EFFECTIVE STUDIES ON PROGRESSIVE COLLAPSE FOR RCC FRAMED STRUCTURE USING PUSHOVER ANALYSIS

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Abstract: In our country, most buildings are reinforced concrete frame structure. Comparing with shear wall structure, frame structure is more likely to collapse due various accidents such as cylinder blast, earthquakes, terrorist attacks, etc. Therefore, the research about progressive collapse of frame structures is very important. 'Progressive Collapse' is defined as whole structure collapses progressively due to failure of primary structural element.

Now a day's Progressive Collapse has gained importance preferably in precast structures, joint plays a crucial role in it. As a result extra reinforcement is required at joints and various other regions to have a control over Progressive Collapse. Conventional (in-situ) RCC frame structures give least importance to extra detailing. Especially for multistory building more attention must be paid towards designing considering Progressive collapse. To serve the purpose many IS Codes and standardization have been already laid should be considered. But to achieve economy, profits this is given rare importance.

This paper shall reflect the importance of Progressive Collapse through study of various Codes and standardization on it. Developing possible alternative as far as possible for achieving economy.

***Keywords*: Progressive Collapse, Pushover Analysis.**

1. Introduction

- **Progressive Collapse**

A building is subjected to progressive collapse when a primary vertical structural element fails, failing adjoining structural elements, which cause further structural failure, leading eventually to partial or total collapse of the structure. The failure of a primary vertical support might occur because of extreme loadings such as a bomb explosion in a terrorist attack, a car colliding with supports in a parking garage, an accidental explosion of explosive materials, or a severe earthquake. Different design codes address the progressive collapse of structures attributable to the sudden loss of a main vertical support such as the General Services Administration (GSA) code and the Unified Facilities Criteria (UFC). The alternative path method (APM) is the main analysis method for evaluating the hazard of progressive collapse in the two codes. The investigated cases include the removal of a corner column, an edge column, an edge shear wall, internal columns, an internal shear wall, and a corner shear wall. The numerical analysis showed that, for an economic design, the analysis should consider slabs and cannot be simplified into a two- or three-dimensional frame analysis. Progressive collapse is a failure mode of great concern for tall buildings, and is also typical of building demolitions.

- **Pushover Analysis**

It is a technique by which a structure is subjected to a incremental lateral load of certain shape.

The sequence of cracks, yielding, plastic hinge formation and failure of various structural components are noted. The structural deficiencies are observed and rectified. The iterative analysis and design goes on until the design satisfies a pre-established criteria. The performance criteria is generally defined as Target displacement of the structure at roof level.

Purpose of doing pushover analysis

The pushover is expected to provide information on many response characteristics that cannot be obtained from an elastic static or dynamic analysis. The following are the examples of such response characteristics:

- The realistic force demands on potentially brittle elements, such as axial force demands on columns, force demands on brace connections, moment demands on beam to column connections, shear force demands in reinforced concrete beams, etc.
- Estimates of the deformations demands for elements that have to form in elastically in order to dissipate the energy imparted to the structure.
- Consequences of the strength deterioration of individual elements on behavior of the structural system.

- Identification of the critical regions in which the deformation demands are expected to be high and that have to become the focus through detailing.
- Identification of the strength discontinuous in plan elevation that will lead to changes in the dynamic characteristics in elastic range.
- Estimates of the inter-story drifts that account for strength or stiffness discontinuities and that may be used to control the damages and to evaluate P-Delta effects.
- Verification of the completeness and adequacy of load path, considering all the elements of the structural systems, all the connections, and stiff non-structural elements of significant strength, and the foundation system.

2. Methodology

Comparative analysis of three different shapes of the building as following

- Rectangular Shape (R-Shape)
- Tee Shape (T-Shape)
- Cross Shape (+ - Shape)

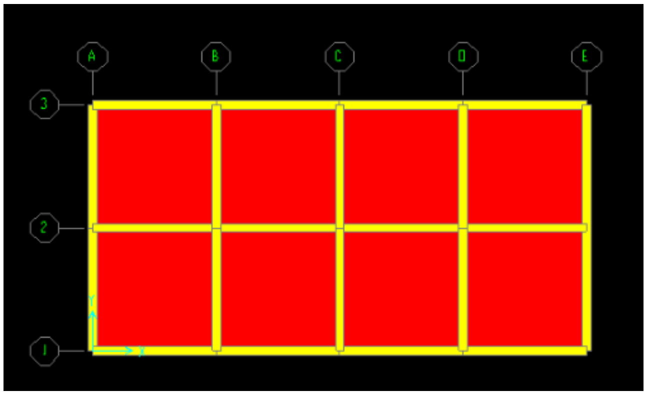

Fig.1 Rectangular Shape (R-Shape)

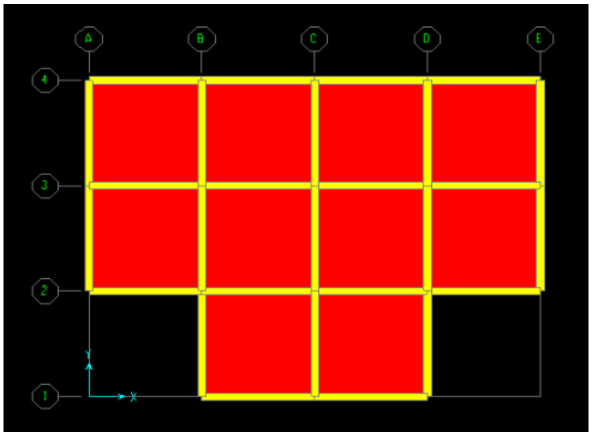

Fig.2. Tee Shape (T-Shape)

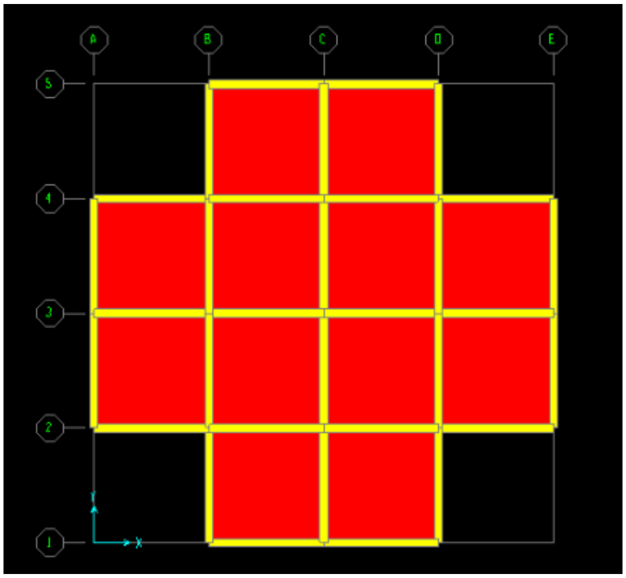

Fig.3. Cross Shape (+ - Shape)

Model making on software SAP2000. Removing the central column (maximum load carrying member) from every shape (R, T & +) building and studying the effect of the failure pattern.

3. Literature Review

Dhileep. M et al., (2011) explained the practical difficulties associated with the non linear direct numerical integration of the equations of motion leads to the use of non linear static pushover analysis of structures. Pushover analysis is getting popular due to its simplicity.

High frequency modes and non linear effects may play an important role in stiff and irregular structures. The contribution of higher modes in pushover analysis is not fully developed. The behavior of high frequency model responses in non linear seismic analysis of structures is not known. In this paper an attempt is made to study the behavior of high frequency model responses in non linear seismic analysis of structures.

Non linear static pushover analysis used as an approximation to non linear time history analysis is becoming a standard tool among the engineers, researches and professionals worldwide. High frequency modes may contribute significantly in the seismic analysis of irregular and stiff structures. In order to take the contribution of higher modes structural engineers may include high frequency modes in the non linear static pushover analysis. The behavior of high frequency modes in non linear static pushover analysis of irregular structures is studied. At high frequencies, the responses of non linear dynamic analysis converge to the non linear static pushover analysis. Therefore non linear response of high frequency modes can be evaluated using a non linear static push over analysis with an 19 mplemental force pattern given by their modal mass contribution times zero period acceleration. The higher modes with rigid content as a major contributing factor exhibit a better accuracy in non linear pushover analysis of structures when compared to the damped periodic modes.

- **General overview of Roissy's Terminal 2E**

Description of the terminal

Terminal 2E consists of three parts: the main building, the boarding area and the isthmus that connects the two buildings. The boarding area is formed by a succession of ten shells giving access to aircrafts through nine gateways (Fig. 1). The 650 m long terminal is made up of a series of 4 m wide panels adjacently connected, forming a deformed tube which rests on parallel longitudinal beams. Structurally it acts as a form of an extreme portal frame. There is a 30 cm thick precast concrete shell and a steel external tension truss, with simple vertical struts connecting the elements. The tube is surrounded by a glazed roof which feeds light into the structure through square voids cast into the shell (Fig. 2). Three walkways are cut into the structure (it was at one of these points that the structure failed). These footbridges link the boarding area to the central area of the terminal.

Fig. 1. Roissy's Terminal 2E

Incidents before the collapse between the beginning of the construction phase and the date of the collapse, many incidents took place: right after installing the first rings, cracks were seen in the columns. After the striking, we had instantaneous deformations and a spreading of the shell. This deformation continued over time because of the creep and shrinkage of the concrete. Cracks near the fixation plates of the footbridges were observed in zones where the collapse occurred. These cracks have been attributed to the deformation of the shell, but without showing any undue concern. Transverse cracks appeared very quickly in the midline (under the support line of struts) of all solid elements located at the extremity of the shells. 2.4. Collapse of the terminal On Sunday May 23rd at 6:57, six arcs located in the boarding pier collapsed abruptly with a loud cracking noise (Fig. 3). A police lieutenant who witnessed the collapse found around 6:45, a significant tear in the lateral wall of a concrete element of a solid shell adjacent to the footbridge in the middle of the zone which later on collapsed. This tearing was reported about 5:30 by a cleaning crew and it also seemed that there was concrete dust that fell before the accident.

- **General overview of Ronan Point**

The development of design guidance in the United States for the mitigation of collapse began with the Ronan Point apartment building collapse in the United Kingdom (UK) in 1968. A gas explosion on an upper story resulted in the progressive collapse of the southeast corner of the building. The results of the investigation led the UK engineering community to develop a number of design approaches to address the weaknesses that were identified and in particular the connections between the structural elements. In the United States, the Ronan Point collapse motivated research at the National Bureau of Standards and universities and a number of technical workshops that were held in the 1970s. During this period, engineers expressed concern about continued optimization in structural design and the trend toward speeding erection during construction; this may lead to reduced robustness and continuity in the structural system, exposing structures to a greater risk of progressive collapse when unexpected loads occur. Ultimately, the work in the United States during the 1970s led to general structural integrity provisions in American National Standards Institute (ANSI) A58.1 [ANSI 1982, later to become ASCE 7 Minimum Design Loads for Structures (ASCE 2006)] and adoption by the American Concrete Institute (ACI) of integrity provisions for panelized construction to address the issues found in the Ronan Point structure.

Fig. 2. Ronan Point

- **Khobar Towers**

In June 1996, the Khobar Towers complex in Saudi Arabia,housing U.S. DoD personnel, was bombed. As a result, the U.S.Congress directed DoD to develop antiterrorism standards for construction of military facilities. The standards were for the reduction of the vulnerability of structures on military installations to terrorist attack and to improve security of occupants. In 2001, DoD issued interim design guidance specifically addressing progressive collapse to clarify interim antiterrorism requirements (DoD 2001). This guidance adopted an alternate load path method to reduce the risk of progressive collapse that was similar to the GSA criteria.DoD updated its antiterrorism standards for buildings in the 2002 publication of Unified Facilities Criteria (UFC) 4-010-01 Minimum Antiterrorism Standards for Buildings (DoD 2002) that included the requirement to consider progressive collapse.

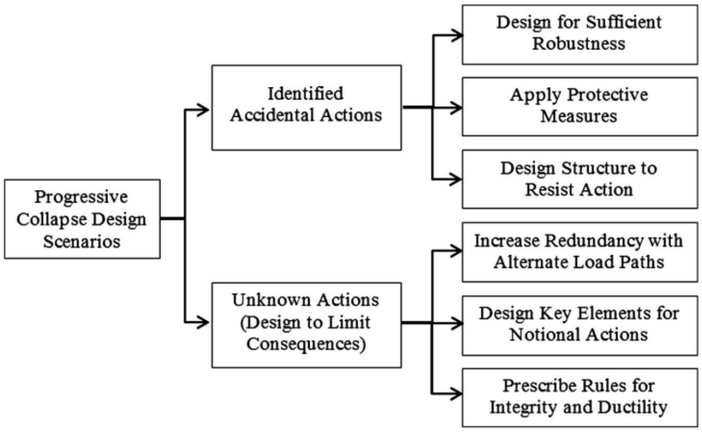

Fig. 3.Design strategies for disproportionate collapse, adapted from BSI (2006)

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