International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 05 | May -2017 www.irjet.net p-ISSN: 2395-0072

Progressive collapse analysis of steel frame structures

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Abstract - *Progressive collapse is defined as a situation where local failure of a primary structural component leads to the collapse of adjoining members, which in turn leads to additional collapse. Hence, the extent of total damage is disproportionate to the original cause. Progressive collapse of building structures is generally triggered by a local failure due to accidental actions, followed by subsequent chain effect of the structures which may result in wide range failure or even collapse of the entire buildings. In the recent past years, there have been many incidents of structural collapses in terms of buildings or other structures, whether they were because of improper designs, poor maintenance, natural calamities or terrorist attacks. The research towards collapse or progressive collapse has been increasing. This will make the structure more safe avoiding casualties. So far the work done in this areas are for progressive collapse analysis in different number of stories and for different dynamic conditions. They found that progressive collapse potential decreased as the number of story increased since more structural members participate in resisting progressive collapse and by increasing damping ratios in dynamic analysis the maximum lateral deflection decreased for all frames. comparison of corner and middle column removal effects in base and 25% of building height are not studied at. In this work numerical simulation will be performed to investigate the progressive collapse potential of a steel frame building during the failure of corner and middle column in an accident. The structure behave pattern is also studied. So middle and corner column was analytically removed from the building to understand the subsequent load redistribution within the building. The axial force and DCR values are studied. By comparing these parameters and conclude that corner column removal in base is more effective in a building. This project is done by using ETAB.*

Key words: Finite element analysis, E TABS

1. INTRODUCTION

Progressive collapse is the result of a localized failure of one or two structural elements that lead to a steady progression of load transfer that exceeds the capacity of other surrounding elements, thus initiating the progression that leads to a total or partial collapse of the structure. The progressive collapse of building structure is initiated when one or more vertical load carrying members (typically column) are removed. Once a column is removed due to vehicle impact, fire, earthquake or any other man made or natural hazards, the building's weight (gravity load) transfer to neighbouring columns in the structure. Due to the redistribution of forces, the stresses within the remaining structural elements such as other columns and beams would be changed and if the stresses exceed the yield stresses of the element it fails. This failure can continue from an element to another and eventually the building collapses. This failure is defined as progressive collapse of the multi-storey buildings. Steel frames are commonly used as efficient main structural supporting systems in multi-storey buildings. However, up to date, the detailed behaviour of steel frames under progressive collapse is rarely found and there is a lack of information regarding the design of steel frames to overcome progressive collapse leading to the current investigation. Full-scale tests investigating progressive collapse of steel frames are quite costly and time-consuming.

Progressive collapse is generally a rare accident in developed countries, but its effect on buildings is very dangerous and costly. Without significant consideration of adequate continuity, ductility and redundancy, the progressive collapse cannot be prevented. A limited number of investigations are done on steel structures until now. The researches on the progressive collapse resistance of steel framed buildings are gradually increasing with the improvements on steel materials, technology and methods particularly in the developed countries.

1.1 Objectives

In the recent past years, there have been many incidents of structural collapses in terms of bridges or other structures, whether they were because of lack of information's in designs, poor maintenance, natural calamities or terrorist attacks

- To study the progressive collapse of the steel building by looking in to history of building collapses.
- To develop finite element model and study the behaviour of building before and after column removal by linear static analysis in ETABS
- To compare DCR values and axial force of sample building with column removal at corner and middle of the longitudinal side of building (outer edge) in base
- To compare the DCR values and axial force of sample building with column removal at 25% of building height.

1.2 Scope

The focus of this analysis is to determine if a structure is susceptible to progressive collapse and study the effects of

instantaneous removal of a load bearing element such as column and suggest the possible way to prevent the progressive collapse.

2. MODELLING

The building chosen for the project is eight story steel frame building, with six bays in the longitudinal direction and three in the transverse direction. The longitudinal direction has a uniform column spacing of 8.25 m, while on the three-bay side columns are spaced every 9.75 m. Main girders are IS MB550. Floor-to-floor height for every story is 4.3 m. IS MB550 columns and ISMB350 grade secondary beams are used. The floor diaphragms are constructed of composite metal deck with slab thickness of 90 mm. The modulus of elasticity, yield strength, and Poisson's ratio of the steel material is taken as $2x10^5$ MPa, 345 MPa, and 0.2, respectively

2.1 DCR Values

The GSA progressive collapse analysis and as per design guidelines define analysis procedure to evaluate the vulnerability of structure against progressive collapse. When vertical members are removed, GSA uses Demand-capacity ratios(DCR) to analyse that the structure will lead to progressive collapse.

$$DCR = \frac{Mmax}{Mp}$$

Where Mp is the ultimate moment capacity (plastic moment) and calculated by yield strength (fy) x plastic modulus (Zp).

Table -1: Computation of DCR values

Descriptions	Maximum moment (KN-m)	Plastic moment fy x Zp (KN-m)	DCR
Corner column removal in base	1345.3	729	1.84
Middle column removal in base	1199.0363	729	1.64
Corner column removal in 25% of building height	1310.4652	729	1.79
Middle column removal in 25%of building height	1151.1934	729	1.57

Using DCR criteria, the structure has DCR values greater than 2 are considered as severely damaged or collapsed (GSA). Here the structure is not severely damaged in all cases. From the above data, it can be concluded that removing middle column in 25% of building height shows a lesser DCR values. Here low risk for progressive collapse.

2.2 Axial Force

An axial force is a force that acts directly on an object's center axis. Axial force is the compression or tension force of the member.

Table -2: Axial force near the removed column

Story	Elevation	Corner column removal in base	Middle column removal in base	Corner column removal in 25%of building height	Middle column removal in 25% of building height
1	4.3	6414.5634	6105.5601	6129.6095	5826.1249
2	8.6	5581.804	5276.3013	5622.0324	5341.7626
3	12.9	4727.006	4472.4333	4801.6032	4527.4595
4	17.2	3903.6914	3692.223	3957.6194	3736.7283
5	21.5	3097.6223	2930.6879	3141.0717	2965.3382
6	25.8	2305.9704	2183.6144	2337.8533	2208.9748
7	30.1	1525.2009	1447.24	1546.2255	1463.7925
8	34.4	746.0738	719.6345	755.8424	727.7163

From above it can be drawn that axial force near the removed column is more in case of corner column removal as compared to middle column removal. As it is showed that, by removing corner column, the axial force of its adjacent column is increased significantly and other columns do not have a major role in this change of axial force. It also showed that the column adjacent to the removed column underwent higher force than other columns, which implied the redistribution of forces from the removed column to the nearest columns

3. CONCLUSIONS

- By removing the corner column, a great force is imposed to its adjacent column which shows progressive collapse direction. This situation does not have great influence to the other columns; however, in some columns axial force is decreased.
- By removing the middle column, the axial force is transferred to its two adjacent columns.
- Removing the corner column is more critical in comparison with removing the middle column.
- Using DCR criteria, the structure has DCR values greater than 2 are severely damaged or collapsed (GSA). Here the structure is not severely damaged. By comparing DCR values in all the column removed condition, conclude that corner column removal in base is more effective in a building.

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