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Progressive Collapse Analysis of Multi Storey Steel Structure with Bracing Systems using E-Tabs

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ABSTRACT

Progressive collapse refers to the phenomenon in which the local damage of a primary structural element leads to total or partial structural system failure, without any proportionality between the initial and final damage. Even if the probability of structural collapse is low, if it occurs, it can cause significant losses. In the past few decades, many incidents of the total or partial collapse of structures due to fire, explosions or impacts have occurred. In the present study, Multi storey structure is considered. The modelling and analysis are carried out using E-tabs software. The different bracing systems are used to analysis the structural behavior. The Structure is later verified for progressive collapse analysis at 3 different locations such as corner, Centre and middle of the structure. The progressive analysis is carried out and results are extracted and discussed. The displacement control can be easily achieved by providing bracings. The displacement of bare frame models can be reduced by 55%, 55% and 63% by adopting bracings such as Diagonal bracing, V Bracing and X Bracing systems. The progressive collapse analysis shows the failure of upper level beams. It is estimated that, the maximum increase in percentage of DCR value for beams are around 38%, 52% and 59% for location A, B and C respectively. And hence the beams are super designed for these additional capacities to avoid progressive collapse. From the overall results, it is concluded that, the bracings are very much necessary for the reductions of displacement and drift effect in a building. However, its Importance is not of much use in case of progressive collapse state. The X Bracings are preferred for bracing system.

KEYWORDS: *Progressive collapse, equivalent static analysis, bracings, displacements, storey drift, base shear, time period, acceleration, E-Tabs*

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1. INTRODUCTION

A structure could be subjected to more than one critical action during its entire service period. It may be a manmade or natural disaster can lead to structural instability which influences the partial or complete collapse of the building. Natural disasters include earthquake, wind blast or fire. And these manmade disasters include terrorist attack or gas cylinder explosion or instant removal of the primary structural element. progressive collapse is one outcome of these critical loads.

The progressive collapse can be defined as a situation where local failure of a primary structural component leads to total collapse of the structure. Progressive collapse happens when relatively local structural damage, causes a chain reaction of structure elements failures, disproportionate to the initial damage, causing in partial or full collapse of the building. Local damage that initiates progressive collapse of building is called initiating damage. In general, progressive collapse occurs in a very short time in seconds. It is also possible that it can be characterized by the loss of load-carrying capacity of a relatively small portion of a building due to a typical load which, in turn initiates a fall of failures affecting a main portion of the structure.

To minimize the progressive collapse of the structure bracings provides stability and resists lateral loads. In case of steel structure to resist the lateral force and increase the stiffness of steel frame, bracings play very vital role. Bracing will make structure indeterminate. But it stiffens the structure and also helps to resist the sway of the structure. Bracings are straight member and carry only axial forces. Generally, the use of bracings instead of Shear walls provides lower stiffness and resistance for a structure but it should not be forgotten that such a system has lower weight and more useful for architectural purposes. Use of braces for seismic rehabilitation of structures should not cause any torsion disorder and designers should be aware of increasing the axial loads of columns in bracing panels. The probable uplift in columns and foundations should be controlled too.

A. Bracings

Bracing systems are very simple to construct and also to understand the theory behind it. This system is the economic way to construct a lateral load resisting system. These systems are in expensive and works exactly like truss behaviour. It will not transfer the bending moment. It can only transfer the axial loads. Bracing mainly take care of lateral loads whereas frames take care of axial loads.

The primary function of bracings is to provide stability and resist lateral loads, either from diagonal steel members or from concrete 'core'. Due to bracing, displacement of the structure gets reduced considerably it is up to 90% but in case of X-bracing material required will be more and hence V or Inverted V bracing effectively resist the displacement as compared to all other types of bracings.

Using bracing systems axial reaction is reduced and hence the footing size also gets reduced. Also, reduction in moment at base will definitely help to reduce the size of the footing and due to bracing the torsional moment in base column increases.

In this study the different bracings such as Diagonal bracing, V Bracing and X Bracing systems are used to analysis the structural behavior. The Structure is later verified for progressive collapse analysis at 3 different locations such as corner, Centre and middle of the structure. The progressive analysis is carried out and results are extracted and discussed.

B. objectives

The following objectives are considered in the present studies

A. To Study the behaviour of Multi storey steel structure.
B. To understand the behaviour of structure when accidental collapse of columns for various locations.
C. To study the various bracings system such as Diagonal, V and X bracings.
D. To understand the comparison of different models based on the parameters such as displacement, Storey drift, base shear, time period, acceleration.

2. METHODOLOGY

A. Steel structure is modelled, designed as per IS-800-2007.
B. The models are analysed for Static Analysis and progressive collapse.
C. The modelling is carried out using FEM based ETABS software.
D. Result obtained from gravity loads and then lateral loads are applied to check the behaviour of the models and Results are extracted for X direction only.

3. MODELLING AND ANALYSIS

In the present study, 8 storey structure is considered. Totally sixteen number of models are created and analysed. The model details are listed below. There are four major models, i.e., M1, M2, M3 and M4. However, the remaining models are the same models with removal of column location A, B and C respectively.

The model is 8 storey height with regular structure.

A. Description of building model

Seismic Zone	III
Seismic Zone Factor (Z)	0.16
Importance Factor (I)	1.5
Response Reduction Factor	4
Damping Ratio	0.05
Soil Type	Hard Soil (Type I)
Height of the building	32m (8 Storey)
Story to story Height	4.0 m
Span Length	5m
Column used	ISMB
Thickness of Slab	125 mm
Floor Finish	1.0 KN/m^2
Live Load	3.0 KN/m^2
Grade of Concrete(f_{ck})	M35
Grade of Structural Steel (f_{ys})	Fe 350
Grade of Reinforcing Steel	Fe 500

Table 1: Material properties and design parameters

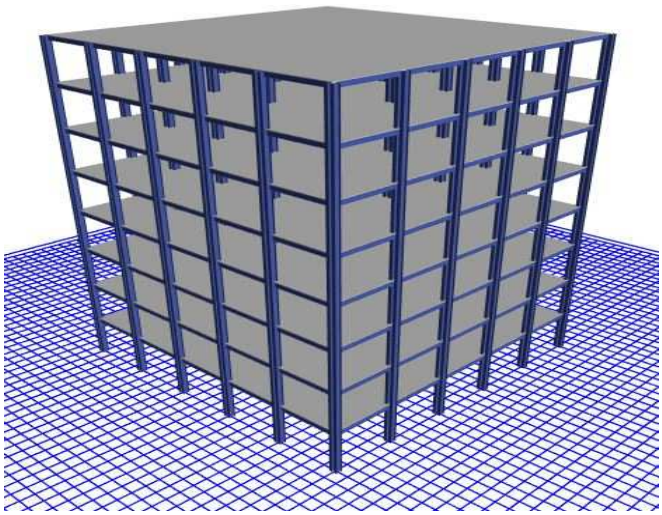


Fig 1:M1- Multi storey steel structure with no bracings

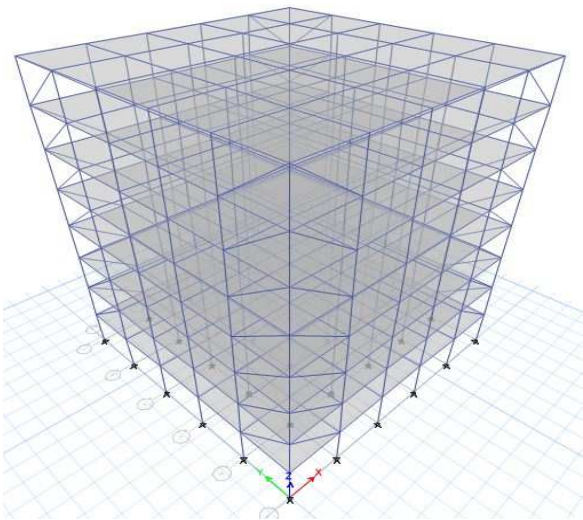


Fig 2:M2-Multi storey steel structure with diagonal bracings

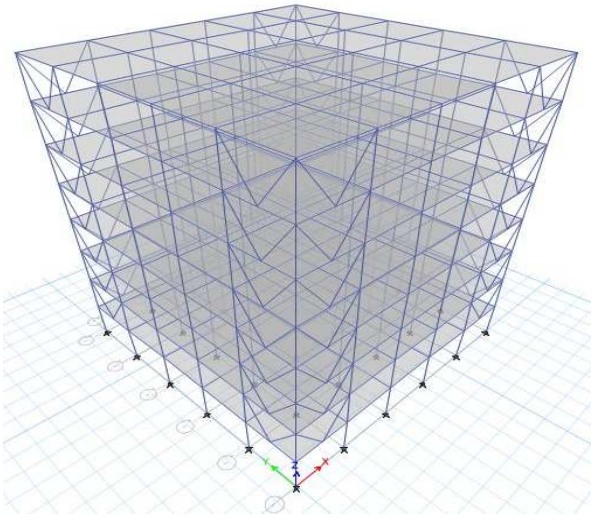


Fig 3:M3-Multi storey steel structure with V bracings

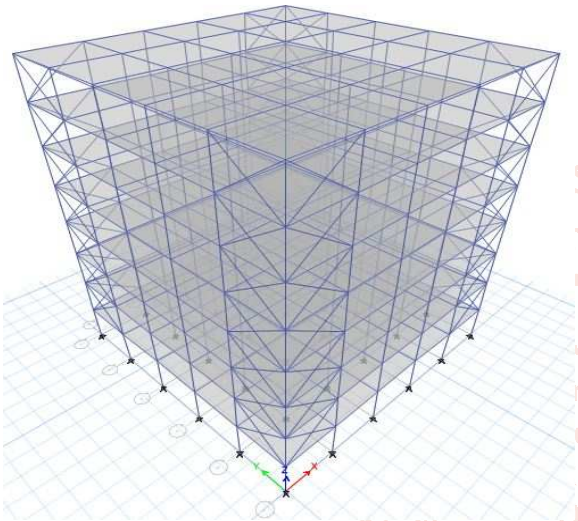


Fig 4:M4-Multi storey steel structure with X bracings

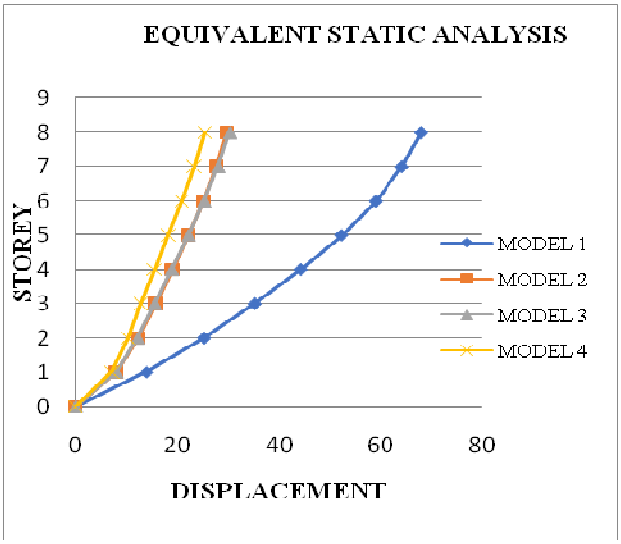
4. RESULTS AND DISCUSSION

The models are first loaded with gravity loads and then lateral loads are applied to check the behaviour of the models. Since, the models are symmetrical in both X and Y direction, the results are extracted for X direction only.

The structural results of various analysis of M1, M2, M3 and M4 are listed below.

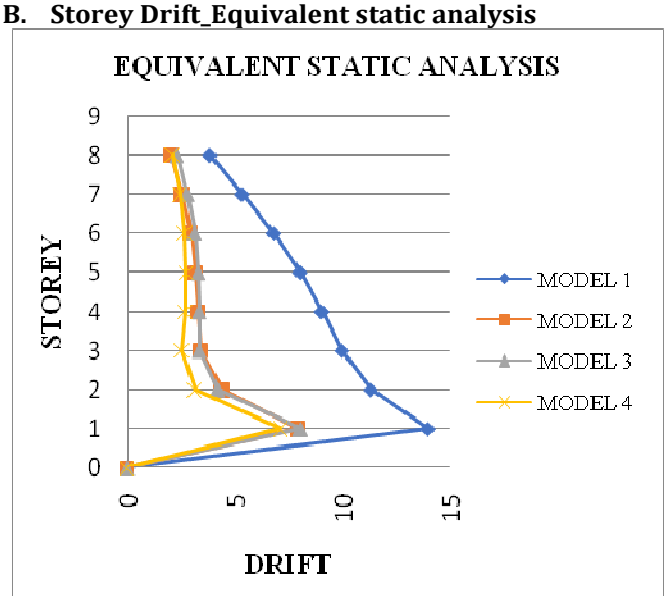
A. Displacement_Equivalent static analysis

The displacement of models in X direction is tabulated and presented below.



Graph 1: Storey v/s Displacement in x direction_EQX

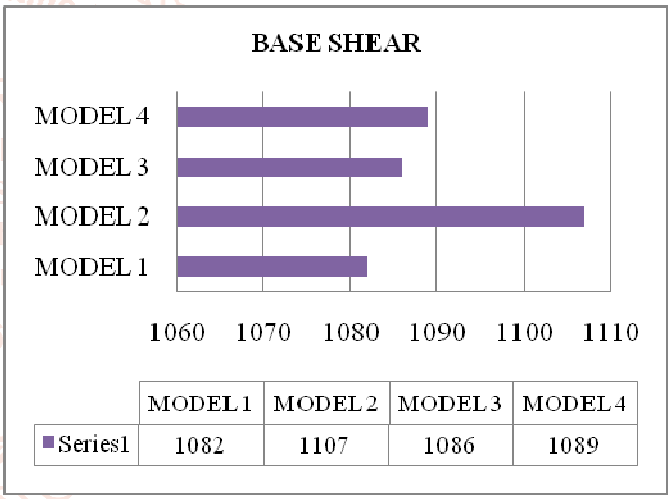
B. Storey Drift_Equivalent static analysis



Graph 2: Storey v/s Displacement in x direction_EQX

C. Base shear_Equivalent static analysis

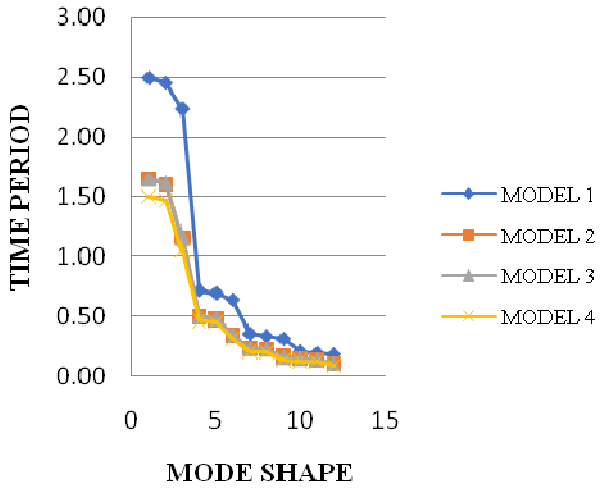
Base shear is the shear force at base or foundation level. The following table indicates the base shear value for different configurations.



	MODEL 1	MODEL 2	MODEL 3	MODEL 4
Series1	1082	1107	1086	1089

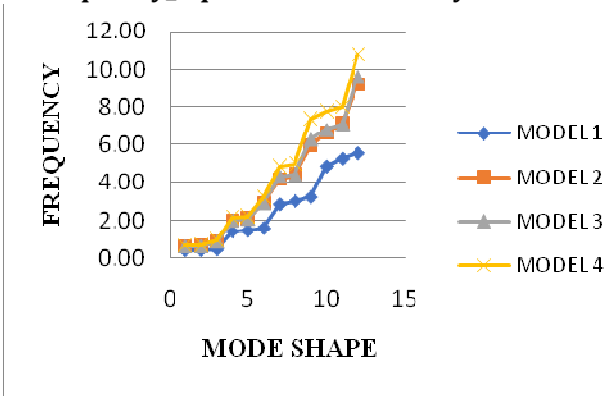
Graph 3: Base shear comparison of M1, M2, M3 and M4

D. Time period_Equivalent static analysis



Graph 4: Time period v/sMode shapes

E. Frequency_Equivalent static analysis



Graph 5: Frequency v/sMode shapes

F. Progressive Collapse Analysis

Progressive collapse analysis has been performed as per GSA specification. In case of regular framed structure removal of one column at corner (Location A), middle (Location B) at exterior frame and middle at immediate interior frame at middle (Location C) of the building is done as per GSA specification. Since in this work, Structural systems has been considered, where distance between columns are 6 m, column is assumed to be collapsed (supporting Storey 1) at locations as shown in Figures below.

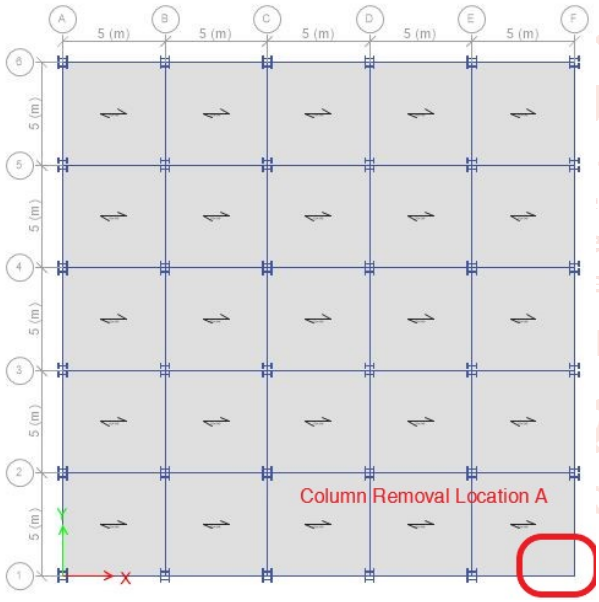
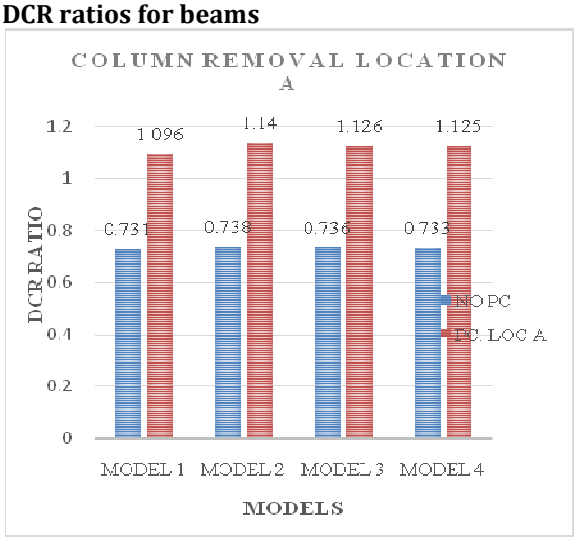
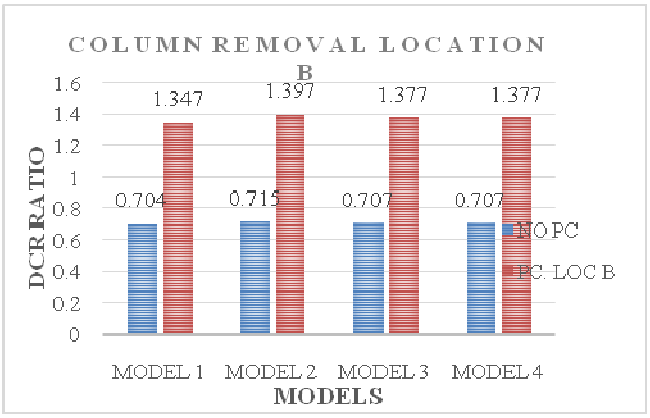


Fig 5: Assumed column removal location A Plan view

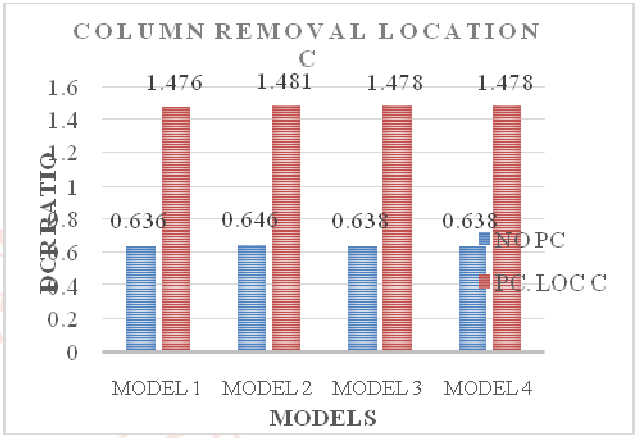
1. DCR ratios for beams



Graph 6: DCR Ratio of Beam 71 for Column Removal @ Location A

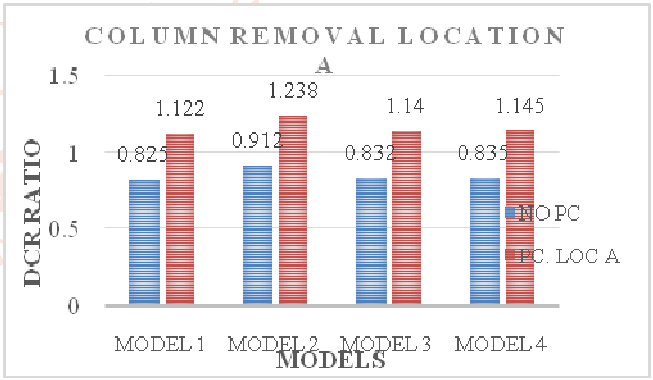


Graph 7: DCR Ratio of Beam 70 for Column Removal @ Location B

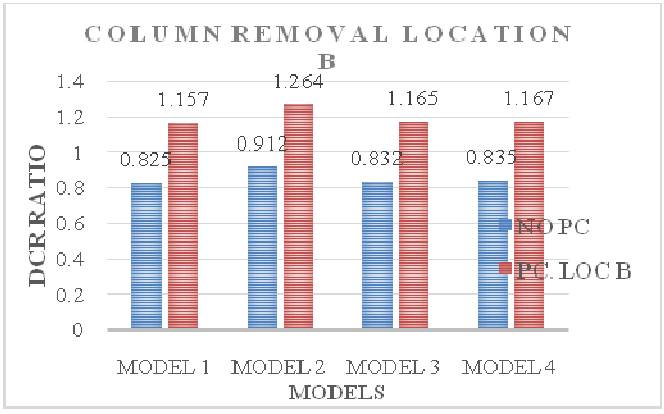


Graph 8: DCR Ratio of Beam 75 for Column Removal @ Location C

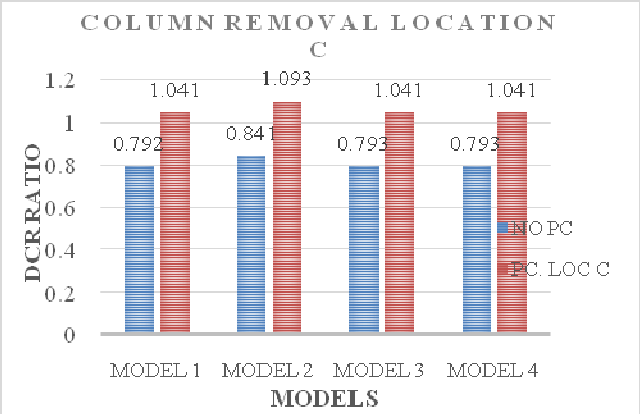
2. DCR ratios for column



Graph 9: DCR Ratio of Column 25 for Column Removal @ Location A



Graph 10: DCR Ratio of Column 25 for Column Removal @ Location B



Graph 11: Axial Load on Column 25 Column Removal @ Location C

5. CONCLUSIONS

Based on the results and discussions, the following conclusions are drawn,

- The displacement control can be easily achieved by providing bracings.
- If in case to reduce the displacement of the models without increasing the member sizes, the bracing can be provided to achieve economy.
- The displacement of bare frame models can be reduced by 55%, 55% and 63% by adopting bracings such as Diagonal bracing, V Bracing and X Bracing systems. The storey drift values for bare frame model M1 is more but within the allowable limit i.e., with in h/250 = 4000/250 = 16. However, Model M1 maximum value is found to be 14. Hence, the bracing systems can greatly reduce the drift values to 8.This reduction of drift is significant, which greatly reduces the drift values and avoids local failure.
- The base shear values for all models are almost similar. Since, all the models are possessing same weight, the base shear values are same. However, the model 2 with diagonal bracing system is showing morebase shear comparatively.
- The rigidity of models increases with the bracing system. The model 4 is having lowest time period value and having lesser flexibility.
- The model M2, M3 are having same flexibility compared with other models since the time period of both the models are similar.
- The Model M4 is having maximum frequency than other models. The time period is inversely proportional to frequency and the lesser the time period more will be the frequency.
- From the progressive collapse analysis, it is found that, the DCR ratio of column increase only for removal adjacent columns.
- Column Removal Location A
- The removal of column at location A shows the results such as there is an increase in the percentage of DCR ratio of beam is noticed at Storey 3 compared to storey 1. The DCR ratio is found to be more for model 2.
- The DCR Ratio of column is found maximum in model M2A.
- The increase in percentage of axial Load is found in model M4A.

Future scope

- The structure can be studied further by increasing the number of storey and for different zones.
- Pushover analysis can be adopted to study the localized behaviour.
- Time history analysis can be considered.

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