Pancake-type collapse—preventing downward progression

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Summary

This paper investigates to what extent a downward progression of a collapse triggered by the loss of all columns in one or several neighboring intermediate stories in a high-rise building is preventable. Various examples of historical pancake-type collapses showing different degrees of destruction are discussed, with the focus on partial collapses which remained confined to the topmost stories only. An explanation for this particular phenomenon is proposed, which shows how such a collapse is most probably triggered and why, in many cases, a downward progression cannot occur. Based on this, a design strategy for high-rise buildings using a tube system is proposed, which limits the extent of vertical collapse, should it be triggered, to the floors above the zone of initial failure only.

Keywords: high-rise buildings, pancake-type collapse, column failure, vertical collapse progression, mitigation strategy

1. Introduction

Pancake-type collapses are most often observed after strong earthquakes, although the triggering event may also be something else. The extent of collapse can vary from the loss of a single story to total collapse. The Kobe earthquake (Japan, 1995) led in some buildings to the failure of the columns of an entire intermediate story causing the upper structure to fall onto the lower one, but no collapse progression in upward or downward direction occurred. An explanation of how the released potential energy was dissipated was proposed in [1]. This type of failure was not new to structural engineers at the time. The Mexico City earthquake (1985) had already brought to light the possibility of intermediate story collapse (Fig. 1a). Pancake-type collapse of all stories above some intermediate level (Fig. 1b) was also frequently observed during this earthquake. A collapse with a similar outcome occurred in the Windsor Tower in Madrid, Spain, in 2005, this time triggered by fire.

It is a common reaction after a building collapse, in trying to prevent it from occurring in similar buildings, to focus only on the weaknesses that caused it, and thereby possibly to overlook hidden potentials of the structure which may also lie revealed in the collapse scene. This seems to be the case with the collapses in Mexico City and Madrid mentioned above. Little attention has been paid to the important aspect that these collapses were only partial, although, by a closer examination, important lessons for the design against progressive pancake-type collapse can be learned. To the knowledge of the authors, no significant attempts have yet been made to explain why the collapses remained arrested.

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