

# Dynamic Breakdown Analysis of Asymmetric High Rise Building

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**Abstract:** The structures for the most part get breakdown because of the disappointment of one or a couple of underlying segments which at that point advances over the progressive of different segments. This interaction is alluded as reformist breakdown of the design. Neighborhood harm that starts reformist breakdown is called starting harm. To consider the breakdown in logical manner, stacking example or limit conditions are needed to be changed so other underlying components inside the design are stacked past their ability. This prompts advancement of elective burden ways to start the reallocation of burdens. A commonplace model of a 12 story structure is made on ETABS Software and investigation of built up concrete outlined construction under basic section expulsion has been conveyed utilizing the straight static examination techniques according to the rules gave in GSA (2003) and FEMA: 356 rules separately thinking about the arrangements of IS1893:2002 codes to reproduce dynamic breakdown issues. The outcomes are then analyzed for the boundaries, for example, Demand limit proportion PMM proportion and Robustness marker were checked for the acknowledgment models gave in GSA 2003. Based on outcomes and contrasting DCR estimations of various bars and sections with acknowledgment rules given in GSA 2013 and American Society of Civil Engineering (ASCE) 41 [10].

**Index Terms – Dynamic Breakdown, GSA, Demand capacity ratio, base shear, ETABS, PMM ratio.**

## I. INTRODUCTION

The term “Progressive Collapse” can be simply defined as the ultimate failure or proportionately large failure of a portion of a structure due to the spread of a local failure from element to element throughout 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.

A progressive collapse is forceful event as it comprises of the vibrations of structural components and results in forceful internal forces. These internal forces could be such as inertia forces etc., whose intensity is not absorbed by the building structure. Progressive collapse is a natural non-linear event, in which structural components are stressed beyond their elastic limit to occur the failure.

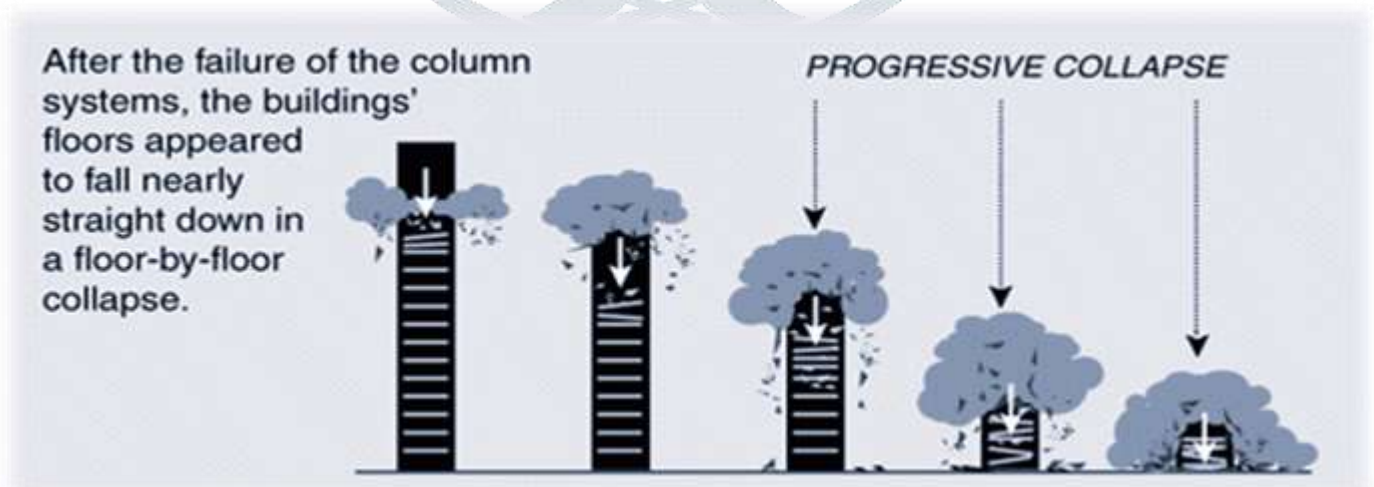


Figure 1: Dynamic Breakdown

Progressive collapse is the spread of local damage, from an initiating event, from element to element resulting, eventually, in the collapse of an entire structure or a disproportionately large part of it; also known as disproportionate collapse (*Bruce R. Ellingwood, 2007, p. 1*). As can be seen the different norms approach the progressive collapse in different ways, but they have

in common some limits for the extent of the damage. Typically destruction in such a collapse would extend one structural part, 100 m<sup>2</sup> of floor area, or two stories. That kind of crash can be initiated by many causes, including design and construction mistakes and load events that are over design dimensions or are not taken into account. Such events would include abnormal loads not usually considered in a project.

The potential abnormal loads that can cause the progressive collapse are categorized like that:

- a. Pressure Loads
  - Internal gas explosions
  - Blast
  - Wind over pressure
  - Extreme values of environmental loads
- b. Impact Loads
  - Aircraft impact
  - Vehicular collision
  - Earthquake Overload due to occupant overuse Storage of hazardous materials

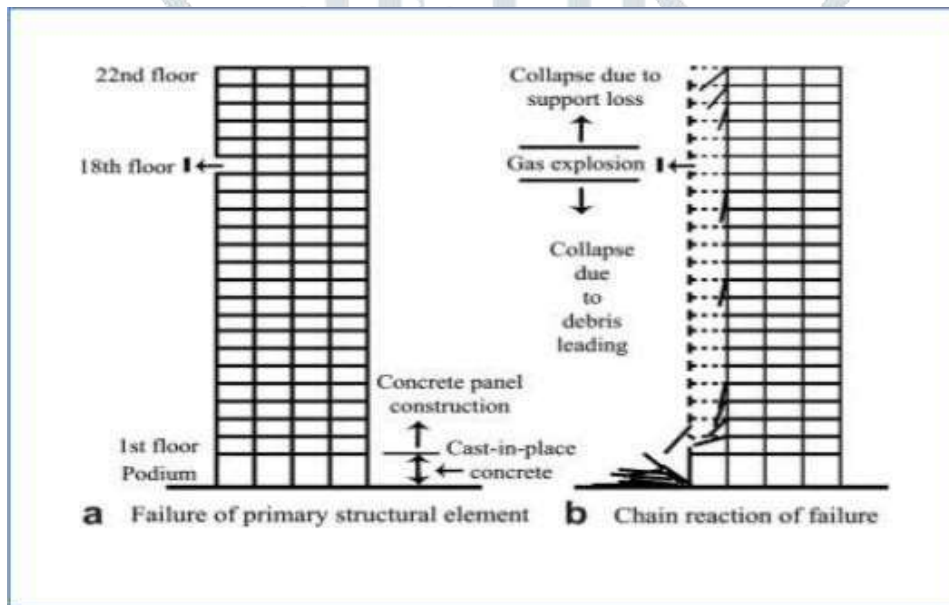


Figure 2: Process of Dynamic Breakdown

In the above figure the general process of Dynamic Breakdown is explained. Let us assume a column of 18<sup>th</sup> floor in any 22 storey building is lost due to fire or explosion of LPG cylinder in the kitchen (as shown in fig a.) the building is a multistorey building may be of precast concrete panels. This failure may lead to the failure of building elements (beams and columns) near to this damaged column of 18<sup>th</sup> floor that will form a chain reaction of failure (shown in fig b.).

The similar phenomenon can happen due to explosion of outer column in a terrorist attack on any high rise building (as done in WTC 9/11).

## II. THE GSA (GENERAL SERVICE ADMINISTRATION)

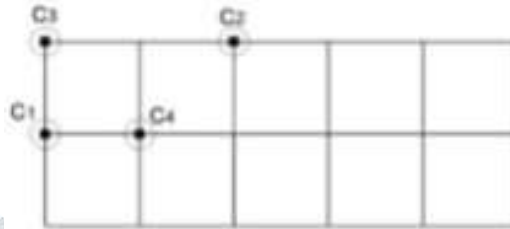
The aim of General Service Administration (GSA) guidelines is to minimize potential for the progressive collapse and provides help for evaluating the progressive collapse risk in new and existing buildings. The GSA (General Service Administration) provides a step-by-step guidance for the structure analysis which is subjected to a sudden removal of load carrying structural element. This guideline also provides provisions for removal of the columns including external and internal columns and load-bearing walls.

The purpose of these Guidelines is to:

- Assist in the reduction of the potential for progressive collapse in new Buildings.
- Assist in the assessment of the potential for progressive collapse in existing Buildings.
- Assist in the development of potential upgrades to facilities if required.

#### The GSA (2003) Guidelines Recommended Missing Column Scenario:

The potential for progressive collapse is evaluating using linear static analysis and nonlinear static analysis in four damage analysis cases. These four damaged column cases are shown in the fig. below:



The loss of an exterior column located near the middle of the short side (case C1).

The loss of an exterior column located near the middle of the long side (case C2).

The loss of a corner column (case C3).

The loss of an interior column (case C4).

### III. SOME TERMINOLOGIES USED IN THIS STUDY

#### • *Robustness Indicator:*

Robustness indicator (R) is defined as the ability of building to survive the local failure to withstand the loading and does not cause any disproportionate damage.

Where,

$$R = V_d / V_i$$

$V_d$  is the Base shear of damaged building,

$V_i$  is the Base shear of intact building.

The value of Robustness indicator must be equal to 1, then the structure is able to provide an alternative load path.

#### • *Demand-Capacity Ratio:*

The magnitudes and distribution of potential demands on both the primary and secondary structural elements have been identified through linear elastic analysis to quantify the potential collapse areas. These magnitude and distribution of demands are being indicated by Demand-Capacity Ratios (DCR).

Acceptance criteria for the primary and secondary structural components is determined as:

$$D.C.R. = QUD / QCE$$

Where,

$QUD$  = Demand force (acting) such as bending moment, axial force, shear force

$QCE$  = Expected ultimate, un-factored capacity of the component and/or connection/joint (moment, axial force, shear and possible combined forces)

The load bearing structural elements are considered to be severely damaged or collapsed if their DCR values through linear elastic approach, exceeds the allowable values. These, the allowable values of DCR are:

DCR < 2.0 for typical structural configurations (GSA 2003 Section 4.1.2.3.2)

DCR < 1.5 for atypical structural configurations (GSA 2003 Section 4.1.2.3.2)

- **Compression-bending Ratio (PMM ratio):**

The Compression-bending Ratio (PMM ratio) is the sum of axial force demand /capacity ratio and the maximum bending moment demand /capacity ratio. The PMM ratio for any member is the compression-bending ratio considering Euler and Lateral-torsional buckling based on the interaction equations.

$$\text{PMM ratio} = \text{P ratio} + \text{M ratio}$$

Where,

**P ratio** = Axial force demand / capacity ratio

**M ratio** = Bending moment demand capacity ratio

Acceptance criteria for the primary and secondary structural components is given as

$$\text{PMM ratio} = \text{P ratio} + \text{M ratio} < 1.5$$

#### IV. OBJECTIVES OF THE STUDY

The main objective of this work is to do the Progressive Collapse Assessment of an asymmetric G+11 HOTEL BUILDING situated in zone II and of India. The same structure is modeled and analyzed by ETABS software

Following are the objectives of this work-

- 1) To identify the critical columns for the progressive collapse analysis of a multi-storey building.
- 2) To determine the DCR (demand capacity ratio) for beams neighboring to removed columns in both shear and flexure criteria.
- 3) To determine the PMM Value (Column forces) for columns neighbouring to removed columns and determine the percentage increment in the forces as compared to the intact conditions.
- 4) To plot the maximum displacement curve for all the structures.

#### V. METHODOLOGY

In this work, the analysis based on linear static method is used to investigate **Progressive Collapse Assessment of High rise Asymmetric building under Accident loading and its Modelling Using Etabs Software** as per IS-standards. In order to study the effect seismic force on Progressive Collapse Assessment zone II of India is considered.

Table 1: Cases Considered for the Study

Specifications	Data
Typical Storey Height	3 m
Base Storey Height	3.0 m
No. of Bays along X-Direction	4
No. of Bays along Y-Direction	5
Bay Length along X-Direction	7.5 m
Bay Length along Y-Direction	8.0 m
Concrete Grade	M-30
Density of R.C.C.	25 KN/m <sup>3</sup>
Density of Masonry	20 KN/m <sup>3</sup>
Columns (perimeter)	600 mm x 600 mm
Columns (interior)	600 mm x 600 mm
Beams	250 mm x 550 mm
Slab Thickness	150 mm
Bottom Support Conditions	Fixed
Live Load- Roof	1 KN/m <sup>2</sup>
Rest of the structure	2 KN/m <sup>2</sup>
Soil Conditions	Type 2 Soil (medium)
Damping Ratio	5%, as per IS-1893: 2002 (Part-1)
Poisson Ratio	0.2
Response Reduction Factor	4
Importance Factor	1
Zone Factor	As per IS1893- 2002 (Part 1) for different Seismic Zones

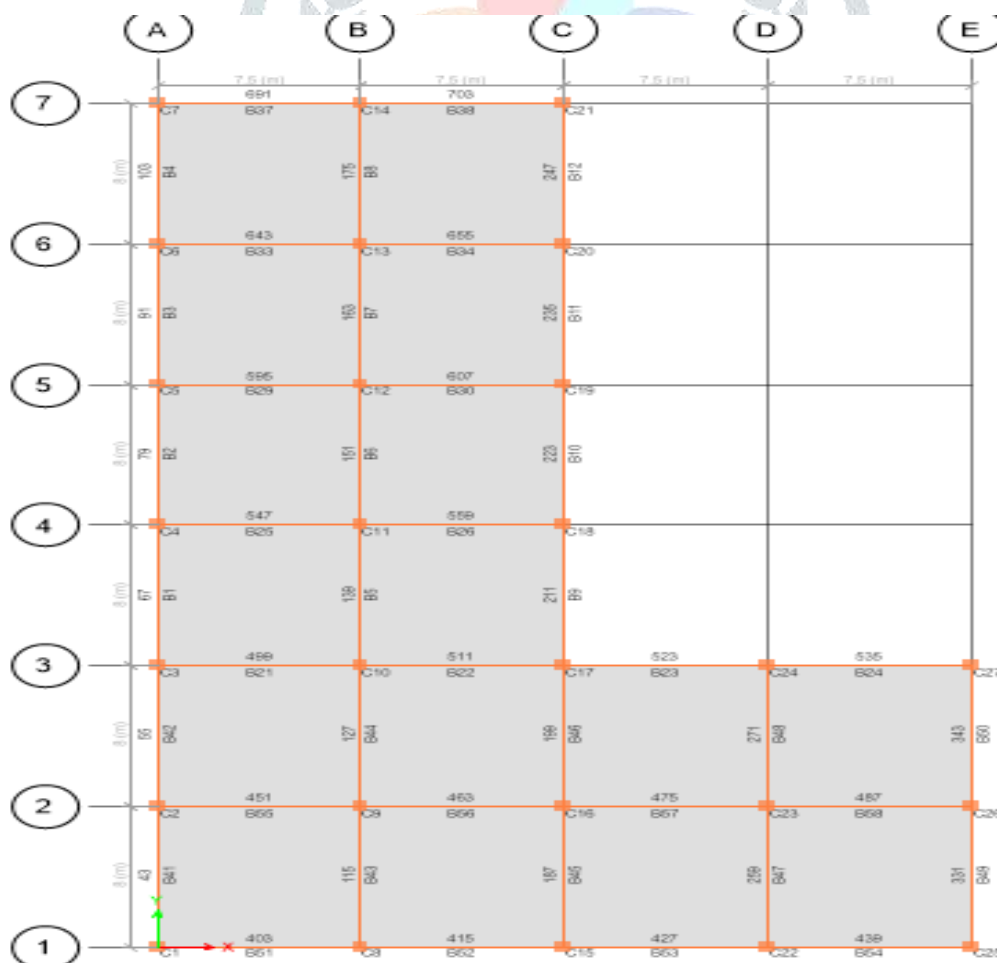


Figure 3: Plan view of the structure

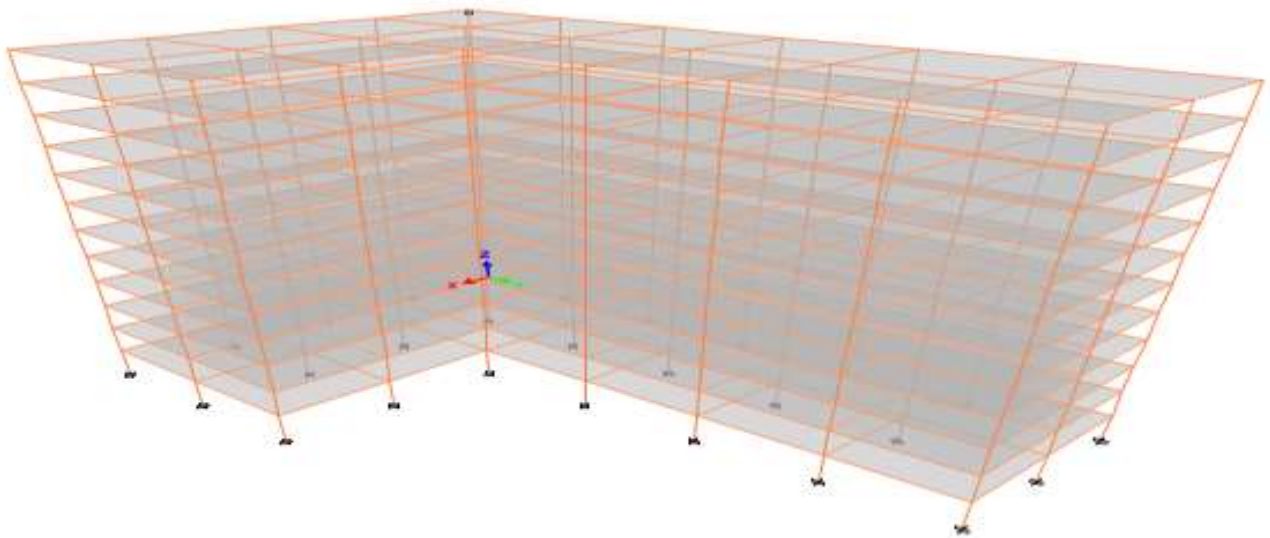


Figure 4: 3-D view of the structure

**Cases considered for analysis**

The following cases has been considered for the analysis of work. Modeling has been carried out using ETAB 16.2.1.

**CASE (1) ASYMMETRICAL BUILDING SUBJECTED TO SEISMIC FORCES IN GENERAL CONDITION**

**Case (2) Column is lost due to Gas explosion – In this Interior column will be lost.**

**VI. RESULTS**

(1) DETERMINATION OF DCR (DEMAND CAPACITY RATIO) VALUES FOR THE BEAMS NEIGHBORING TO REMOVED COLUMNS:

In this case we consider that interior column C 10 of ground floor is suddenly removed. The effect of that on the neighbouring elements is explained in the form of parameters discussed below.

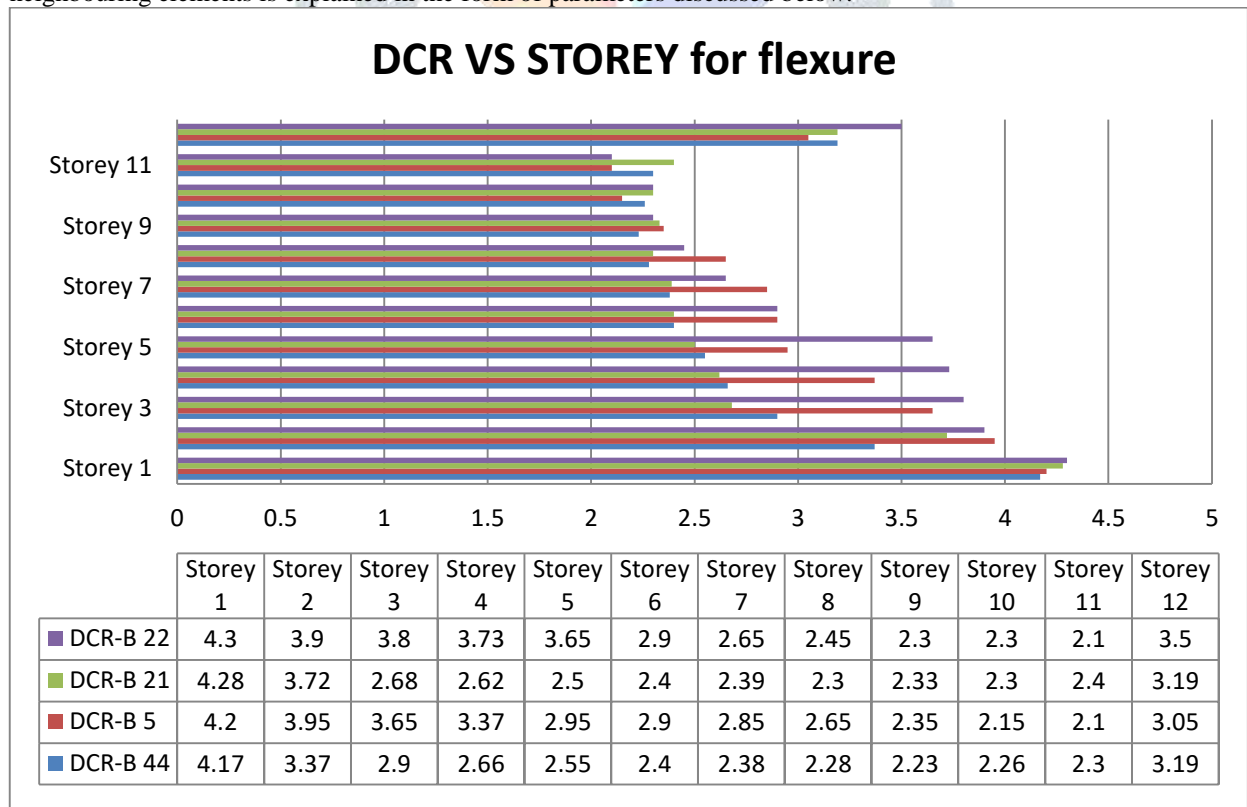


Figure 5: DCR values for flexure

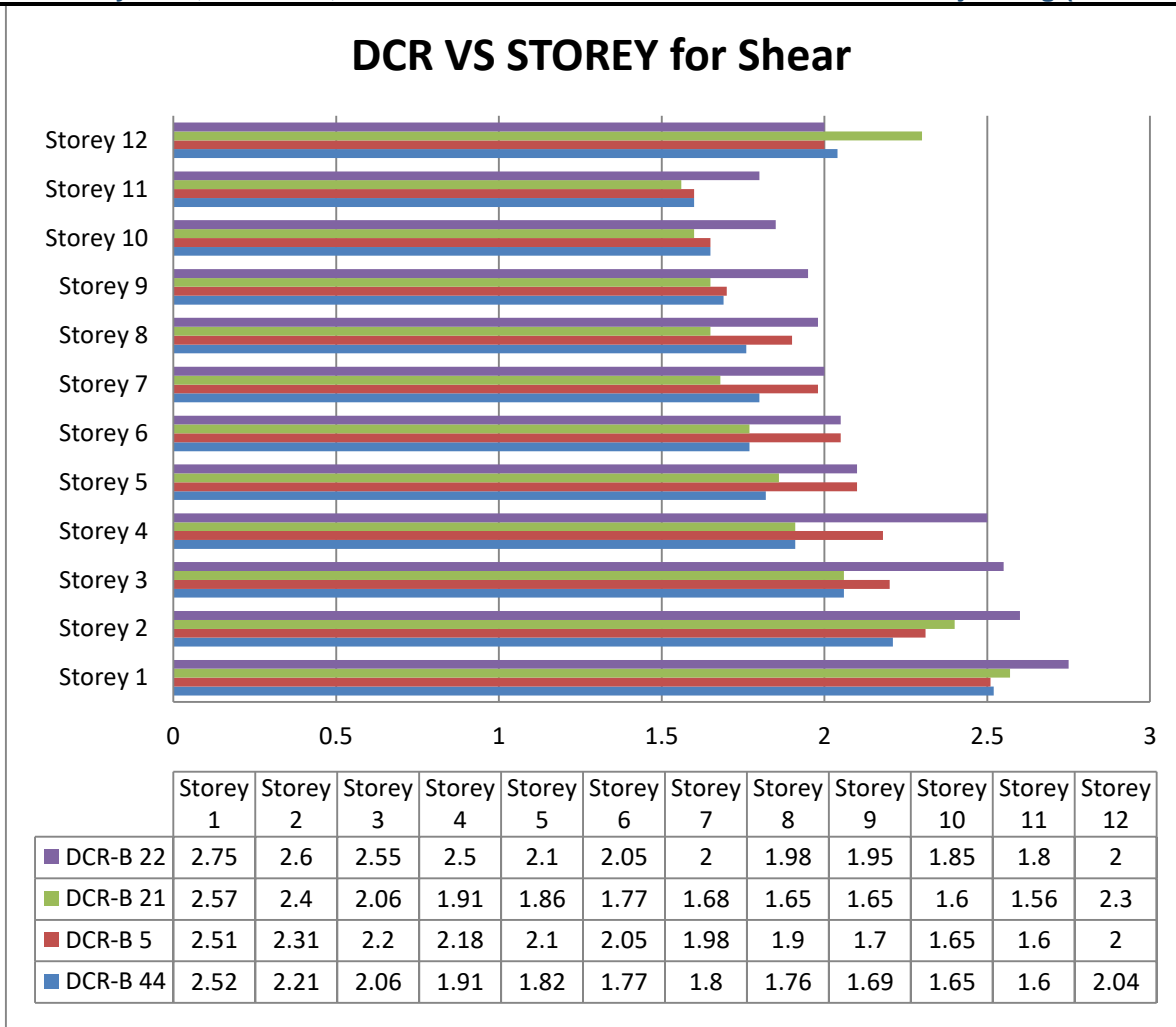


Figure 6: DCR values for Shear

(2) DETERMINATION OF PMM (COLUMN FORCES) VALUES FOR THE COLUMNS NEIGHBORING TO REMOVED COLUMNS

Table 2: Column forces (in C-9) for the case of removal of critical column C-10

Building parameters related to C-9	Value in Damaged condition	Value in Intact condition	Increment in Percentage
Axial load (kN)	6220.20	4120.77	50.94%
Bending moment (kN-m)	288.98	185.54	55.75%
Shear force (kN)	112.47	54.22	107.43%

Table 3: Column forces (in C-8) for the case of removal of critical column C-10

Building parameters related to C-8	Value in Damaged condition	Value in Intact condition	Increment in Percentage
Axial load (kN)	6234.20	4137.23	50.68%
Bending moment (kN-m)	258.98	184.69	40.46%
Shear force (kN)	106.47	54.39	95.78%

(3) DETERMINATION OF MAXIMUM BASE SHEAR REPRESENTATION FOR ALL THE STRUCTURES

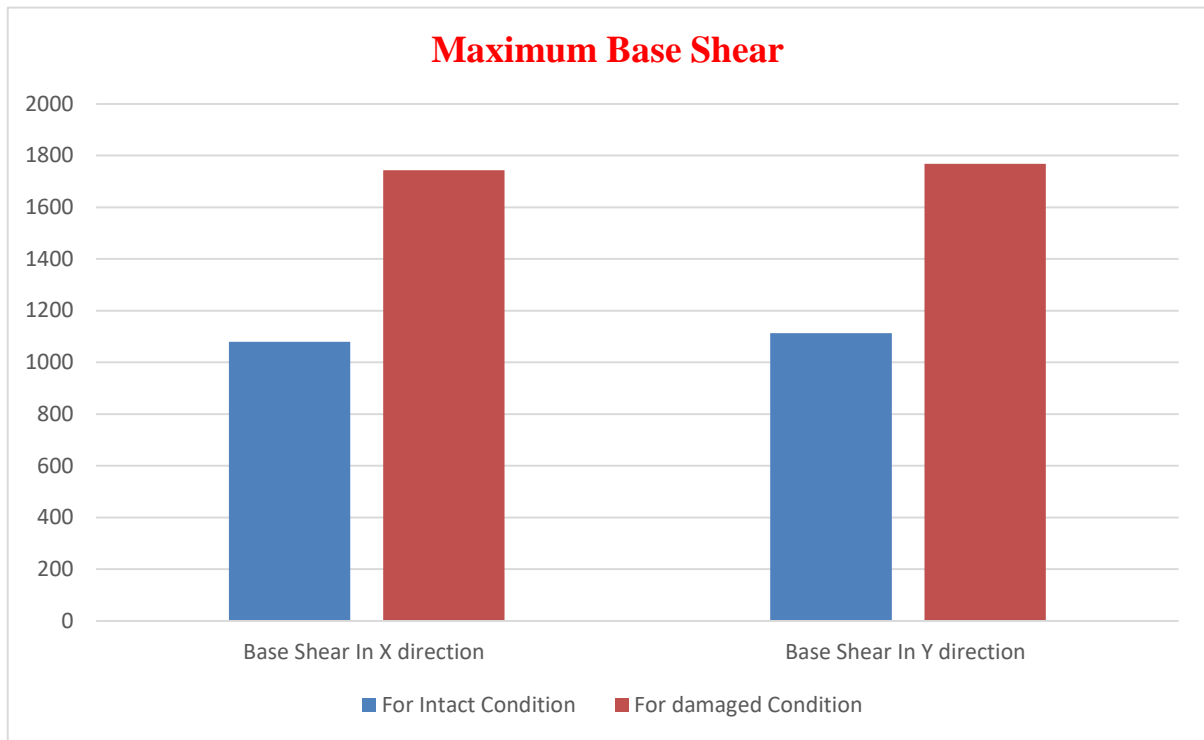


Figure 7: Maximum Base Shear in X &Y direction

(4) DEFORMED SHAPE REPRESENTATION FOR ALL THE STRUCTURES

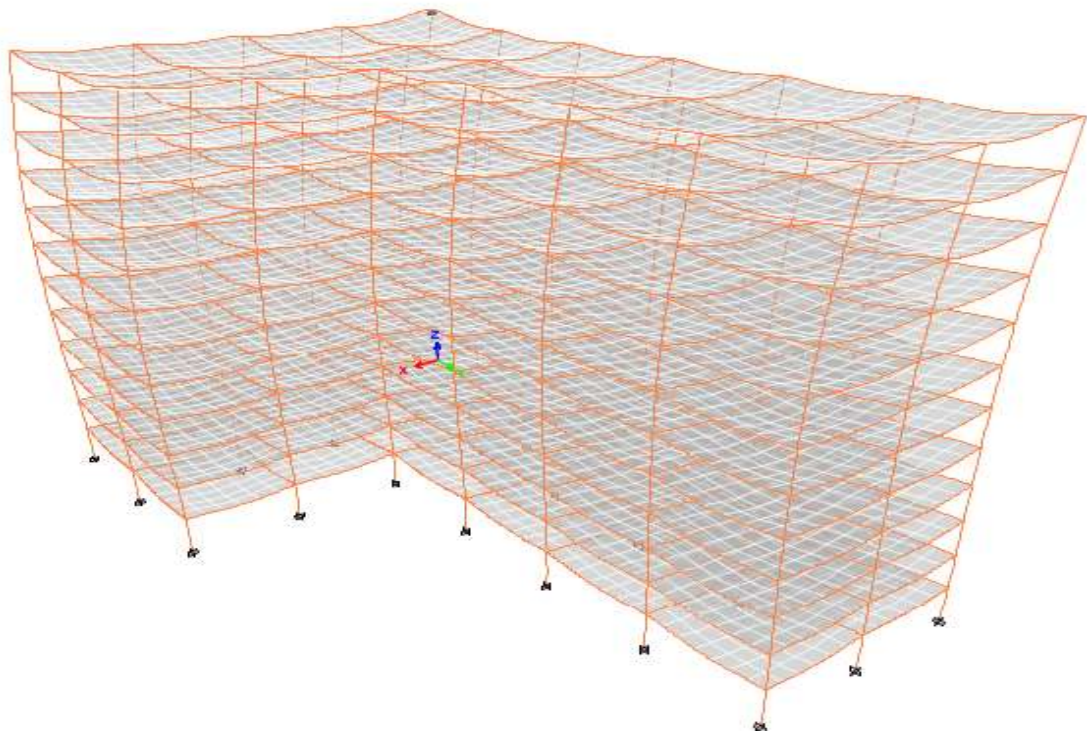


Fig 8 Deformed shape of Structure When No column is lost



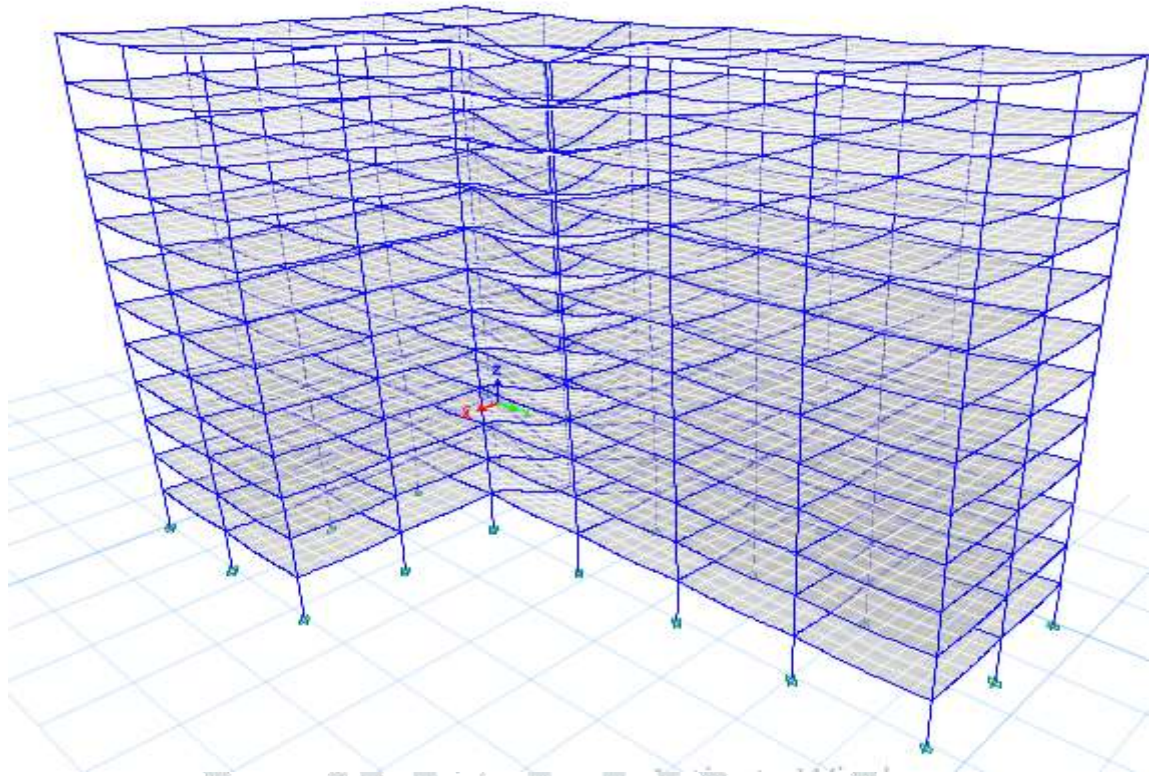


Fig 9: Deformed shape of Structure When Interior column C-10 is lost

## VII. CONCLUSIONS

Linear static analysis for progressive collapse resistance of a 12 storey Asymmetric RC building has been done for column removal cases namely interior as per General Service Administration (GSA) 2013 guidelines. It can be concluded that **Sudden removal of Interior column** leads to the generation of progressive collapse in Asymmetrical building subjected to seismic forces. The Demand Capacity ratios (DCR) for all the beams in flexure is very high (maximum 4.5 to minimum 3.5) that is approximately double of the limiting value 2.0 given by GSA 2013. **Hence flexure in beam is the critical criteria for ground floor column removal case** in progressive collapse process of building. The Demand Capacity ratios (DCR) for all the beams in Shear are just more than 2 (not exceeded by 2.6). **Hence Shear in beam is not critical for ground floor column removal case** in progressive collapse process of building. **The base shear in the building (Interior column removal case) is increased by 61.44 % in X direction and 58.59 % in Y direction** after the sudden removal of interior column. Redesigning of beams in flexure is required to prevent the progressive collapse of building.

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