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Progressive Collapse of Tall Buildings

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Abstract - The prime concern of the structural engineering fraternity across the globe is the safety of human lives. The community of structural engineer is well aware about the consequences of accidental and rare events like Earthquake, Tsunamis, Fire, Tornado and Blast. Therefore, lot of research is being done in all parts of the world to design the structure that can minimize or eliminate causalities in such rare but devastating events. Progressive collapse is one of the most devastating types of building failures, most often leading to costly damages, multiple injuries, and possible loss of life. Factors such as construction errors, miscommunication, poor inspections, or design flaws contribute to these progressive collapses, which have lead to many changes in building codes throughout the world.

The U.S. General Services Administration (GSA) document and Unified FacilityCriteria – Department of Defense (UFC – DoD), USA guideline provides the general guidelines to assess the potential for progressive collapse in RCC and Steel buildings. In present study G+5, G+10 and G+ 20 storied structures are analyzed using Linear and Non Linear Static Analysis procedures by both, GSA (2003) and UFC (2013) guidelines. The comparison is made between both available guidelines. To understand effect of geometrical irregularity, L-shaped buildings and Rectangular buildings are considered in present study. As the method of GSA guidelines have some drawbacks, researchers had developed a different method called Push – Down Analysis for progressive collapse which is also studied and compared with that of GSA method.

***Key Words*:** Tsunamis, GSA, Linear Analysis, Push down Analysis

.INTRODUCTION

There have been countless instances of buildings gradually collapsing during construction. Low material strength, construction overload, and inappropriate construction practises have all been linked to these construction disasters [5]. Ones under construction have a higher chance of collapsing than the same buildings after completion, according to historical statistics. Buildings that are resistant to progressive collapse are not a new problem in structural engineering. Since the partial collapse of the Ronan Point apartment building in 1968, many structural engineers and academic scholars have been working to prevent further collapse.

Glimpse in the past

The partial collapse of the Ronan Point Apartment building in London, England in 1968 generated a widespread concern for progressive collapse of buildings in chainreaction mode, triggered by a local failure. The Ronan Point collapse was brought about by a gas explosion in an apartment on the 18th floor of a 22-story precast concrete building. The gas explosion blew out the exterior bearing wall of the apartment that caused the upper floor slab to fall.

Fig 1.1 Ronan Point Collapse [29]

The falling debris of upper floor triggered the collapse of the floor below. As a result, the collapse of one corner of the building almost to the ground takes place as shown in Figure 1.1.

Since the Ronan Point collapse was considered as ―progressive collapse" both in the vertical and horizontal directions that led to a total or a disproportionately large failure relative to an initiating local failure

L'Ambiance Plaza was another large collapse that followed a progressive collapse failure pattern. It was a 16-story residential complex in Bridgeport, Connecticut, that was under construction. Two wings of post-tensioned concrete flat slabs supported on steel columns made up the structure. The lift-slab method of erection was used, which entailed casting all floor slabs at grade level, one on top of the other. Columns were inserted through holes left in the stack of slabs for this reason, in sections that were many storeys high. The slabs were jacked up the columns in groups after jacks were erected at the tops of the columns. At their permanent placements on the columns, the lower slabs were attached in sequence. The lift- slab technique was used to construct the constru ction, which required the floor slabs to be cast on the gro und and then raised into place by a jacking operation.The building collapsed completely on April 23, 1987, just afte r one of the jacking operations was completed (Figure 1.2).

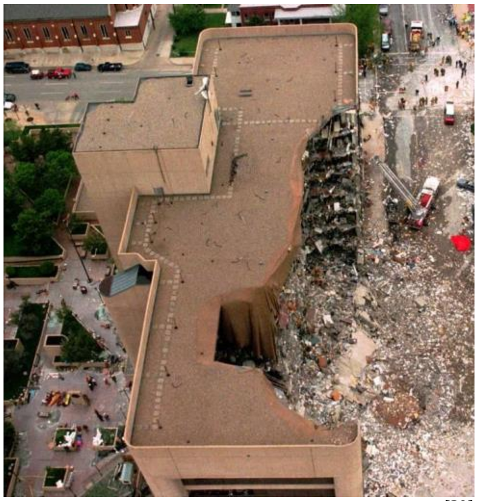

Fig 1.2 Alferd Murrah Building Collapse [30]

In an another scenario, the Alfred P. Murrah Building in Oklaho ma City, Oklahoma, was a federal government office building. B etween 1970 and 1976, the Murrah Building was designed and b uilt.

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The Murrah Building had a 9story reinforced concrete ordinary moment frame as its structural arrange ment. The Murrah Building was the target of a terrorist a ttack on the morning of April 19, 1995, when a truck bo mb exploded in front of its north side. The building suffe red substantial structural damage as a result of the explos ion.

The Murrah Building's north side, which was immediately hit by the blast, suffered major structural damage. The north half of the rectangular footprint was destroyed in its entirety. The damage spanned the full length of the structure. The blast immediately destroyed three columns that supported the transfer girder on the third floor, causing the top stories to fall. It was believed that around half of the building's usable space had collapsed (Figure 1.2).

Terrorist activity caused the collapse of the US Marine Barracks in Lebanon (Figure 1.3). The structure was hit by two truck bombs, which caused the American embassy to gradually collapse. The blast destroyed the horseshoe-shaped building's whole central front, leaving balconies and offices in stacked levels of rubble and flinging masonry, metal, and glass pieces across a wide expanse. Aside from these, there are a number of other important events that contribute to the progressive collapse of structures, including:

(a) Kansas City Hyatt Regency Hotel Walk Way Collapse
(b) Skyline Plaza – premature formwork removal (Figure 1.4)
(c) Civic Arena Roof collapse
(d) World Trade Centre
(e) Khobar Towers
(f) Jackson Landing Skating Ring – Excessive ice load

Fig 1.3 U. S. Marine Barracks Collapse [31]

3. CONCLUSIONS

When one or more vertical loadbearing parts, notably columns, are severely damaged or collapse duri ng any abnormal occurrence, progressive collapse of the building occurs. The building's gravity load is transferr ed to surrounding elements in the structure when a colu mn fails.

This component of the structure will break if these mem bers are not properly built to resist and redistribute the e xtra load.

As a result, a significant portion of the structure could c ollapse, causing more damage than the initial collision.T he US General Service Administration (GSA) [1] establi shed the "Progressive Collapse Analysis and Design Gui delines for New Federal Office Buildings and Major Mo dernization Projects" to assess risk of progressive collap se. The guidelines provide a threat independent methodology for minimizing and assessing the progressive collapse potential in new and existing Reinforced concrete and steel buildings.

Department of Defense (DoD) [2] of United States of America (USA) published the Unified Facilities Criteria UFC 4-023-03 (2009) for ―Design of Buildings to Resist the Progressive Collapse". The guidelines incorporate the new knowledge related to design of buildings to resist progressive collapse. This includes steel beam-column connection, wood structure under blast damage and collapse loading, reinforced concrete slab response to large deformations. Guidelines are also provided for linear static, nonlinear static and nonlinear dynamic analysis methods.

National Institute of Standards and Technology(NIST)[3] developed the document ―Best Practices for Reducing the Potential for Progressive Collapse in Buildings." The main objective of the document is to provide best practices to engineers to minimize the progressive collapse of building in the event of abnormal loading. Practical means for reducing risk for new and existing buildings are presented in the document. The document also discusses the various analysis methods for progressive collapse. A design consideration for different structural materials is summarized. The methodology for evaluating and mitigating progressive collapse potential in existing building is also discussed. Case studies of progressive collapse and progressive collapse provisions in various design standards are also presented.

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BIOGRAPHIES

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