Collapse analysis of irregular flat slab structure at different seismic zones

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Abstract - *A flat slab is a reinforced concrete slab supported directly by concrete columns without the use of beams. Reinforced concrete flat slabs are one of the most popular floor systems used in residential buildings, car parks and many other structures. They represent elegant and easy to construct floor systems. Flat slabs are favored by both architects and clients because of their aesthetic appeal and economic advantage. The structure should possess namely simple and regular configuration, adequate lateral strength, stiffness and ductility to accomplish well under Earthquake. Structures with simple regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation are considered to suffer much lesser damage than structures with irregular forms.*

***Key Words*: lateral displacement, punching shear, axial load, flexural load, ETABS, SAFE.**

1. INTRODUCTION

Progressive collapse of the structure alludes to a nearby harm because of intermittent and irregular occasion, for example, gas blasts bombarding assault and vehicular impact. The neighborhood harm causes an ensuing chain response instrument spreading all through the structure which thusly prompts a catastrophic collapse, by and large, progressive collapse of the structure is described by an imbalance in size between an activating occasion and the subsequent collapse different structures all through the world have experienced halfway or aggregate progressive collapse all through the previous a very long while. These collapses have come about because of gas blast, dread assault and different components. Progressive collapse of a structure happen when the auxiliary component are loaded past their definitive conveying limit and falls flat .When any component fizzles, the rest of the component of the structure attempt to discover alternate load paths to redistribute the load connected to it .thus ,other component may come up short, bringing on disproportion instrument. It is a dynamic process, typically joined by extensive twisting ,in which the caving in framework persistently discover alternate load path keeping in mind the end goal to survive .The vital normal for progressive collapse is that the last harm is not relative to starting harm.

1.1 Present study

The building considered for an analysis is RC commercial building with a height of 29 meter with an area of 684 m^2.The building consists of 10 stories. The structural system of the building consists of RC flat slab system. Linear static Response spectrum analysis, collapse analysis and design are carried out for bare Frame in ETABS 15.2.2 in different seismic zone according to Indian standard. All the supports were modeled as fixed supports. Flat slab analysis and Design is also carried out in the SAFE ver.2014.column removal at different locations as per GSA 2013. Additional gravity load considered as per GSA 2013 for different column removal positions.

1.2 Aim and Scope of study

In the present study, an attempt is made to understand the behavior of the irregular RC flat slab structure susceptible to sudden column loss at a different location in different seismic zones. Based on the collapse analysis using Etabs15.2.2 & SAFE2014.

The specific objectives of the study are:

1. To study the performance of a Flat slab structure as per GSA guidelines2013.2.
2. To carry out linear static analysis using software ETABS V2015.2.2 of irregular Flat slab structure for progressive collapse in different seismic zones.
3. To carry out the flat slab design using software SAFE2014.
4. To monitor the DCR Limits, column punching shear and large deformation of the flat slab structure for sudden column loss at different positions in different seismic zones.
5. To prevent the collapse and render the building as safe for progressive collapse.

1.3 Type of models

- **Models for Zone II**

1. Flat slab frame without column removing case-1
2. Flat slab frame of ground floor interior corner column C25 removed case-1A
3. Flat slab frame of ground floor along the Y-axis's column C10 removed case1B
4. Flat slab frame of ground floor along the X-axis's ColumnC4 removed case 1C

- **Models for Zone III**

1. Flat slab frame without removing thecolumn-2
2. Flat slab frame of ground floor interior corner column C25 removed case-2A
3. Flat slab frame of ground floor along the Y-axis's column C10 removed case-2B
4. Flat slab frame of ground floor along the X-axis's column C4 removed case-2C

- **Models for Zone IV**

1. Flat slab frame without removing thecolumn-3
2. Flat slab frame of ground floor interior corner column C25 removed case-3A
3. Flat slab frame of ground floor along the Y-axis's column C10 removed case-3B
4. Flat slab frame of ground floor along the X-axis's column C4 removed case-3C

- **Models for Zone V**

1. Flat slab frame without removing the column-4
2. Flat slab frame of ground floor interior corner column C25 removed case-4A
3. Flat slab frame of ground floor along the Y-axis's column C10 removed case-AB
4. Flat slab frame of ground floor along the X-axis's column C4 removed case-4C

1.4 Modeling:

Model Definition:

In this study we take a 10-storey RC building the geometrical parameters of the multi-story frames is as follows:

Type of building	- SMRF
Number of stories	- 10 stories
Floor height of each story	- 3m
Base supports	- Fixed
Structural type	- RCC Framed structure
Grade of concrete	- M30
Grade of steel	- Fe500
Size of columns	- 750mm x 750mm, 600mm x 900mm 900mmx900mm
Depth of slab	- 250mm
Live load	- 4 kN/m²
Floor finish	- 1 kN/m²
Gld as per (GSA2013)	- 30 kN/m²
G as per (GSA2013)	- 15 kN/m²
Seismic zones	- Zone II, III, IV, V
Zone factors	- 0.1, 0.16, 0.24, 0.36
Importance factor	- 1
Reduction factor	- 5
Soil type	- II

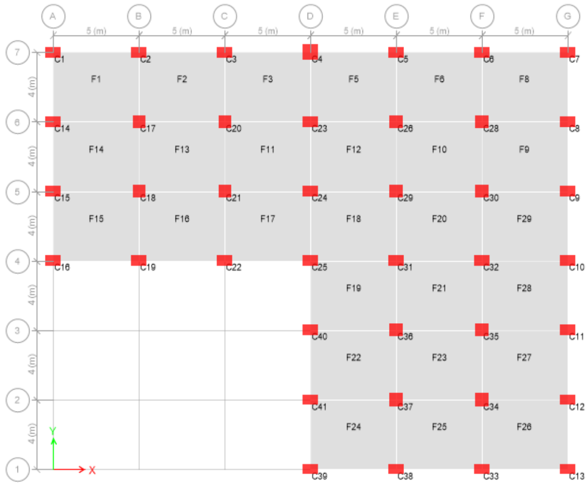


Fig -1: Building 1st storey Plan

Fig -2: Building 10th storey Plan

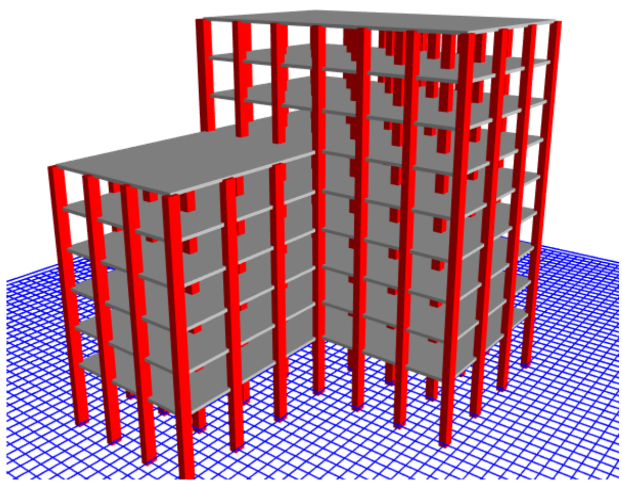


Fig -3: 3D rendered view

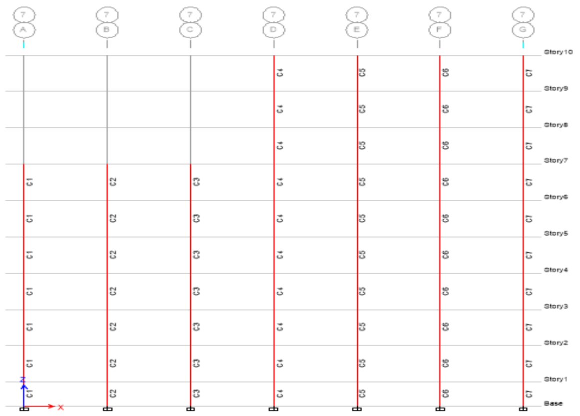
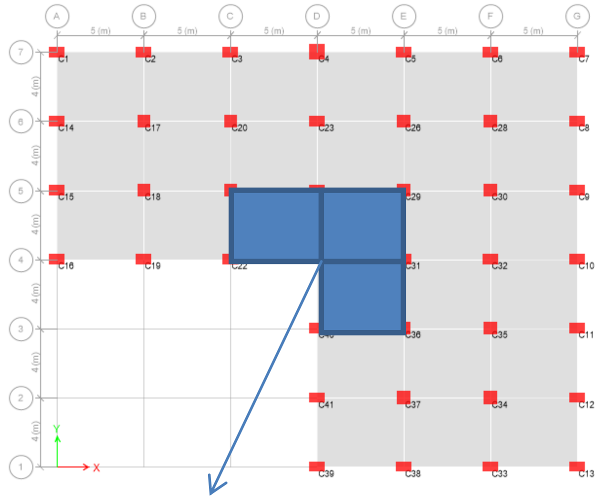
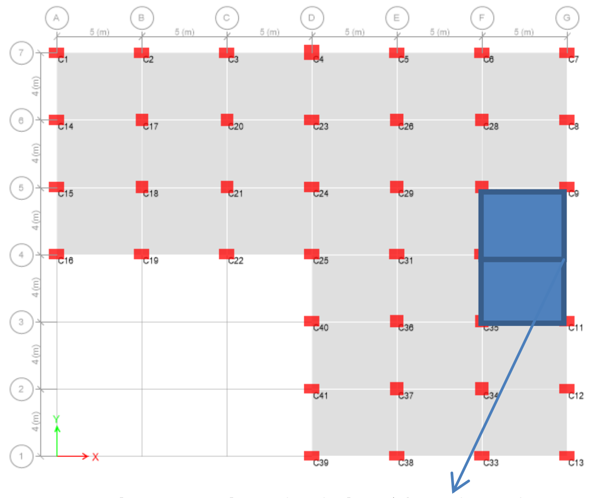


Fig -4: Elevation of building



Removed Column (C25) at interior corner (case-1)

Fig -5: Additional gravity load G_{ld} and G applied on floor above the removed Column C25 as per GSA2013



Removed exterior Column (C10) along 'y' axis (case-2)

Fig -6: Additional gravity load G_{ld} and G applied on floor above the removed Column C10 as per GSA2013

Removed exterior Column (C4) along 'X' axis (case-3)

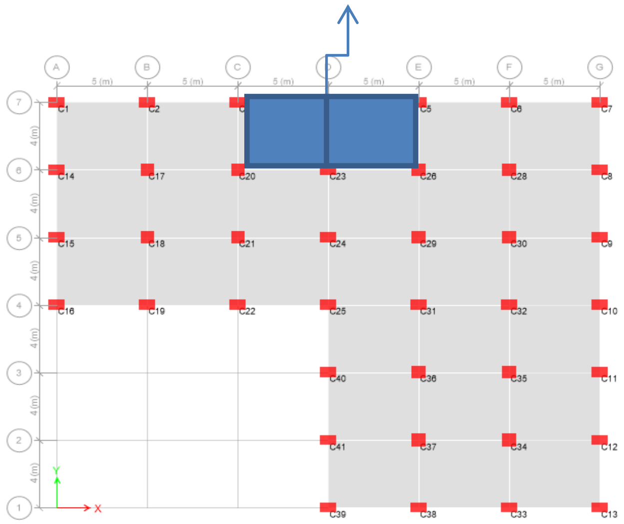


Fig -7: Additional gravity load G_{ld} and G applied on floor above the removed Column C4 as per GSA2013

2. RESULTS

A Linear static analysis is carried out for earthquake load combination in Zone II, III, IV and V as per IS1893:2002 in ETABS15.2.2. Analysis and design of flat slab is also carried out in SAFE2014 .with & without column removal cases.

Three models in each zone, totally 12 models were considered to evaluate the DCR limits in axial, DCR limits in flexure and displacement. Punching shear check is also made for the column removal cases. DCR limits for columns which are exceeding 1.5 for axial and flexures and punching shear values of flat slab which are exceeding 1.25 are considered as failed columns.

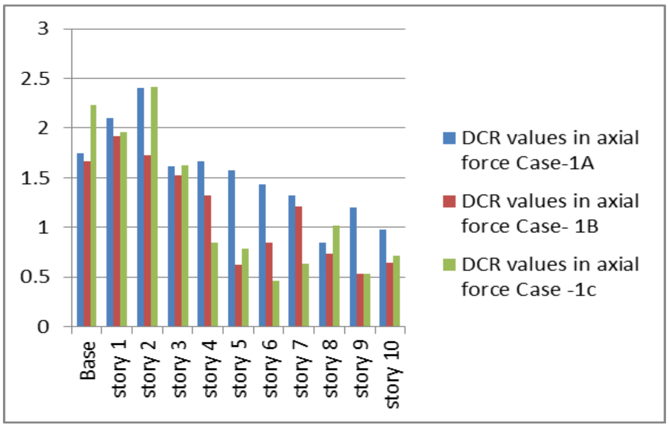


Chart-1: Comparison of the DCR Values in Axial force for Column removal case- 1A, Case-1B & Case-1C in Zone-II

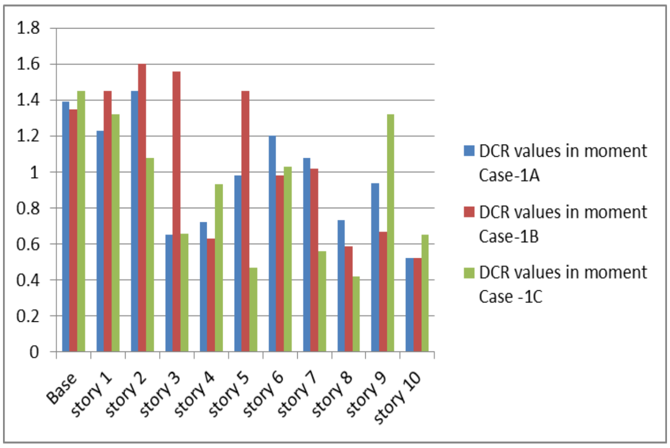


Chart-2: Comparison of the DCR Values in Flexure for Column removal case-1A, Case-1B & Case-1C in Zone-II

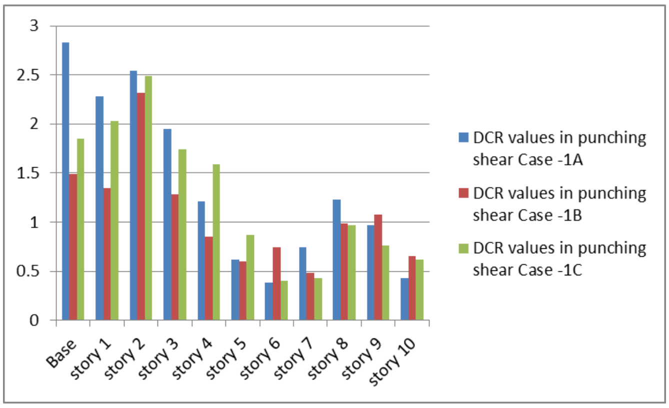


Chart-3: Comparison of the DCR Values in punching shear for Column removal case-1A, Case-1B & Case-1C in Zone-II

Column removal case-1A (interior corner columnC25), case-1B (Exterior Middle column along Y-Axis (C10) and case-1C Exterior column along X-Axis (C4) from analysis results it was found that due to sudden column loss redistribution of loads (alternate load path) takes place in neighboring columns. Only neighboring columns which are not capable in baring the additional loads are failing in all three cases of analysis in Zone II. Figures 8, 9 & 10 shows the comparison results of columns failing in axial load, flexure & punching shear due to sudden column loss at different locations. It is observed that when the interior corner column C25 is removed obtained DCR is high when compared to C10 & C4 column removal cases and columns are failing up to the 5th floor in axial load and columns are failing in flexure at 2nd & 3rd floor. Punching shear capacity is also exceeding 1.25 till 4th floor. When an interior column is removed there is a potential for progressive collapse in the zone- II.

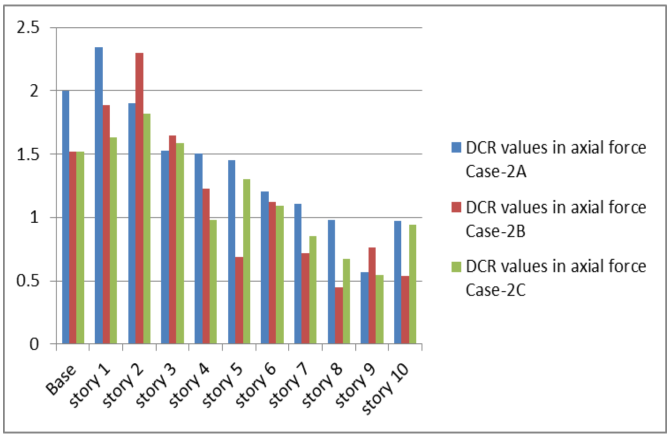


Chart-4: Comparison of the DCR Values in Axial force for Column removal Case- 2A, Case-2B & Case-2C in Zone-III

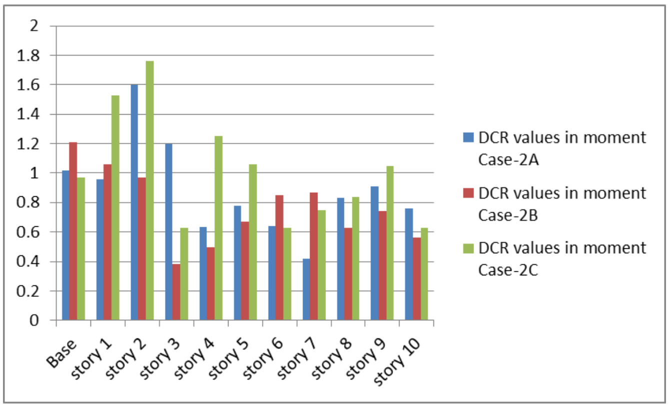


Chart-5: Comparison of the DCR Values in Flexure for Column removal case-2A, Case-2B & Case-2C in Zone-III

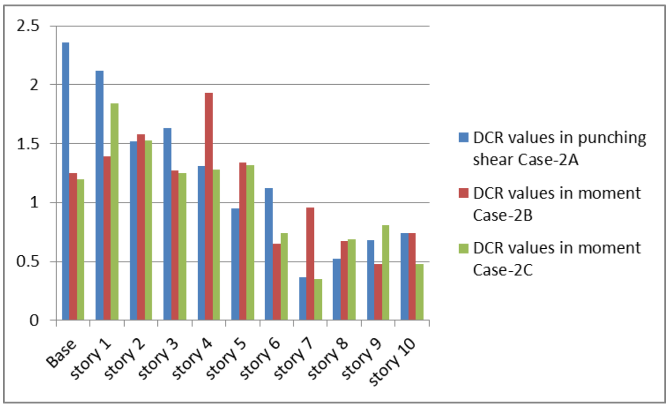


Chart-6: Comparison of the Punching Shear Values for Column removal case-2A, Case-2B & Case-2C in Zone-III

Column removal case-2A (interior corner columnC25), case-2B (Exterior Middle column along Y-Axis (C10) and case-2C Exterior column along X-Axis (C4) from analysis results it was found that due to sudden column loss redistribution of loads (alternate load path) takes place in neighboring columns. Only neighboring columns which are not capable in baring the additional loads are failing in all three cases of analysis in Zone III. It also represents the flat slab-columns which failing in Punching shear capacity and Max. displacement in each floor. Figures 11, 12 & 13 shows the comparison results of columns failing in axial load, flexure & punching shear due to sudden column loss in different locations. It is observed that when the interior corner column C25 is removed obtained DCR is high when compared to C10 & C4 column removal cases and columns are failing up to the 4th floor in axial load and columns are failing in flexure at 1st & 2nd floor. Punching shear capacity is also exceeding 1.25 till 5th floor. When an interior column is removed there is a high potential for progressive collapse in the zone- III.

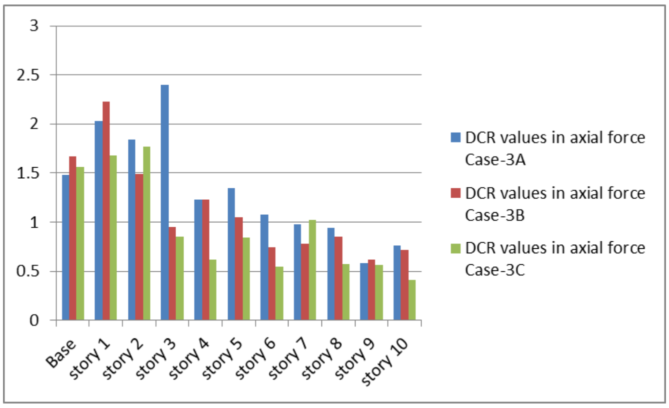


Chart-7: Comparison of the DCR Values in Axial force for Column removal case- 3A, Case-3B & Case-3C in Zone-IV

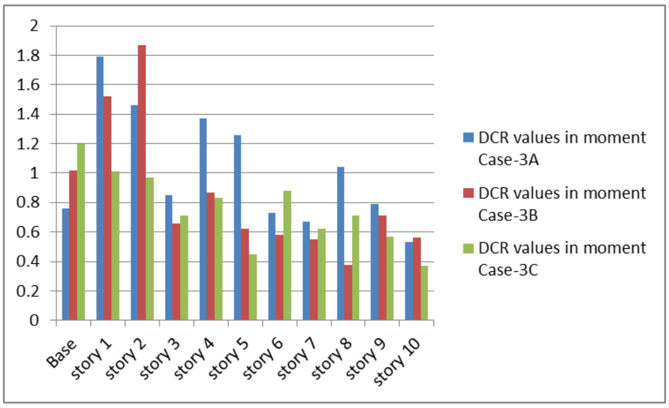


Chart-8: Comparison of the DCR Values in Flexure for Column removal case-3A, Case-3B & Case-3C in Zone-IV

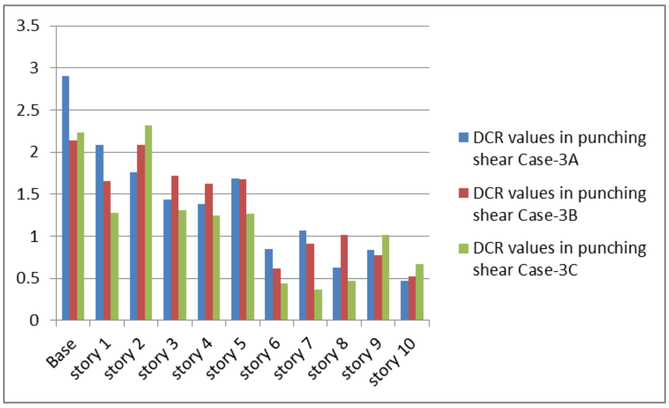


Chart-9: Comparison of the Punching Shear Values for Column removal case-3A, Case-3B & Case-3C in Zone-IV

Column removal case-3A (interior corner columnC25), case-3B Column along Y-Axis (C10) and case-3C Exterior column along X-Axis (C4) from analysis results it was found that due to sudden column loss redistribution of loads (alternate load path)takes place in neighboring columns. Only neighboring columns which are not capable to baring the additional loads are failing in all three cases of analysis in Zone IV. Figures 14, 15 & 16 shows the comparison results of columns failing in axial load, flexure & punching shear due to sudden column loss in different locations. It is observed that when the interior corner column C25 is removed obtained DCR is high when compared to C10 & C4 column removal cases and columns are failing up to the 3rd floor in axial load and columns are failing in flexure at 1st & 2nd floor. Punching shear capacity is also exceeding 1.25 till 5th floor. When an interior corner column is removed columns are failing till 5th floor and there is risk for progressive collapse till 5th floor in zone IV.

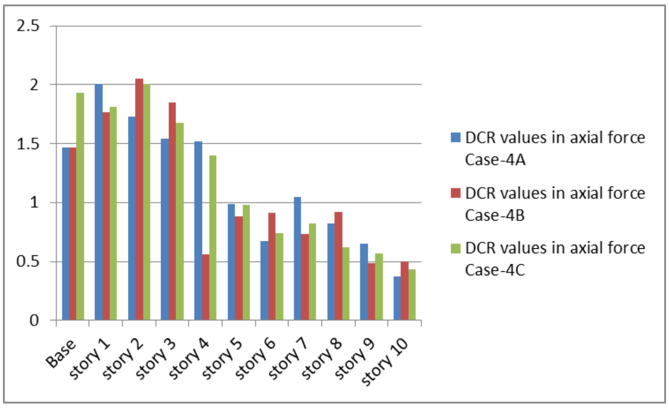


Chart-10: Comparison of the DCR Values in Axial force for Column removal Case- 4A, Case-4B & Case-4C in Zone-V

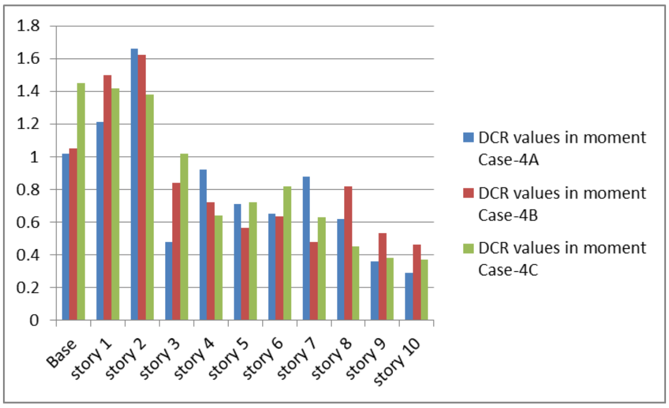


Chart-11: Comparison of the DCR Values in Flexure for Column removal Case-4A, Case-4B & Case-C in Zone-V

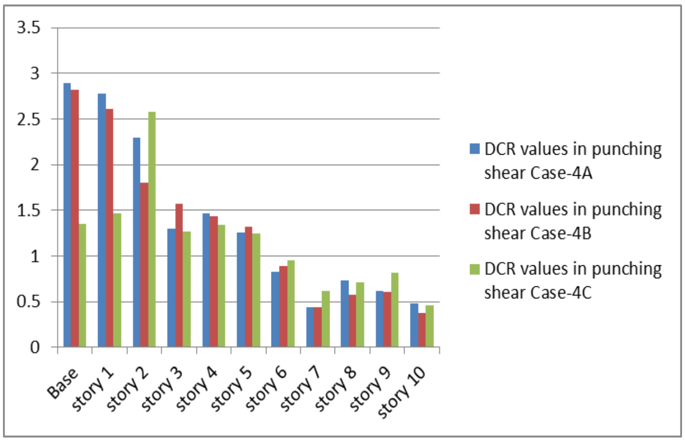


Chart-12: Comparison of the Punching Shear Values for Column removal Case-4A, Case-4B & Case-4C in Zone-V

Column removal case-4A (interior corner Column C25), case-4B (Exterior Middle column along Y-Axis (C10) andcase-4C Exterior column along X-Axis (C4) from analysis results it was found that due to sudden column loss redistribution of loads (alternate load path) takes place in neighboring columns. Only neighboring columns which are not capable in baring the additional loads are failing in all three cases of analysis in Zone V. Figures 17,18 & 19 shows the comparison results of columns failing in axial load, flexure & punching shear due to sudden column loss in different locations. It is observed that when the interior corner column C25 is removed obtained DCR is high when compared to C10 & C4 column removal cases and columns are failing up to the 4th floor in axial load and columns are failing in flexure at 1st & 2nd floor. Punching shear capacity is also exceeding 1.25 till 4th floor. When an interior corner column is removed columns are failing till 5th floor and there is risk for progressive collapse till 5th floor in zone V.

Summary:

From the above results it is concluded that in Zone II & V there is a high progressive collapse hence there is a need for additional steel to resist the additional gravity loads. Up to 5th floor flat slab is failing in punching shear due redistribution of loads, hence additional shear reinforcement should be provided for shear in flat slab to resist the additional gravity load. In Zone III & Zone IV even though columns are exceeding DCR limit 1.5 till 5th floor the amount of DCR limit compare to Zone-II & V are less but still additional steel should be provided to resist the Progressive collapse. Flat slab up to 5th floor failing in punching shear capacity due redistribution of loads and the dynamic effect, hence shear reinforcement should be provided. The extent of damage is high in Zone II & V compared to Zone III & IV. Even though building is seismically design for different Zones .Structural engineers should design the building considered the combination of additional gravity loads and Earthquake loads. So, that the risk of progressive collapse can be minimized.

2. CONCLUSIONS

1. The performance of the RC flat slab structure is very much dependent on the capability of slab-column connections to resist extreme or abnormal loading.
2. RC Flat slab structures are strong and can resist the progressive collapse provided brittle failure, punching shear is prevented.
3. The performance of the RC flat slab structure is very much dependent on the capability of slab-column connections to resist extreme or abnormal loading.
4. Increasing the grade of concrete rather increasing the size of the drop thickness in flat slab and by providing the additional shear reinforcement can avoid the punching shear failure.
5. For all Zones when interior corner column (C25) is removed there a high potential of progressive collapse, next exterior middle column (C10) along y-axis, finally exterior column (C4) along y-axis.
6. By providing the additional steel and higher in the columns will be more effective in avoiding or delaying collapse of the structure.
7. A building design to resist combination of earthquake loading and additional gravity loading has inherent ability to resist progressive loading.
8. Higher the Storey there is a high risk of progressive collapse.

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REFERENCES

[1] Bureau of Indian Standards: IS-875, part 1 (1987), for dead loads on buildings and Structures, New Delhi, India.

[2] Bureau of Indian Standards: IS-875, part 2 (1987), for live loads on buildings and Structures, New Delhi, India.

[3] Bureau of Indian Standards: IS-1893, part 1 (2002), "Criteria for earthquake resistant

[4] Design of structures: Part 1 General provisions and buildings", New Delhi, India.

[5] Indian Standard, IS 456-2000 "Code of Practice for Plain and Reinforced Concrete", BIS, New Delhi, India.

[6] The U.S. General Services Administration (GSA) developed the "Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Projects"2003

[7] GSA Alternate Path Analysis and Design Guidelines for Progressive Collapse Resistance October 24, 2013.