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Sensitivity analysis of steel buildings subjected to column loss

Jinkoo Kim [a], Jun-Hee Park [b], Tae-Hyung Lee [c,*]

[a] Department of Architectural Engineering, Sungkyunkwan University, Suwon, Republic of Korea
[b] Korea Atomic Energy Research Institute, Daejeon, Republic of Korea
[c] Department of Civil Engineering, Konkuk University, 1 Hwayang-dong, Gwangjin-gu, 143-701 Seoul, Republic of Korea

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ABSTRACT

In this study, the sensitivity of design parameters of steel buildings subjected to progressive collapse is studied. To this end, design parameters such as yield strengths of beams, columns, and braces, live load, elastic modulus, and damping ratio were considered as random variables. The Monte Carlo simulation, the Tornado Diagram analysis, and the First-Order Second Moment method were applied to deal with the uncertainties involved in the design parameters. The analysis results showed that among the design variables beam yield strength was ultimately the most important design parameter in the moment-resisting frame buildings while the column yield strength was the most important design parameter in the dual system building. Sensitivity of the vertical displacement to uncertain member strength showed that progressive collapse mechanisms of the moment-resisting frame buildings and the dual system building completely differed due to different patterns of the vertical load redistribution.

1. Introduction

When a structure is subjected to unexpected loads such as explosion, impact, fire, etc. that are not considered in the normal design process, the structure may become vulnerable. The phenomenon whereby the failure of one or more load-resisting structural members due to an unexpected load leads to the collapse of the entire structure, especially in a domino-like way, is commonly called progressive collapse [1].

The collapse of the Alfred P. Murrah Building in 1995 and the World Trade Center (WTC) Tower in 2001 are examples of progressive collapse due to a car-bombing and an aircraft impact, respectively. Before the collapse of the WTC, research on progressive collapse had only been conducted by a limited number of researchers because the probability that such an abnormal loading event would occur and that it would trigger progressive collapse was very low. However, the collapse of the WTC, where more than 2000 civilians lost their lives, reminded structural engineers that the mechanism of progressive collapse needs to be thoroughly understood to prevent such a disaster recurring in the future.

To prevent the progressive collapse caused by abnormal loads, the National Building Code of Canada [2] specified requirements for the design of major elements, the establishment of connection elements, and ways of providing load transfer paths. Eurocode 1 [3] presented a design standard for selecting plan types for preventing progressive collapse and recommended that buildings should be integrated. In the United States, specific provisions related to progressive collapse have not yet been provided in design codes such as the International Building Code [4]. However, the American Concrete Institute [5] requires structural integrity (for example, continuity insurance of reinforcing bars) so that partial damage by abnormal loads does not result in the collapse of the entire structure. The ASCE 7-05 [6] also recommends a design method, a load combination, and structural integrity, as does ACI 318. The General Service Administration (GSA) presented a practical guideline for design to reduce the collapse potential of federal buildings [7]. The Department of Defense (DoD) also presented a guideline for new and existing DoD buildings [8]. These guidelines address design procedures and analysis methodology for progressive collapse.

Research on progressive collapse can be categorized according to two different approaches: (1) developing structural systems that prevent progressive collapse, and (2) developing an analysis methodology. Crawford [9] proposed the use of connection details such as Side Plate™, developed for earthquakes, the use of cables imbedded in reinforced concrete beams to activate catenary action, and the use of mega-trusses in high-rise buildings to resist progressive collapse. Suzuki et al. [10] showed that

* Corresponding author. Tel.: +82 2 450 4093; fax: +82 2 2201 0783.
E-mail address: thlee@konkuk.ac.kr (T.-H. Lee).

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