PROGRESSIVE COLLAPSE RESISTANCE OF FLAT SLAB BUILDING

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Abstract— *When an initial local failure causes the loss of gravity load capacity of building structures, it may lead to the eventual collapse of the entire building or a large part of it. This type of collapse is defined as progressive collapse or disproportionate collapse. Previous researches on progressive collapse of building structures mainly focuses on concrete and steel frame structures. But, here investigation carried out on Flat slab RC Structure to study the effect of column elimination in different storeys of building on progressive collapse and also influence of column eliminated at corner position, exterior middle position and interior middle position of the building is quantified. For this investigation; 5 storey building is modelled and linear static analyses are carried out and conclusions are drawn. The collapse ratio of the building increases because as observed the percentage of axial force increases as there is elimination of column in the interior middle position. As observed elimination of column in the interior middle there is large increase in axial force and moments.*

Key Words: progressive collapse, RC slab, punching-shear, flat slab, ETABS software, demand capacity ratio. etc

Introduction : When an initial local failure causes the loss of gravity load capacity of building structures, it may lead to the eventual collapse of the entire building, or a large part of it. This type of collapse is defined as progressive collapse or disproportionate collapse. There is significant interest in developing methods to avoid such instances. Extensive research has examined the behaviour of structures following the loss of column. It is a dynamic process, usually accompanied by large deformations, in which the collapsing system continually seeks alternative load paths in order to survive. One of the important characteristics of progressive collapse is that the final damage is not proportional to the initial damage. RC slabs with long spans extended over several bays and only supported by columns, without beams known as flat slab. Flat-slab structures are much more vulnerable to disproportionate collapse than moment-frame structures as there are no beams to redistribute the loads initially resisted by the lost column. Moreover, the propagation of punching-shear failure at slab–column connections due to load redistribution may result in the collapse of the entire slab. Thus, increased attentions should be paid toward assessing the disproportionate collapse performance of flat-slab structures. Flat slabs analysis and design of flat slabs are still the active areas of research and there is still no general agreement on the best design procedure.

Fig1: Plan of 4x4 bay Storey Building

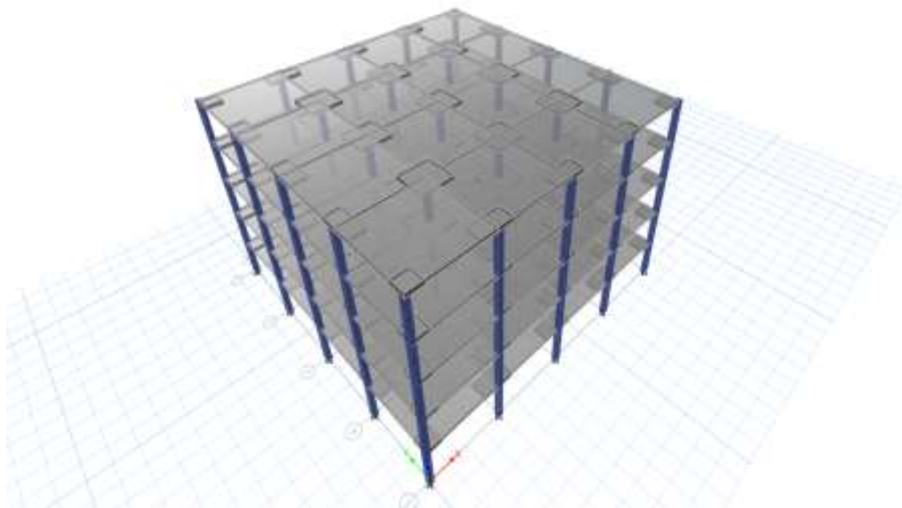


Fig 2: 3D Model of 5 Storey Building

Fig 3: Elevation of 5 Storey Building

Linear static analysis

This analysis is the most fundamental and the easiest type for progressive collapse analysis. It involves statically removal of major structural elements. Since this method is most basic and almost accurate, most conventional load conditions are applied with highly moderate assessment conditions.

Step1:5 storey flat slab without eliminating column.

Step2: To determine the effect on columns at different storey levels by eliminating Column C1 in corner position for Progressive collapse analyses.

Step3: To determine the effect on columns at different storey levels by eliminating column C2 in exterior middle position for Progressive collapse analyses.

Step4: To determine the effect on columns at different storey levels by eliminating column C3 in interior middle position for Progressive collapse analyses.

Step5: The demand capacity ratio is more than 1which suggests that the removal of column will affect any structural elements in the building significantly which leads to progressive collapse of building.

Step6: After redesign the failure columns with different column size and % of A_{st}.

Step7: After redesign of column it is observed that the demand capacity ratio is less than one, progressive collapse is not observed hence all columns are safe.

Step8: Structure will not going to fail due to failure of any column at any position.

Methodology:

1. Modelling of 5 storey buildings with flat slab for non-collapse cases.

2. Modelling of 5 storey buildings with eliminating column in corner position for all storeys.

3. Modelling of 5 storey buildings with eliminating column in exterior middle position for all storeys.

4. Modelling of 5 storey buildings with eliminating column in interior middle position for all storeys.

5. Progressive collapse analyses are carried out using ETABS software.

6. Comparisions of the results obtained from different models are done.

7. Conclusions are drawn.

Detailed data of the building

Normal design,

The storey height is 4m and column size 450mmx450mm, slab thickness 250mm,drop 3000x3000x400 and % of A_{st} is 2.5%

Redesign,

column size 550mmx550mm and % of A_{st} is 2.72%

Intensities of load considered are as follows

live load:2KN/m^2 , floor load:1.3 KN/m^2 and live load for the top storey:1.5KN/m^2

Material properties considered are as follows

Grade of Concrete: M30,Grade of Rebar:HYSD500 ,Modulus of Elasticity:27386.13MPa

Poisson's ratio of Concrete: 0.2, the structural properties such as Thickness of Slab= 250mm is taken.

Seismic loading is taken into consideration as per IS: 1893 (part1):2002 [5]

Zone V, Soil type II, Response Reduction Factor(R) = 5,Importance factor (I) =1.5

Results and Discussions:

The main objective of this project is to Study the behavior of flat-slab building for progressive collapse. Here all the models are designed for the IS 875-1987 (PART-5) code combinations. Progressive analyses are carried out and the results are tabulated. The results drawn are in terms of axial force, moments and demand capacity ratios. the results of models of flat slab building are studied by analyzing the percentage of axial force and moments distributed on the other columns by eliminating the single column in a particular storey.

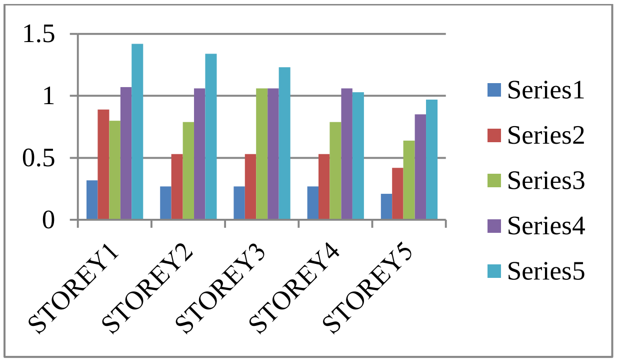


Chart 1

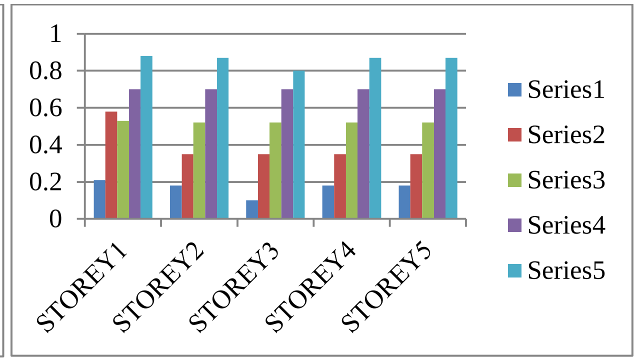


chart 2

Chart 1 and 2: demand capacity ratio after removal of column in corner position (C1) in all the storeys

From the chart 1, designing the columns it is observed that the maximum demand capacity ratio is 1.34 when column is removed from the corner position (C1). Even after removal of 1 column from the storey there is more increase in the demand capacity ratio. Hence there is failure of the building due to progressive collapse.

From the chart 2, after redesigning the columns it is observed that the maximum demand capacity ratio is 0.87 when column is removed from the corner position (C1). Even after removal of 1 column from the storey there is less increase in the demand capacity ratio. Hence there is no failure of the building due to progressive collapse.

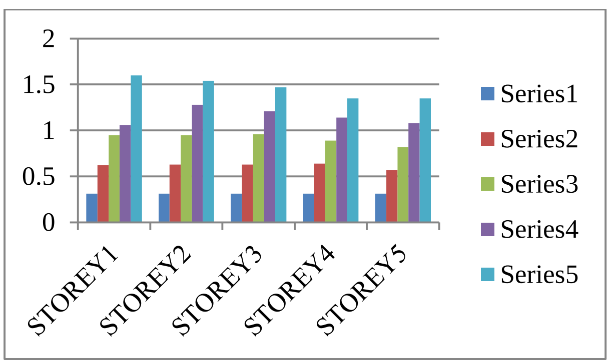


Chart 3

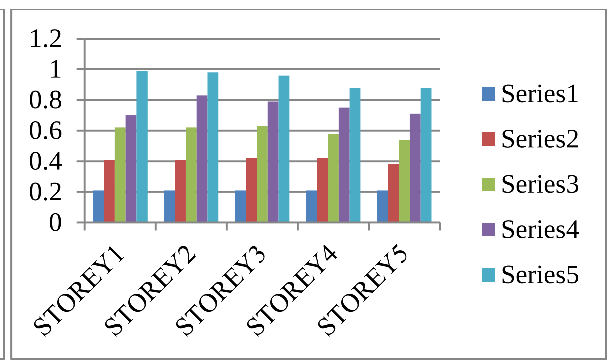
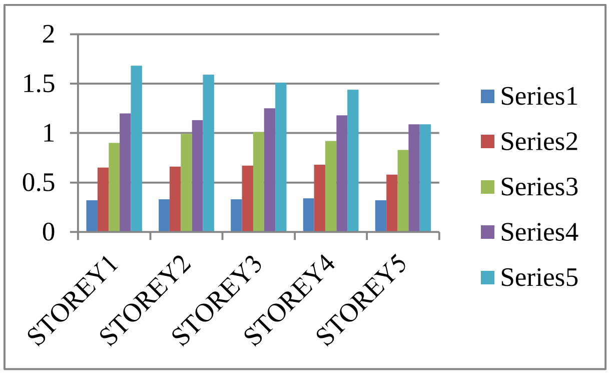


chart 4

Chart 3 and 4: demand capacity ratio after removal of column in corner position (C1) in all the storeys

From the chart 3, designing the columns it is observed that the maximum demand capacity ratio is 1.6 when column is removed from the Exterior middle position (C2). Even after removal of 1 column from the storey there is more increase in the demand capacity ratio. Hence there is failure of the building due to progressive collapse.

From the chart 4, after redesigning the columns it is observed that the maximum demand capacity ratio is 0.99 when column is removed from the exterior middle position (C2). Even after removal of 1 column from the storey there is less increase in the demand capacity ratio. Hence there is no failure of the building due to progressive collapse.



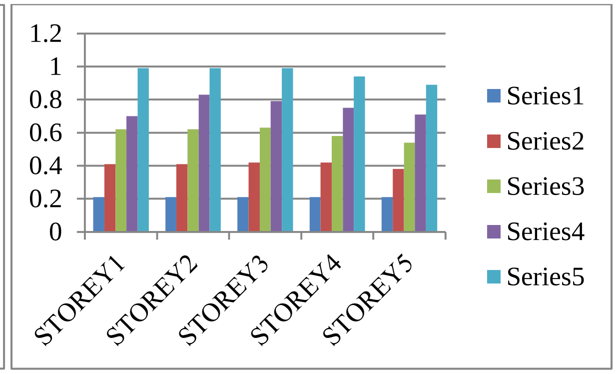


Chart 5 chart 6

Chart 5 and 6: demand capacity ratio after removal of column in corner position (C1) in all the storeys

From the chart 5, designing the columns it is observed that the maximum demand capacity ratio is 1.68 when column is removed from the interior middle position (C3). Even after removal of 1 column from the storey there is more increase in the demand capacity ratio. Hence there is failure of the building due to progressive collapse.

From the chart 6, after redesigning the columns it is observed that the maximum demand capacity ratio is 0.99 when column is removed from the interior middle position (C3). Even after removal of 1 column from the storey there is less increase in the demand capacity ratio. Hence there is no failure of the building due to progressive collapse.

Final Observation:

Normal design,

Column size – 450mmx450mm and % of A_{st} – 2.5%

Modelling of 5 storey buildings with eliminating column in corner position for all storeys

Modelling of 5 storey buildings with eliminating column in exterior middle position for all storeys

Modelling of 5 storey buildings with eliminating column in interior middle position for all storeys

Redesign,

Column size – 550mmX550mm and % of A_{st} – 2.72%

% of the area of column= ((redesign column size- normal column size)/normal column size)X100

% of the area of column= ((550x550)-(450x450))/(450x450)X100 =49.38 %

% of A_{st}= (redesign % of A_{st}- normal % of A_{st})/(normal % of A_{st})X100

% of A_{st} = (2.72-2.5)/(2.5)X100 = 8.8%

Structure will not going to fail due to failure of any column at any position.

CONCLUSION:

Normal design,

1. It is observed that after elimination of column C1 in storey1, the demand capacity ratio is increased by 1.42 in column C16 of storey1

2. In general elimination of column C1of storey1 the demand capacity ratio will not vary significantly as it will not affect more number of columns.
3. It is observed that after elimination of column C2 in storey1, the demand capacity ratio is increased by 1.6 in column C8 of storey1
4. In general elimination of column C2 of storey1 the demand capacity ratio will vary significantly and it will affect more number of columns.
5. It is observed that after elimination of column C3 in storey1, the demand capacity ratio is increased by 1.68 in column C17 of storey1
6. In general elimination of column C3 of storey1 the demand capacity ratio will vary significantly and it will affect more number of columns.
7. The elimination of column internally affects the adjacent columns by increasing the moments compared to the axial force when elimination of columns is done along the perimeter.
8. As observed from demand/Capacity ratio of columns in above structural models, the value is less than 1 which suggests that the removal of column in the structure will not affect any structural elements in the building significantly. if the demand capacity ratio is more than 1which suggests that the removal of column will affect any structural elements in the building significantly which leads to progressive collapse of building.

After Redesign,

1. It is observed that after elimination of column C1(corner position) in storey1,storey2,storey3,storey4,storey5 the maximum demand capacity ratio is 0.88,0.87,0.81,0.87,0.87 in column C18,C19,C8,C17,C17 respectively of storey1,storey2,storey3,storey4,storey5.
2. It is observed that after elimination of column C2 (exterior middle position) in the maxim storey1,storey2,storey3,storey4,storey5 um demand capacity ratio is 0.99,0.99,0.96,0.88,0.88 in column C8,C8,C8,C19,C19 respectively of storey1,storey2,storey3,storey4,storey5.
3. It is observed that after elimination of column C3 (interior middle position) in storey1,storey2,storey3,sorey4,storey5 the maximum demand capacity ratio is 0.99,0.99,0.98,0.94,0.89 in column C12,C8,C8,C18,C18 respectively of storey1,storey2,storey3,sorey4,storey5.
4. In general after redesign of column it is observed that the demand capacity ratio is less than one, progressive collapse is not observed hence all columns are safe.

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