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JOURNAL OF CIVIL ENGINEERING RESEARCHERS

A review on Progressive Collapse of Steel Buildings

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Abstract

Progressive collapse of buildings is generally begun by a local failure due to unexpected actions continued by subsequent chain effect of the structures which may result in extended range failure or even collapse of the entire buildings. Progressive collapse of building structures has been widely studied by designers and researchers last years. This paper assesses and compares the current researches on this object from experimental study, numerical simulation and theoretical analysis. Given the limitation of costs and problems of experimental tests, the experimental studies investigate the collapse mechanism such as development of stresses and strains of materials and also damage to failure extending of them mainly via the scaled down samples of structural constituents and substructures. On the other hand, the collapse behavior of entire building structures is analyzed via the numerical procedures such as the finite element method. Furthermore the collapse resistance demand and the stability assessment for building structures are theoretically studied in depth at simplified theoretical models.

Keywords: Progressive Collapse; Numerical Simulation; Mechanism; Finite Element Experimental Study;Theoretical Analysis

1. Introduction

With regard to scarcity of urban areas and subsequently need to development tall buildings for appropriate efficiency, safety and needful level of it is necessity and it is one of the most important cases in building industry. A progressive collapse of a building is initiated by an unexpected event that causes local damage and subsequently propagates throughout the structural system leading to a final damage state in large – scale or entire collapse of the building. A progressive collapse can be triggered by accident action including fire hazard, gas explosion, terrorist attack, vehicle collision, design and construction errors and environmental corrosion with the development of industrialization the buildings with multi – function and high complication become more common of which the safety and stability are

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far more concerned. Hence, it seems to pay attention to progressive collapse and handling for this issue to cumulating is useful matters as review papers that can include optimal analysis and design options from judgment view is more important. In this review paper that is basis of recent studies on mentioned issue analysis procedures, design codes and various parameters in the form of literature review have presented and finally discussion and conclusion have been given.

2. Codes and Regulations

After collapse of major structures like world trade center building (WTC) the necessity of codification and evolution of new design codes regarding building resistance versus progressive collapse is far more concerned .various researches and studies have been performed on scaled models in the form of experimental and numerical work and logical results trying to be applicable for engineers and designers in which the theoretical and guidelines have been applied. The general design guidelines and suggestions given in the commentary in ASCE 7 include: plan layout (including reducing large spans), integrated systems of ties, changing of span directions of floor slabs, load bearing of interior partitions, catenary action of the floor slab, ductile detailing and the addition of reinforcements for blast and load reversal[15]. British standards and Eurocode1 employ the tying force method to maintain continuity in an event of abnormal loading [16]. Totally it can be noted that two general design processes for progressive collapse basis on last researches have codified in codes and used by researchers which are fallows:

2.1. Alternative Load Path Design Method

In the alternative load path design methods, the structure is designed in such a way that a new load path could be developed to bridge the local failure zone. This method is a threat- independent method and avoids designing for an extreme event of specific magnitude that may be exceeded during the service life [17].

2.2. Specific Local Resistance Method

The basic concept behind the specific local resistance is to design any structural element over which the building cannot bridge as a key or protected element, capable of resisting a specific level of threat, which may be in the form of blast, impact or any other abnormal event. The limits of allowable collapse progression are given in many design codes and guidelines. For example the specific local resistance in British standards is 34 KN/m² [16].

3. Progressive Collapse Analysis Procedures

Analysis procedures must be compatible with design methods, hence, analysis procedure must be selected based on design method .The alternate load path method requires an assessment if the capacity of frame to redistribute load away from damaged members. This requires the engineer to consider the most suitable analytical procedure, model complexity and design assumptions within the constraints of expense, computing power and time. In general, there are five procedures used to perform such an analysis [11], [18];

a. Linear static analysis using dynamic load factors
b. Non – linear static analysis using dynamic load factors
c. Non – linear static pushover analysis (energy balance procedure)
d. Linear dynamic analysis
e. Non – linear dynamic analysis

Linear methods require the material response to remain in the elastic range and second – order ($P - \Delta$) effects and instabilities to be ignored. This limits their use small displacements and often leads to conservative design in order to prevent invalidating the assumptions. Non - linear methods include material plasticity and are able to account for geometric non – linear effects as they become more significant; they also have the potential to allow for the development of alternative load path mechanisms, such as arching action or catenary action [18]. The US General Service Administration guidelines (GSA) advise the use of three dimensional analytical models

subject to a linear elastic or static analysis procedure, but two - dimensional models may also be used .The potential for progressive collapse is assessed for the case of instantaneous column loss at a variety of floor levels for both interior and exterior columns .once the column is removed, the survivability of the individual elements is assessed using demand capacity ratios (DCRs) as defined demand resistance to available capacity[18].whereas various factors such as degree of indeterminacy ,behavior coefficient and time of column loss affect to progressive collapse, dynamic procedures give more real results but explanation of the results requires enough experience and judgment .

4. Literature Review

This chapter presents a brief review of recent researches and studies performed by the researchers. The detail review of every papers would be difficult here .Most of the studies and researches have focused on column loss in different places in floors[3],[10], effect of span length of frames[4] and two or three dimensional analytical models[1],[11] .From view of researchers the maximum potential in creation and development of progressive collapse is due to corner column loss which develops in adjacent slender columns as elastic buckling, in moderate columns as inelastic buckling and in short columns as failure of materials[3] .Researches show that failure propagation exist like yielding in connections, beams and slabs but the failure mode of column is the chief factor . The other issue is that in tall frames column buckling mechanism occurs but in short frames beam yielding mechanism happen. Some researchers showed that both two and three dimensional models can be used in progressive collapse analysis but three dimensional models to explain the results is better than the two dimensional models and this is due to participation of transverse elements in bearing and their effect on circumstance of progressive collapse development[3]. One of the other studies have been performed by the researchers is the effect of span length of frames that show reduce span length to half dose the resistance of frame versus progressive collapse twice. Studies on progressive collapse due to blast show the type and quantity of explosive materials in simulation and place of its creation and also different building points affect results explanation [6]. The researches show that linear and non – linear static analysis methods are more logical for symmetric structures and unsymmetrical structures must use non–linear dynamic analysis methods, too [11]. Most of researches focus on demand resistance to capacity ratio (DCR) in structural elements for assessment progressive collapse potential of building after column loss and comparison has been performed by available quantities in codes specially U.S guidelines and conclusions[3],[4],[10]. In performed researches more non-linear static analysis method (push over) has been used [11].

5. Discussion

As mentioned in literature review chapter, it is obvious that most of researches focus on column loss for assessment progressive collapse and regard its different positions in building but beams loss has ignored that it can be assessed as one factor. Performed analysis is more non – linear static (push over) methods that attend dynamic properties of available loads and inelastic behavior of materials in progressive collapse, necessity of effective non-linear dynamic analysis performed is more concerned. In design codes, the U.S code (GSA) and British standards (BS) is more used as reference that seems to study progressive collapse phenomenon at every region or country must compatible by its material properties and execution procedures and code. The parameter of progressive collapse assessment in most researches treated as demand resistance to capacity ratio (DCR) that is total factor and certainly other factors such as number of stories, beam to column length ratio, connections and e.tc. Also must be concerned. In study blast effect on creation and development of progressive collapse, adjacent surface blasts are more attended and subsurface or internal blast effects and also impact of body to building have

not been studied and it is necessary for design code evolution.

6. Conclusion

From the above review we have concluded that a lot of research on progressive collapse of steel buildings have been carried on the column loss and results explanation have been performed more on the basis of demand resistance to capacity ratio .Hence, total conclusion can be presented from review as following suggestions :

1. Beam loss, number of stories, beam to column length ratio, connections and their type effects and different forms of blast loads (subsurface, internal, impact) must be studied in progressive collapse potential assessment.
2. To study progressive collapse in tall and unsymmetrical buildings specially, dynamic analysis must be performed.
3. Progressive collapse resistant buildings design code for every region or country must be set by that material properties and execution conditions.
4. To assess the potential for progressive collapse of buildings more parameters must be concerned on the basis of important priority and building serviceability.
5. If we can simulate more appropriate scales of buildings as experimental models and research their failure development under incremental loads and mentioned parameters more real perception from progressive collapse phenomenon will form and influence on workable codes evolution.

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