for Model E. Based on DCR ratio, location 2 is more severe compared with locations 1 & 3.
3.The DCR value of column is more critical for model D. However, the column removal at location 1 is critical for columns compared to locations 2 & 3. This is due to the reason that the column load is transferred to only 2 columns in case of column removal at location 1, while in the case of column removal at locations 2 & 3, column load is transferred to 3 & 4 columns.
4. From the overall analysis of progressive collapse, it was observed that the column removed at location 1 is critical compared to other locations. Also, irregular type of structure is more critical than regular structure in case of progressive collapse analysis though this margin is very nominal.

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