

Mitigation of Progressive Collapse Through Optimal Internal Forces Distribution

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Abstract

Progressive collapse of a structural system can lead to catastrophic disasters. Most of the literature on this research topic aims to best describe and predict a progressive collapse event; few studies, however, aim to develop techniques to mitigate progressive collapse and, thus, minimize structural system vulnerability. This paper aims to present and validate a Finite Element (FE) model developed to study optimal positioning of stiffening members; previous study of Andrade et al. [1] has shown that stiffening elements can mitigate progressive collapse in moment resisting frames through optimal internal forces distribution. The FE analyses were carried out in Abaqus [2]. Preliminary results of models are presented on which stiffening element were positioned at the middle, first third and second third of the span. The FE models well capture a progressive collapse event and further research shall be carried out on this topic.

Key words:

Progressive collapse, stiffening element, moment resisting frame.

Introduction

Progressive collapse is an event triggered by a local failure that leads to partial or total collapse of the structure [3]. The triggering event is usually described as an extreme event such as: explosions, objects collisions, and severe fires.

Three approaches can be identified to prevent progressive collapse: event control, indirect methods and direct methods [3]. Event control focuses on avoiding the extreme events. Indirect methods are based on defining minimum requirements in the design of a structural system; these requirements are based on past accidents assessments. The direct method consist of a thorough non-linear FE analysis that satisfactorily describes the event. This paper aims to present a model based on the last method.

Results and Discussion

A Python script for Abaqus [2] was developed to easily carry out a parametric and optimization study in future research projects. The Python script is set up to perform the progressive collapse analysis of a moment resisting planar frame; dimensions, mechanical properties, and cross section geometry are based on the 20-story Los Angeles building presented in the FEMA 355-C [5].

The FE model consists of a geometrically and materially nonlinear analysis with imperfections included (GMNIA); Timoshenko beam elements (B32OS and B32) were used to simulate each member. After a column is removed, the initial dynamic response was not included, but a dynamic factor increases the uniform loading applied to the beams above the removed column.

According to Pantidis and Gerasimidis [3], in a planar frame, two mechanisms can lead the structure to collapse: the yield-type and loss-of-stability mode. The yield-type mode is characterized by the formation of plastic hinges in both ends of the beams above the column removal. The loss-of-stability mode is characterized when a column reaches its critical load, and, thus, buckles [3].

Several progressive collapse analysis of the L.A. Building were carried out and the results are depicted in Figure 1. In each analysis one exterior column was removed from each floor separately. The presence of stiffening elements introduced at one third, two third or half of the

span between the exterior column and the adjacent interior column was also analysed; preliminary results depicted in Figure 1 are not consistent to what was expected – an increase in the collapse loading – thus, further research shall be carried out.

In the parametric analyses performed for non-stiffened frames, one can divide the results in five groups: (i) group 1, independently of the removed column, the first column to buckle is located at the 5th floor, (ii) group 2, the interior column adjacent to the removed column is the first one to buckle, (iii) group 3, in addition to depicted in (ii), plastic hinges is formed in some beams above the removed column, (iv) group 4, the column to buckle is located at 14th floor, and (v) group 5, is characterized by the yield-type mode.

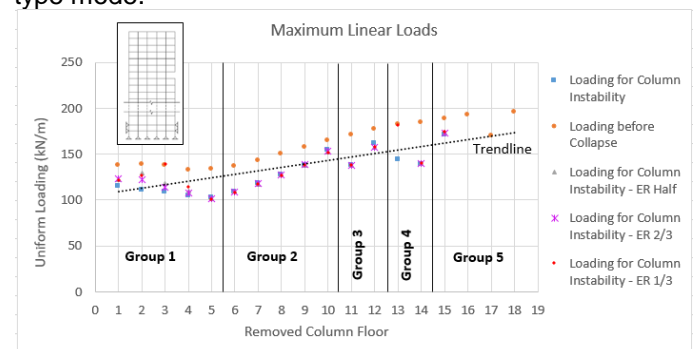


Figure 1. Collapse uniform loading and removed column floor.

Conclusions

The Python script developed to create a FE model in Abaqus [3] of a moment resisting planar frame leads to results consistent to the models presented in the literature [3]. Further studies shall be carried out on stiffening elements.

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¹ Andrade, S.S.; Vieira, L.C.M. XXIII Congresso de Iniciação Científica, 2015.

² Abaqus Documentation, *Dassault Systèmes*, 2016.

³ Pantidis, P.; Gerasimidis, S. *Annual Stability Conference* 2016.

⁴ Szyniszewski, S.T. *University of Florida* 2009.

⁵ FEMA-355C *Federal Emergency Management Agency* 2000.