Progressive Collapse Potential in Tube in Tube Structures

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***Abstract*: In recent decades, vulnerability of tall buildings to unforeseen loads induced by progressive collapse has drawn researchers' attentions. There is a growing tendency among engineers to design tall buildings using complicated structural systems with adventurous load paths that are inconsistent with the existing guideline recommendations. One of the major causes for failures of many high profile structures took place, around the world, is extreme loading effects generated due to hurricane, flood, earthquake, explosion and terrorist attacks on buildings. This type of event imposes abnormal loading on the building structure. Generally, members of building are not designed to resist this type of abnormal loading and results into failure. One of the mechanisms of failure during such event is referred to as Progressive Collapse.**

This paper describes a recommended methodology for calculating the dynamic increase factor (DIF) using nonlinear static analysis. Based on this method, the specific load factor corresponding to the progressive collapse potential of building structures is evaluated by a proposed collapse index. In the development of the methodology, selected tube-type structural system is to be investigated. This study was conducted to assess the collapse behaviour of tubular building models under sudden loss of vertical load-bearing elements by using nonlinear static analysis

Keywords: Dynamic increase factor, Progressive collapse

1. INTRODUCTION

In structural engineering, the tube is the system where in order to resist lateral loads (wind, seismic, etc.) a building is designed to act like a hollow cylinder, cantilevered perpendicular to the ground. Nowadays, the advancements in structural systems, increase in building height and slenderness, use of high strength materials, reduction of building weight etc., has necessitated the consideration of lateral loads such as wind and earthquake in the design process. Lateral forces resulting from wind and seismic activities are now dominant in design considerations. Lateral displacement of such buildings must be strictly controlled, not only for occupants comfort and safety, but also to control secondary structural effects. Tubular structures have been successfully utilized and are becoming a common feature in tall buildings.

Basic forms of tubular systems are

- Framed tube
- Braced tube
- Bundled tube
- Tube-in-tube

The tube system concept is based on the idea that a building can be designed to resist lateral loads by designing it as a hollow cantilever perpendicular to the ground. In the simplest incarnation of the tube, the perimeter of the exterior consists of closely spaced columns that are tied together with deep spandrel beams through moment connections. This assembly of columns and beams forms a rigid frame that amounts to a dense and strong structural wall along the exterior of the building.

II.OBJECTIVES

1. To find out the dynamic increase factor of the tubular structures
2. To identify the worst case scenario of the removed load carrying elements

III. METHODOLOGY

In this project, progressive collapse analysis of G +15 storey RC tube in tube structure is carried out as per the GSA guidelines. As per GSA guidelines three column removal case one at a time has studied, namely Corner column removal at ground floor, Exterior column at ground floor and interior column at ground floor

A.Modelling

The tube in tube structure has been created in ETABS software.

Table 3.1 Dimensional details

Property	**Value**
Floor height	3 m
External column size	750×500mm
Internal column size	500×350mm
External beam size	1200×750mm
Internal beam size	750×500mm

B.Material Properties

Material properties of the building are as follows,

Table 3.2 Material properties

Material Property	Value
Modulus of elasticity	2×10^5 MPa
Grade of steel	Fe 500
Grade of concrete	M 30

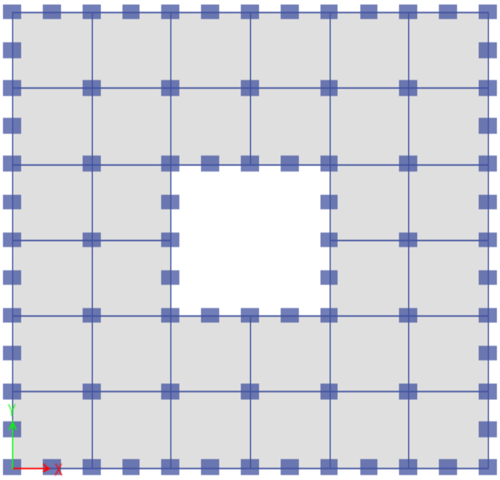

Fig.3.1 Plan view of Tube in tube structure

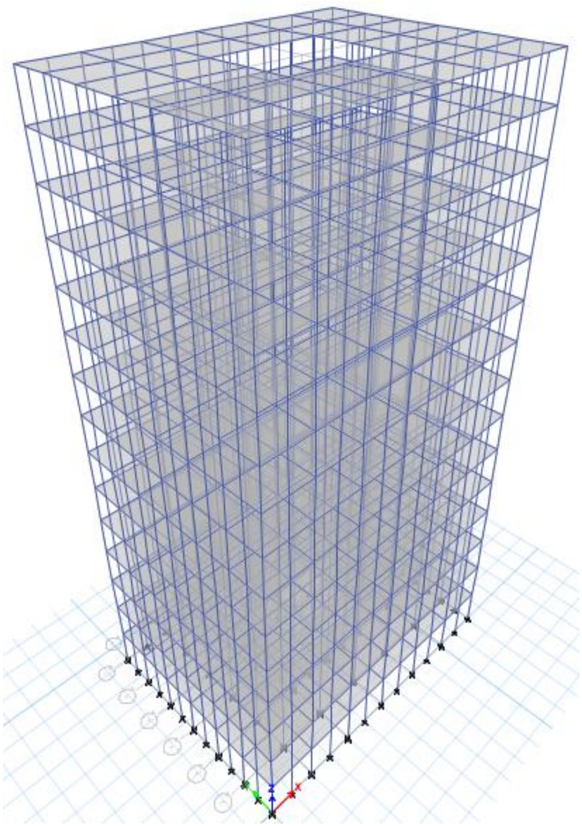

Fig.3.2 Three dimensional view of Tube in tube structure

C. Loading

After having modeled the structural components ,all possible load cases are considered. In addition to structural elements weight, a dead load (DL) 6kN/m^2 applied to the roof and other floors. The live load(LL) is 1.5 kN/m^2 for roof and 2 kN/m^2 for other floors.

Load combination as per GSA, away from column removal region

G = 1.2 DL + 0.5 LL

Load combination as per GSA, for column removal region

GLD = Ω_N (1.2 DL +0.5 LL)

GLD is the increased gravity loads and Ω_N is the dynamic increase factor.

D.Analysis

In this analysis, we are considering 3 different cases of column removal. Each of them from 1st story

Case1 : Analyzed for loss of corner column
Case2 : Analyzed for loss of exterior column
Case3 : Analyzed for loss of interior column
Obtain the displacement and force related to collapse point of the damaged structure (when the maximum load is reached).

$$\lambda=\frac{\text{Strength related to collapse point corresponding to DIF trial}}{\text{Strength related to collapse point corresponding to DIF 1.0}}$$

$$\mu=\frac{\text{Displacement related to collapse point DIF trial}}{\text{Displacement related to collapse point DIF 1.0}}$$

where λ and μ strength and displacement factors based on a nonlinear static analysis

Collapse index = $\lambda \times \mu$

Based on this approach a collapse index is defined using the strength (λ) and displacement (μ) factor for the specific DIF. Then, the collapse index of less than 1.0 identifies the DIF corresponding to progressive collapse capacity of the structure.

When the empirical DIF corresponding to existing capacity of the structures is identified by recommended trial methodology, the gravity load combination for floor areas above and adjacent to the removed columns applied by GSA documents (G) is modified considering inherent capacity of the structure, and is expressed as (G*).

$$G= \Omega_N\times(1.2DL+0.5LL)$$

$$G^*=(1+\Omega_N-\Omega_{N,trial})\times(1.2DL+0.5LL)$$

where ΩN and $\Omega_{N,\ trial}$ are DIFs calculated from GSA guidelines and proposed methods, respectively. The modified load factor is applied to the external frame for the tubular system in which the structural system is located at the perimeter of the building. For internal element removal there is no need to modify load factor recommended in GSA guidelines.

IV. RESULTS

Table 4.1 Collapse Index for Tube in tube Structure with interior column removed

Tube in tube structure	`Collapse Point		μ	λ	Collapse index
	Force (kN)	Displacement (mm)			
1	17851	4.7	1	1	1
1.25	16951	4.9	0.94	1.04	0.98
1.5	15981	5.1	0.89	1.08	0.96
1.75	15633	5.5	0.87	1.17	1.02
2	14941	5.8	0.84	1.23	1.03

Table 4.2 Base shear values for different column removal cases

Tube in tube structure	**Interior column removal**	**Exterior column removal**	**Corner column removal**
Base Shear(kN)	14351	13837	14110

V. CONCLUSIONS

- Building is analysed in ETABS 2015 software and the results where compared.
- The dynamic increase factor for tube in tube structure with interior column removed is 1.5.
- From the base shear value it is obtained that interior column removal is critical when compared to other locations.

REFERENCES

[1] General Services Administration (GSA). (2003). Progressive collapse analysis and design guidelines for new federal office buildings and major modernization projects, GSA

[2] IS 456:2000 (2005). Plain and reinforced concrete code of practice, 4th Revision, 7th Reprint, Bureau of Indian Standards, New Delhi.

[3] [3]. IS 1893 (Part 1):2002 (2006). Criteria for earthquake resistant design of structures.5th Revision, 3rd Reprint, Bureau of Indian Standards, New Delhi

[4] ETAB v 9.7 analysis reference manual, Computers and Structures, Inc., Berkeley.

[5] Abruzzo, J, Matta, A and Panariello, G, 2006, “Study of Mitigation Strategies for Progressive Collapse ofa Reinforced Concrete Commercial Building”, Journal of Performance of Constructed Facilities, vol.20, no.4,pp348-390

[6] ASCE-07, 2005, Minimum Design Loads for Buildings and Other Structures. American Society of Civil Engineers, ASCE 7-05, Reston, VA, USA

[7] Astaneh-Asl, A, 2003, “Progressive Collapse Prevention in New and Existing Buildings”, Ninth Arab structural Engineering Conference, Abu Dhabi, UAE 2003: 1001–1008. AS 2841, 2005, “Galvanized Steel Wire Strand”,Australian Standard.

[8] Abhay A. Kulkarni, Rajendra R.Joshi (2011) “Progressive Collapse Assessment of structure” International JournalEarth Sciences and Engineering , ISSN 0974-5904

[9] B. M. Luccioni et al (2003),“Analysis of building collapse under blast load,” COINCET, Structure institute,National University of Tucuman, Av Roca 1800, 4000 SM Tucuma, Argentina.

[10] Bilow, D N and Kamara, M, 2004, “U.S. General Services Administration Progressive Collapse DesignGuidelines Applied to Concrete Moment-Resisting Frame Buildings”, ASCE Structures Congress, Nashville,Tennessee.

[11] Ellingwood, B . R., 2006, “Mitigating Risk from Abnormal Loads and Progressive Collapse”, Journal ofPerformance of Constructed Facilities (ASCE), vol.20, no.4., pp315-323

[12] Giriunas (2009), “Progressive Collapse Analysis of an Existing Building,” Ohio state University.