Analysis and study of progressive collapse behaviour of reinforced concrete structure with Shear wall

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Abstract - *Progressive collapse can be defined as the failure of a structure due to the spread of a local failure of the structure. Progressive collapse is because of manmade, natural, which can be because of fires, explosions, earthquakes etc. causing failure of support elements which tends to cause progressive collapse failure. The purpose of this study is to understand the nature and process of progressive collapse. This project involves the use of ETABS to perform analysis of a reinforced concrete structure. ETABS is used to observe local failure and its effect on the overall structure. Several column failure conditions are studied and as per General Service Administration (GSA) guidelines.*

***Key Words*: Progressive Collapse, General Service Administration Guidelines, ETABS 2013**

1.INTRODUCTION

When a part of a structure that is assumed to have collapsed, or been severely damaged, by any accidental event the term is called localized failure. Localized failure leads to progressive collapse. Progressive collapse is a initial local failure of a vertical structural component which further leads to the collapse of adjoining members, which causes additional collapse of the structure. When a column fails, it results in the failure of adjoining beam and columns, which eventually leads to the entire collapse of the structure. The failure of column might occur because of bomb explosion, a car colliding with column in a parking, fire explosion, earthquake. A shear wall is a vertical element that is designed to resist lateral forces, like wind and seismic loads

2. GSA GUIDELINES

The General Services Administration (GSA) (2003) is an independent agency of the U.S. government. The GSA limits were set to decrease the possibility for progressive collapse of a buildings and, assess the potential for progressive collapse of buildings, and develop potential upgrades to facilities if required. The loading combination according to the GSA code depends on the analysis type.

2.1 ANALYSIS TECHNIQUE

The following static linear elastic analysis approach may be used to assess the potential for progressive collapse. The following analysis procedure shall be performed using well-established linear elastic, static analysis techniques. It is recommended that 3-dimensional analytic models be used to account for potential 3-dimensional effects and avoid overly conservative solutions. Nevertheless, 2-dimensional models may be used provided that the general response and 3-dimensional effects can be adequately accounted for.

2.2 VERTICAL ELEMENT REMOVAL AS PER GSA

1) Exterior Considerations

a. Analyse for the sudden loss of a column for one floor above grade (1 story) located at or near the middle of the short side of the structure.
b. Analyse for the sudden loss of a column for one floor above grade (1 story) located at or near the middle of the long side of the structure.
c. Analyse for the sudden loss of a column for one floor above grade (1 story) located at the corner of the structure.

2) Interior Considerations

a. Analyse for the sudden loss of 1 column that extends from the floor of the underground parking area or uncontrolled public ground floor area to the next floor (1 story). The column considered should be interior to the perimeter column lines.

3) SHEAR/LOAD BEARING WALLSTRUCTURE

Analyze for the instantaneous loss of the entire bearing wall along the perimeter at the corner structural bay or the loss of 30 linear feet of the wall (15ft in each major direction)(whichever is less)for one floor above grade.

3. PROBLEM DESCRIPTION

A typical reinforced concrete framed structure of 20 storey height of height 3m is modeled in ETABS. This is a rectangular RC building containing :6 bays of 6m in X direction and 10 bays of 6m in Y direction. The storey height is 3m and base support are fixed and analyzed using linear static method. The shear wall is located at the corners of the building

The analysis is done using linear static analysis method. The design of structural members is done as per IS 456:2000.

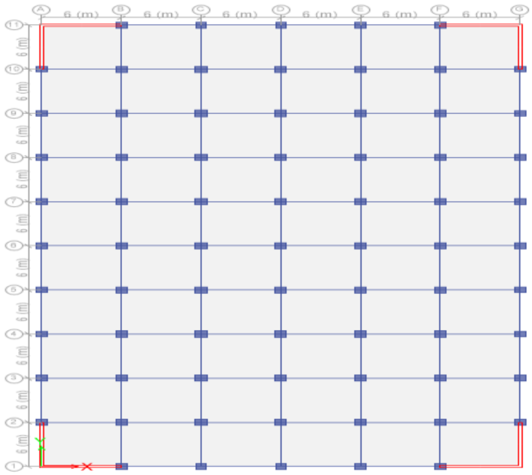

Fig-1 plan view (Shear walls at the corner)

3.1 DETAILS OF THE BUILDING STRUCTURE ARE GIVEN BELOW:

Material Properties

Characteristic compressive strength of concrete (f_{ck}): 30 N/mm^2

Yield Strength of reinforcing steel (f_y): 500 N/mm^2

Section Properties

Beam size: 300x550mm
Slab thickness: 150mm
Shear wall thickness: 250mm
Wall thickness: Exterior walls 230mm
Interior walls 150mm

Interior Columns sizes:

850x850mm (Base to 5th floor)

800x800mm (6th to 10th floor)

650x650mm (11th to 15th floor)

450x450mm (16th to 20th floor)

Exterior Column sizes

800x800mm (Base to 5th floor)

600x650mm (6th to 10th floor)

500x500mm (11th to 15th floor)

450x450mm (16th to 20th floor)

Loads

Dead load: Self weight of the structure
Live load: 2 kN/m^2
Floor finish: 1.5 kN/m^2
Wall load: Exterior wall= 13.8 kN/m
Interior wall= 9 kN/m

Load Combinations

The combination of load taken into account is

Load = 2(DL+0.25LL)

Where, DL is Dead Load and LL is Live Load

2 is dynamic factor

3.2 DEMAND CAPACITY OF RATIO (DCR)

Demand Capacity Ratio is the ratio between structural member force after removal of column to the member's ultimate strength or capacity of the member.

DCR = Qud/Que

Qud = demanding or acting force in member or connection or joint.

Que = Un factored capacity of the member or expected ultimate strength of member.

DCR acceptance criteria are as follows,

Demand Capacity Ratio <2.0 for regular structures.

Demand Capacity Ratio<1.5 for irregular structures.

Demand Capacity Ratio<3.0 for steel structures.

Calculation of Mulimit to determine DCR for the structural members are given below.

DCR= Mu/Mulimit

Structure with shear wall

Beam:

Breadth, b = 300 mm

Depth, D = 550 mm

Cover, d' = 30 mm

Effective depth, = D- d' =550-30 =420 mm

fck = 30 N/mm^2

fy = 500 N/mm^2

Calculation of ultimate moment:

Mulimit = 0.133*fck*b*d*d

= 0.133*30*300*520*520

= 323.66 kN-m

Structure without shear wall:

Beam:

Breadth, b = 300 mm

Depth, D = 500 mm

Cover, d' = 30 mm

Effective depth, = D- d' =500-30 =470 mm

fck = 30 N/mm^2

fy = 500 N/mm^2

Calculation of ultimate moment:

Mulimit = 0.133*fck*b*d*d

= 0.133*30*300*470*470

= 264.42 kN-m

4 ANALYSIS AND RESULT

Reinforced concrete building is modelled in ETABS and is analyzed using linear static analysis method. Progressive collapse potential of a building is analyzed for two different cases of column removal.

Case 1: Exterior column removal at ground floor

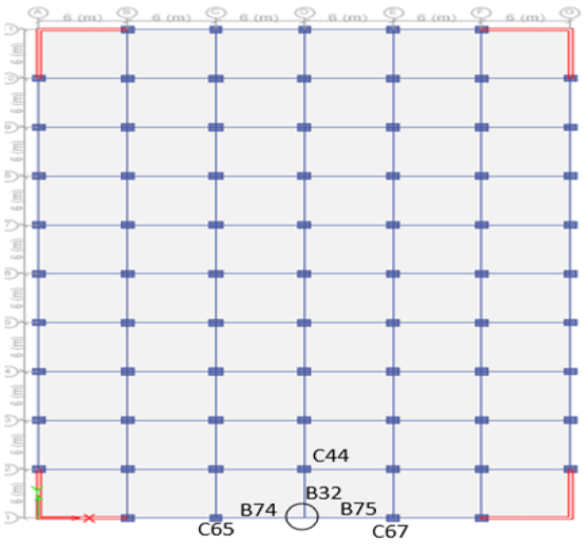

Fig 4.1 Plan view Exterior column removal at ground floor

When Column C66 is removed at Base floor, most critically affected columns and beams are:

Columns: C65,67and C44 and Beams: B74, B32, B75

Variations of Demand Capacity Ratios for above beams is given:

BeamB74,75

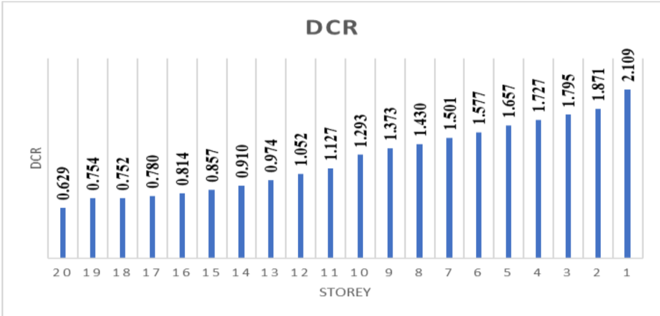

Chart -1: Demand Capacity Ratio V/S storey of beam

Beam B32

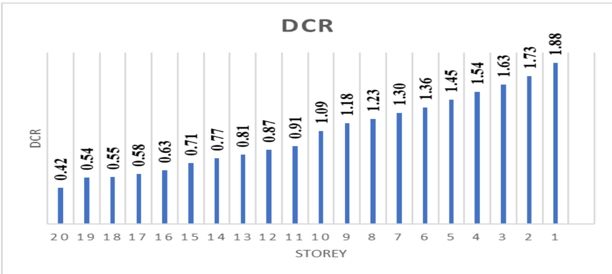

Chart -2: Demand Capacity Ratio V/S storey of beam

Case2: Interior (Central) column removal at ground floor.

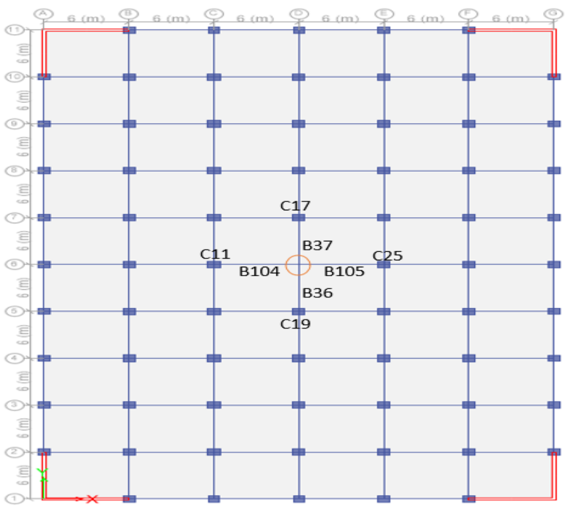

Fig4.2 Plan view (Interior column removal at ground floor.)

When Column C18 is removed at Base floor, most critically affected columns and beams are:

Columns: C11, C17, C25, C19 and Beams: B104, B105, B37, B36.

Variations DCR values for the above beams respectively is given as follows

Beam 36

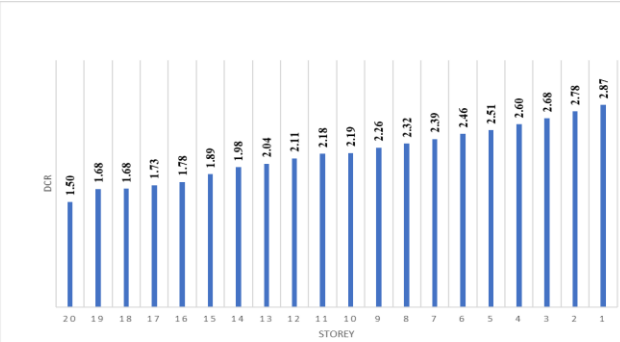

Chart -3: Demand Capacity Ratio V/S storey of beam

Beam 37

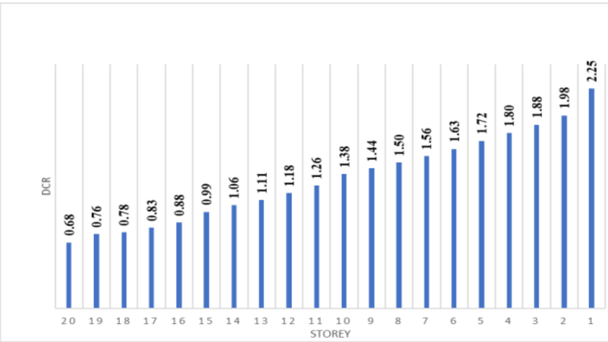

Chart -4: Demand Capacity Ratio V/S storey of beam

Beam 104

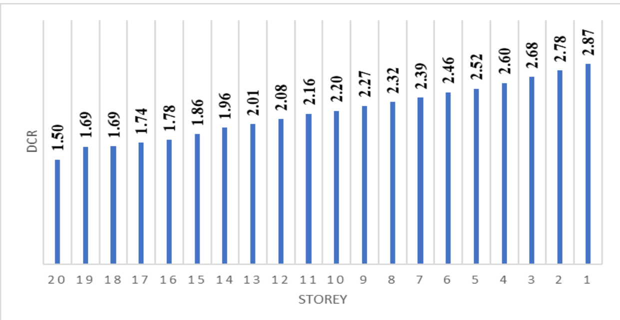

Chart -5: Demand Capacity Ratio V/S storey of beam

Beam 105

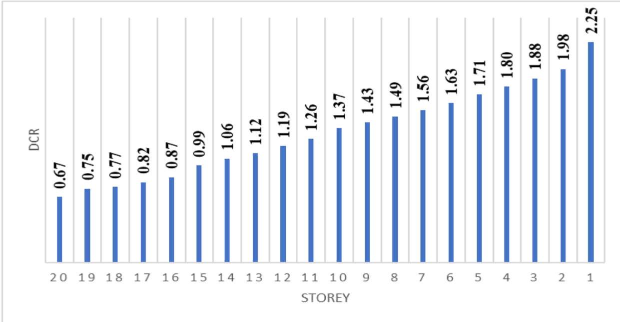

Chart -6: Demand Capacity Ratio V/S storey of beam

4.1 Comparison of DCR between structures with and without Shear wall
Case 1: Exterior column removal at ground floor.

DCR value are compared for structures with and without Shear wall for

Beam74,75:

Structure with shear wall

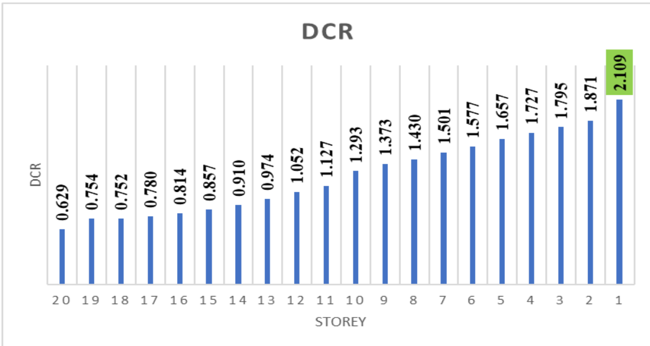

Chart-7: Demand Capacity Ratio V/S storey of beam

Structure without shear wall

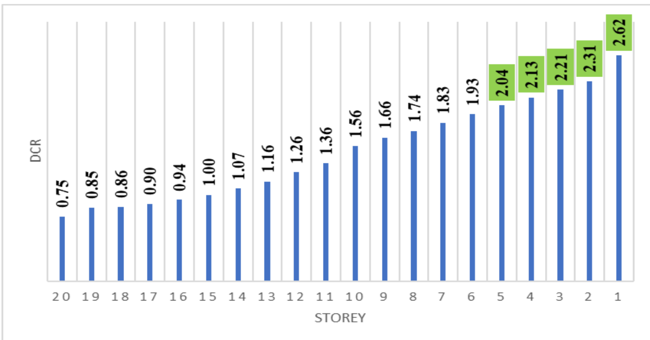

Chart-8:Demand Capacity Ratio V/S storey of beam B74,75

Beam32: Structure with shear wall

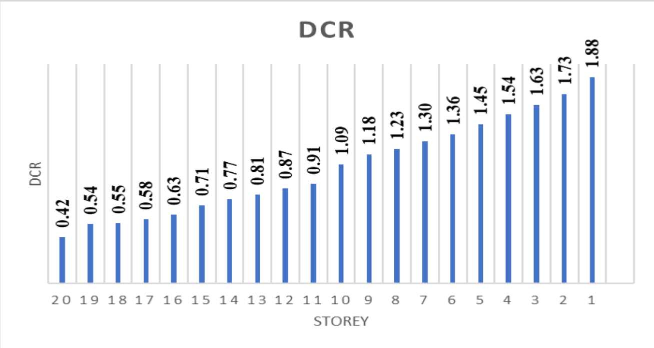

Chart-9: Demand Capacity Ratio V/S storey of beam B32

Structure without shear wall

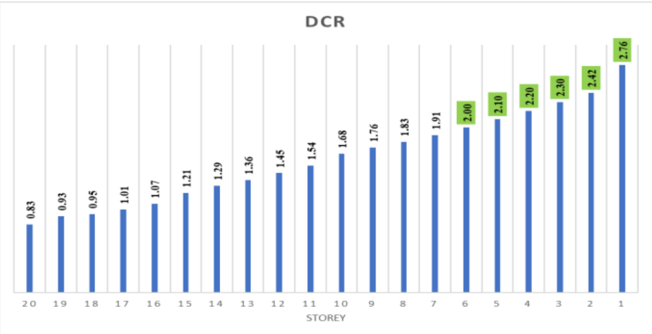

Chart-10:Demand Capacity Ratio V/S storey of beam B32

Case 2: Interior (central) column removal at ground floor.

DCR value are compared for structures with and without Shear wall for

Beam36: Structure with shear wall

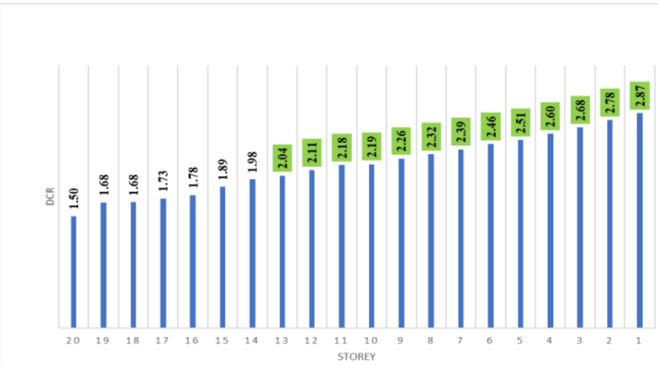

Chart-11:Demand Capacity Ratio V/S storey of beam B36

Structure without shear wall

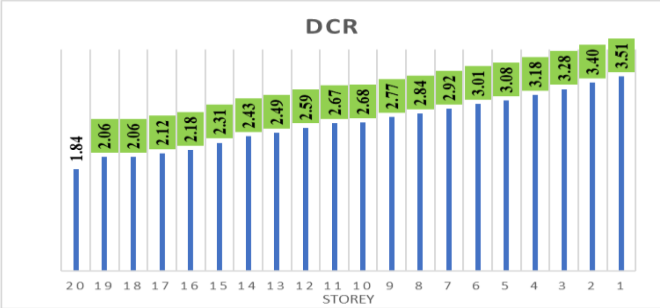

Chart-12:Demand Capacity Ratio V/S storey of beam B36

Beam37: Structure with shear wall

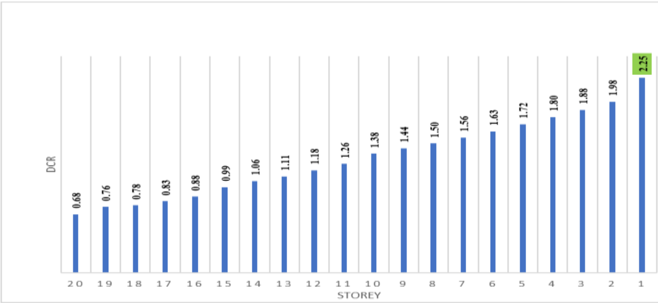

Chart-13:Demand Capacity Ratio V/S storey of beam B37

Structure without shear wall

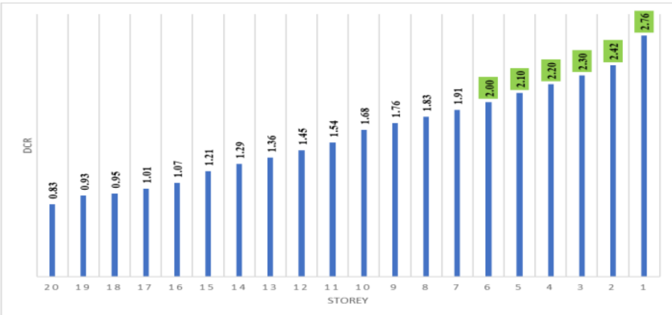

Chart-14: Demand Capacity Ratio V/S storey of beam B37

Beam104: Structure with shear wall

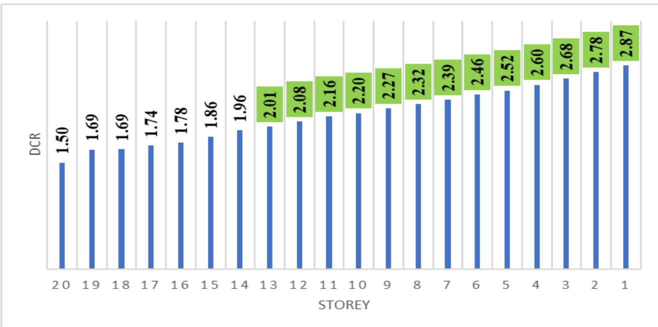

Chart-15:Demand Capacity Ratio V/S storey of beam B104

Structure without shear wall

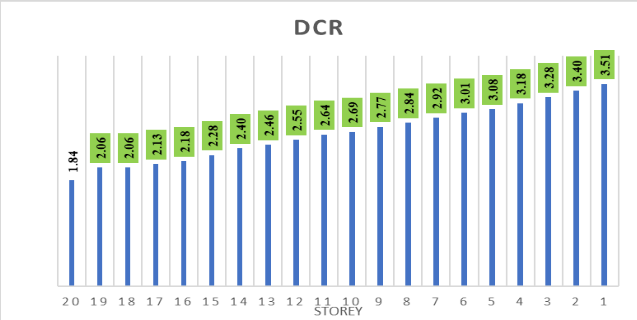

Chart-16: Demand Capacity Ratio V/S storey of beam B104

Beam105:

Structure with shear wall

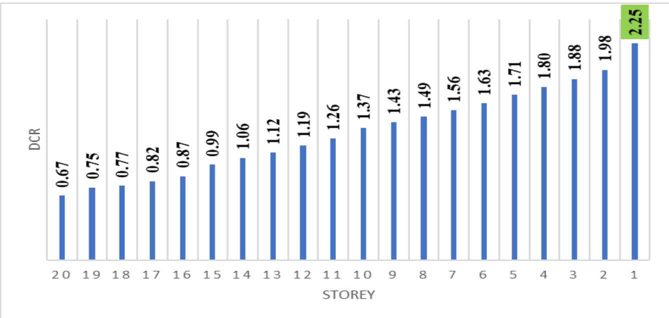

Chart-17: Demand Capacity Ratio V/S storey of beam B105

Structure without shear wall

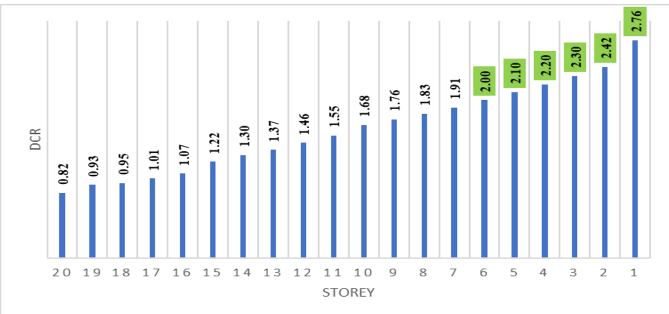

Chart-18: Demand Capacity Ratio V/S storey of beam B105

5. CONCLUSION

Based on the analytical results, the following conclusions were obtained:

1) Case1: Exterior column removal at ground floor

   i. Beams (B74,75) tends to fail from 1st to 5th storey and beam (B32) tends to fail from 1st to 3rd storey, when a column is removed at 1st floor without shear wall, whereas in case of column removal with shear wall (B74,75) fails at 1st storey and (B32) there was no failure observed.

   ii. Axial force before and after column removal are compared for the adjoining columns C65 & C67, the percentage increase is observed to be 30.9% at storey1 and 18.57% at the storey 20 after column removal.

   iii. Axial force before and after column removal are compared for the columns C44 and percentage increase is observed to be 19.4% at storey 1and 9.22% at the storey 20 after column removal.

   iv. It was observed that the DCR values at bottom storeys exceed the limit (2.0) compared to top storeys.

   v. It was observed that structure with shear wall have higher progressive collapse resisting capacity then structure without shear wall.

   vi. To resists the progressive collapse, additional shear walls and bracings can be provided.

2) Case2: Interior column removal at ground floor

   i. Beam (B36) tends to fail from 1st to 19th storey, beam (B37) tends to fail from 1st to 5th storey, beam (B104) tends to fail from 1st to 19th storey, and beam (B105) tends to fail from 1st to 5th storey, when a column is removed at 1st floor without shear wall, whereas in case of column removal with shear wall Beams (B36) tends to failure is arrested up to 13th storey for beam (B37) failure is arrested at 1st storey, for beam (B104) failure is up to 12th storey, and beam (B105) tends to fail at 1ststorey.

   ii. Axial force before and after column removal are compared for the adjoining columns C11 & C25 and the percentage increase is observed to be 21.93% & 21.95% at storey 1 and 12.23% & 12.25% at the 20th storey after column removal.

   iii. Axial force before and after column removal are compared for the adjoining columns C17,C19 and percentage increase is observed to be 21.96% and 21.94% at storey 1 and 12.26% &12.21% at the 20th storey after column removal.

iv. It was observed that the DCR values at bottom storeys exceed the limit (2.0) compared to top storeys.

v. It was observed that structure with shear wall have higher progressive collapse resisting capacity then structure without shear wall.

vi. To resists the progressive collapse, additional shear walls and bracings can be provided.

ACKNOWLEDGMENT

I would like to thank KLS Gogte Institute of Technology, Belagavi, Karnataka for providing all the required facilities and special thanks to faculty for guidance. I would also like to thank all the referees cited in this paper.

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