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Progressive Collapse of Steel Building Subjected to Fire Load

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***Abstract*: Progressive Collapse in a steel building occurs when any heavy structural load carrying member leads to collapse of adjacent members, which is turn in to the additional collapse. In this paper, the G + 8 moment resisting steel frame building is analysed for progressive collapse considering two methods namely as linear static and non-linear static method by using ETABS 2018 software. In this model analysis, the columns at different levels are subjected to varying temperatures ranging from 300℃-1000℃ with the material properties of steel and yield strength as per IS 800-2007. load combinations are considered as per IS 875 part I & II. According to General Service Administration (GSA) 2016 guidelines fire load is applied additionally at different storeys to the selected columns. The structure is analysed by using software and the DCR values of column obtained are checked as per GSA 2016 permissible limits.**

***Keywords*: Steel building, Progressive collapse, ETAB 2018, Demand capacity ratio.**

1. Introduction

In General, Progressive collapse of steel building is due to failure of main supportive member like column and it tends to failure of adjacent member. Steel is a most popular material of construction and now a day's total steel building are also popular like residential building or commercial offices. Steel is efficient than concrete as per availability of material and less time consuming during speed of construction. Steel has high thermal conductivity and loss of strength and stiffness as rise of temperature. So, this study an attempt to understand to change in behaviour of steel structure lead to progressive collapse of structure.

For this study refer guild lines of General Service Administration (GSA 2016) for progressive collapse of structure in different criteria's. These guidelines recommend the DCR (Demand Capacity Ratio) values. which can be calculated using ETAB 2018 software and check the limit of value as per guide lines.

2. Literature Review

[1] Anand Baldota, Bhavana B, et al, (2018) have carried out the Progressive collapse leads to failure of the structure and this happens due to elimination of important structural members which are effected due to loadings from fire, impact loading blast loading etc. Kamel Sayed Kandil, EhabAbd El Fattah Ellobody and Hanady Eldehemy (2013) performed an Experimental Investigation of Progressive Collapse of Steel Frames by conducting two new tests to augment available data highlighting the structural performance of multi-storey steel frames under progressive collapse

[2] C. R. Chidambaram, Jainam Shah, A. Sai Kumar and K. Karthikeyan, et al, (2016) have been studies on the present study investigates the progressive collapse of a moment resisting steel frame residential building (G+7) subjected to fire loading at different levels using ETABS software. he Demand Capacity Ratio (DCR) values of the adjacent structural elements are calculated, when the columns at different levels have been failed due to the fire accidents. Based on the limit of DCR values given by GSA guidelines, the sustainability of the structure to progressive collapse is predicted.

[3] Jian Jiang, Guo-Qiang Li, et al, (2018) have examine the research on progressive collapse mechanism of steel framed buildings exposed to fire. The influence of load ratios, strength of structural members (beam, column, slab, connection), fire scenarios, bracing systems, fire protections on the collapse mode and collapse time of structures is comprehensively reviewed. It is found that the key influencing factors include load ratio, fire scenario, bracing layout and fire protection. The application of strong beams, high load ratios, multi-compartment fires will lead to global downward collapse which is undesirable. The catenary action in beams and tensile membrane action in slabs contribute to the enhancement of structural collapse resistance, leading to a ductile collapse mechanism. It is recommended to increase the reinforcement ratio in the sagging and hogging region of slabs to not only enhance the tensile membrane action in the slab, but to prevent the failure of beam-to-column connections. It is also found that a frame may collapse in the cooling phase of compartment fires or under travelling fires. This is because that the steel members may experience maximum temperatures and maximum displacements under these two fire scenarios.

[4] Harshad D. Mahale, S. B. Kandekar, et al, (2016) have been research on Performance of steel structures in fire depends upon a number of variables such as material degradation at elevated temperature and restraint stiffness of members surrounded by fire. In order to face minimal structural damage, limited casualties particularly in high rise structures and for the

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purpose of selecting suitable fire resisting measures structural response to fire need to be understood. Carrying out experiments on actual steel structure is not always feasible as it requires time, money, space and controlled fire as well hence the use of finite element software's like ANSYS is the best alternative instead.

[5] Tiago A. C. Pires1, João Paulo C. Rodrigues1, José J. Rêgo Silva and António M. Correia1, et al, (2010) have studied the use of concrete filled steel hollow sections (CSHS) in building construction has increased in the last decade. This type of columns has several advantages linked to their high load bearing capacity and good fire performance. However, when columns are inserted in a building structure, the effect of the restraining to their thermal elongation, change significantly the behaviour in case of fire. The high restraining forces developed during the fire, associated to the degradation of the mechanical properties, will lead to their buckling sooner than when they are isolated. In order to study these phenomena a series of fire resistance tests on CSHS columns was carried out in the University of Coimbra. Several parameters expected to have influence in the fire resistance of these columns were studied: the slenderness of the column, the load level, the stiffness of the surrounding structure, the percentage of steel reinforcement and the thickness of the concrete layer inside the column. This paper presents results of the fire resistance, restraining forces, axial deformation and failures mode observed in the tested columns.

[6] Ruirui Sun, Ian W. Burgess, Zhaohui Huang, Gang Dong et al (2015) have been studied A numerical procedure has been developed to model the sequences of failure which can occur within steel beam-to-column connections under fire conditions. In this procedure two recent developments, a static–dynamic solution process and a general component-based connection element, have been combined within the software Vulcan in order to track the sequence of local failures of the connections which lead to structural progressive collapse in fire. In particular, the procedure developed can be used to investigate the structural behaviour in fire, particularly the ductility and fracture of different parts of the steel to-steel connections, and the influence of the connections on the progressive collapse resistance of steel frames in fire.

In the component-based connection model, a connection is represented as an assembly of ''bolt-rows'' composed of components representing different zones of mechanical behaviour whose stiffness, strength, ductility and fracture under changing temperatures can be adequately represented for global modelling. The potential numerical instabilities induced by fractures of individual connection's components can be overcome by the use of alternate static and dynamic analyses. The transfer of data between the static and dynamic analyses allows a seamless alternation between these two procedures to take place. Accuracy and stability of the calculations can be ensured in the dynamic phase, provided that the time steps are set sufficiently small. This procedure has the capacity of tracking the sequence of local failures (fractures of connection components, detachment and motion of disengaging beams, etc.) which lead to final collapse.

[7] Correia, A. M, Pires, T. A. C and Rodrigues et al, (2010) have carried out the behaviour of steel columns subjected to fire is different from the one at room temperature. Thermal restraint from the surrounding unheated structure plays a key role in the stability of the columns. There are many ways in which the column can interact with the adjacent structure, including restrained column thermal expansion, change in the column bending stiffness relative to the adjacent structure, and increased of the P-Delta effect due to the lateral deformation caused by thermal expansion of the adjacent beams. The surrounding structure introduces additional axial load and moment on the heated column, and the internal column force does not remain constant but varies with temperature and the degree of axial and rotational restraint [1], [2]. In 2000, Rodrigues et al. [3] published the results of a set of 168 fire resistance tests on compressed steel elements with restrained thermal elongation. Parameters such as the slenderness, eccentricity of the load and restraining stiffness, were tested. It was shown that for the case of elements with centred loading, the higher is the stiffness of the surrounding structure the lower is the critical temperature. The buckling of the elements with centred loading occurred suddenly while the ones with eccentric loading occurred in a very gentle way.

[8] Yu Liu, Shan-Shan Huang and Ian Burgess et al, (2019) have studied out. In fire conditions the provision of connection ductility is key to the prevention of brittle failure and progressive collapse of steel and steel-concrete composite framed structures. This paper describes the development and testing of a novel connection concept intended to provide appropriate ductility enhancement compared to that of conventional connection types. The connection consists of two connection pieces, each of which takes the form of a web cleat which includes a semi-cylindrical section. This section allows the beam-end to move towards or away from the column-face by deforming plastically. A simplified analytical model has been developed to simulate the mechanical behaviour of the proposed connection, and this model will eventually enable the incorporation of this new connection type into global frame analysis to be used in performance-based structural fire engineering design.

The model has been tested against FEA simulations and against model-scale experiment results, indicating that it can predict the behaviour of the connection with satisfactory accuracy. Preliminary sub-frame analysis results indicate that the proposed connection behaves similarly to an idealized pinned connection under ambient-temperature conditions, but provide significantly larger ductility, and resistance to disproportionate collapse, compared to conventional connection types.

[9] Thomas Gernay, Antonio Gamba et al, (2018) have been studied. In progressive collapse analysis, event-independent column loss is commonly used as a design scenario. Yet this scenario does not account for the fire-induced thermal forces that develop in case of a fire. The thermal forces may cause detrimental load redistributions in the structure, notably during the cooling phase. However, as the response of entire structures during the full course of fires until burnout has received little attention, these effects are not well established. The objective

of this paper is to analyze the mechanisms of load redistribution in a structural system comprising a column subjected to localized fire, with a focus on the effects of the cooling phase.

[10] R. Jeyanthi, S. Mohan Kumar et al, (2016) have been studied the term “progressive collapse” 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. The research work was focused on progressive collapse analysis of reinforced concrete framed structure under column removal consideration using commercially available computer program ETABS. A G+8 RCC Educational building was considered and designed as per Indian Building Code and Pushover analysis was carried out. Then critical columns were identified and removed to initiate the progressive collapse. And parameters such as Demand capacity ratio and Robustness indicator were checked for the acceptance criteria provided in GSA 2003. And result comparison was done for these parameters before and after the progressive collapse of the building. Finally influence of critical eliminated elements has been discussed.

3. Influence of Load Ratio

In case of fire, the local failure mentioned in the definition of progressive collapse is the failure of steel members and slab in the fire compartment. The failure of these heated components will cause failure of adjacent connections, beams and column at ambient temperature, and lead to progressive collapse of total structure. Under the fire condition structure collapse, when it lapses and how it collapses is the main task to researchers.

4. Analysis Work

A. Analysis Part

Analysis of the structure model on ETAB 2018 by under load of dead load, live love, wind load and fire load. Main task to analysed the steel structure is to analysis under the fire load. Application of fire load is in rising manner for 3000c to 10000 c. Apply all load combinations and check the Demand Capacity Ratio (DCR) value of column. As per DCR value can be check column is safe or not.

If the DCR of a member exceeds the acceptance criteria, the member was considered as failed. The demand capacity ratio calculated from linear static procedure helps to determine the potential for progressive collapse of building.

B. Analysis Loading

Gravity loads were calculated as per IS 875 part 1 and assigned, Wind loads were calculated as per IS 875 part 2 and assigned, Design load Combinations and service load combinations were given as per IS 875 part 5.

C. Acceptance criteria as per GSA guidelines

The intent of GSA (General Services Administration) guidelines is to provide guidance to reduce and assess the potential for progressive collapse of Federal buildings for new or existing construction.

Demand Capacity Ratio: Demand Capacity Ratio (DCR) is the ratio of Member force to the Member strength.

DCR = Member Force / Member Strength

Allowable DCR < 2, for typical structural configuration, < 1.5, for a typical structural configuration.

5. Conclusion

As per the review of the analysis of steel structure mostly affected parameters are fire load, load capacity ratio and section properties. For prevention of section from fire heavy sections must be use in design. Fire proofing coating must be applying to structural member before use. It is desirable to strengthen the column by fire protection and web stiffener.

For prevention of failure of structure is to necessary to provide collapse resistance structure in fire. The failure connection can be prevented by using increasing reinforcement in deck slab, by rigid connection between members.

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