DETAILED COLLAPSE BEHAVIOR OF STEEL HIGH-RISE BUILDING WITH DUAL LATERAL LOAD RESISTING SYSTEM

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Earthquake is one of the most fatal natural disasters which causes a massive amount of lives and money losses every year as a result of building collapses. After observing numerous collapse of structures during past earthquakes, study on earthquake-induced collapse of structures became one of the noteworthy subjects in the field of civil/earthquake engineering. On the other hand, tall buildings are the growing structures in the seismic urban areas and well understanding the collapse behavior of these structures, specially, under extreme earthquakes is an important issue. The aim of this paper is to study the step by step earthquake-induced collapse process of a 16-Story high-rise building with dual lateral load resisting system under two extreme earthquake loadings, utilizing the integrated finite element simuation.

For this purpose, at first, a reliable model of the structure is made in ABAQUS, an advantageous finite element program, by using the beam element of B32 as frame elements and layered-shell elements of S4 as floor slabs. During the simulations, calibrated damage parameters, deletion of failed elements as well as impact forces of the structural debris are taken into consideration (Hooputra et al., 2004; Dassault Systèmes Simulia Corp, 2017). Then the collapse simulation of the building is conducted under two increasingly scaled earthquake records of Manjil-Abbar (1990 in Iran, PGA=0.515) and Kocaeli-Iznik (1999 in Turkey, PGA=0.124). The earthquake records are scaled in such a way that the building collapse could be observed during or at the end of the simulation time.

The considered structure for this investigation is a steel high-rise building with dual lateral load resisting system including special concentrically braced frame and special moment frame which is designed according to ASCE 7-16 (ASCE, 2016), AISC 360-16 (AISC, 2016b) and AISC 341-05 (AISC, 2005a). The performance of the building is also checked according to a performance-based seismic design methodology for tall buildings in the city of Los Angeles (LATBSDC, 2017). The building consists of three 5 m bays in each direction and 16 stories with 3.1 m height. Table 1 shows dynamic characteristics of the building including predominant modes of vibration.

Table 1. Dynamic modal characteristics of the building.

Mode no.	Period (s)	Mode type	Mass proportional ratio
1,2	1.85	Translational (X, Y)	0.654
3	0.94	Torsional	-
4,5	0.57	Translational (X, Y)	0.197
6	0.30	Torsional	-
7,8	0.29	Translational (X, Y)	0.049

Figure 1 shows the process of the building collapse under Manjil earthquake at four specific steps of analysis. At t=6 sec, the moderate inelastic behavior of the structure is started by inelastic in-plane buckling of some braces in the 2nd to 6th stories followed by the fracture of the first brace in the 4th story. By continuing the simulation, more buckling and fracture of the braces especially in the lower stories of the building happens which intensifies the role of the moment resisting frame as the second lateral load resisting system. Then, at about t=40 sec, the occurrence of massive fracture of braces in the first-five stories along with the severe inelastic behavior of the moment frame results in the sidesway collapse mechanism of the whole building that finally lead to the total collapse of the building at t=45 sec.

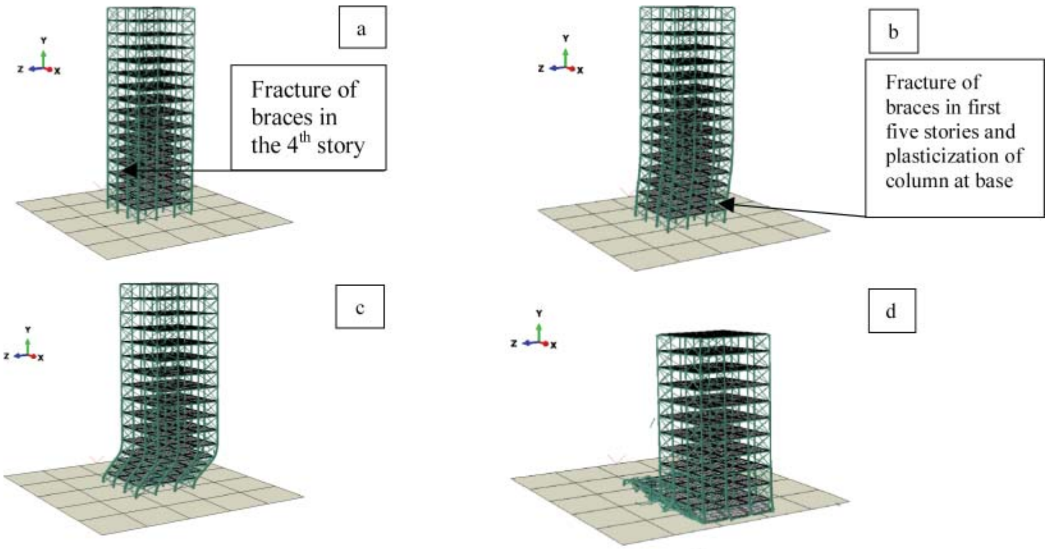

Figure 1. Collapse process of steel high-rise building under Manjil earthquake: a) at t = 6 sec first fracture in braces of 4th story is observed b) t = 40 sec is the time that the fracture of the most of the braces in first five stories is observed c) t = 43 sec is the stage that the structure becomes unstable d) t = 45sec is the time that story number 5 collides to the ground.

A similar procedure is conducted to simulate building collapse under Kocaeli-Iznik earthquake record and the results are compared. It is observed that the seismic characteristics of the ground motion can significantly affect the collapse mechanism of the structure. For example, the collapse of the structure under Manjil-Abbar record is mainly dominated by the first mode of vibration at PGA=3.42 g; while for Kocaeli-Iznik records, it is dominated by higher modes of vibration at PGA=1.38 g.

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