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THE SEISMIC EVALUATION OF UNDER MAINSHOCK- FIRE DAMAGED BUILDINGS UNDER-AFTERSHOCK EARTHQUAKES

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In the current design codes, the concomitant or subsequent occurrence of earthquakes and fires has not been addressed so far. Nevertheless, fire is the greatest danger to the safety of people immediately after the earthquake. Fires are often triggered as a consequence of damage caused by the earthquake and are possible to cause major additional damage to buildings and other constructions. Bursting of gas pipelines, damage to electrical cables and water supply systems failure are the commonest causes of post-earthquake fire in the modern world. Besides that, the process of confronting the fire could be disrupted by the occurrence of earthquake because earthquake could limit accessibility to fire extinguishing systems including fire extinguisher, sprinkler, to name but a handful or disturb the urban transport system and prevent the timely arrival of the firefighters, so fires following earthquakes are often more devastating than earthquakes themselves. For example, one of the most famous earthquakes that led to widespread fires was the 2011 Japan earthquake, which caused powerful tsunami waves and severe structural damage in northeastern Japan including heavy damage to roads and railways as well as fires in many areas and a dam collapse (Tanaka, 2012).

The likelihood of occurrence of aftershocks following the main earthquake may decrease the remained capacity of structures damaged from mainshock and fire following that. The response of the structure to aftershock following the post-earthquake fire has not been considered thus far. In this research, a 10-story moment-resisting steel frame consists of four bays with a span of 7.5 m and each floor 3.5 m height is chosen as case study shown in Figure 1. In the current research, the response of frame to earthquake, fire, and aftershock is investigated and compared with the response of the intact frame, by means of numerical analysis using OpenSees software. In this regard, a three-stage approach is used.

In the first step, the structure is damaged by the mainshock. For this purpose, three acceleration time histories matched with design spectra are applied to the base of the structure and nonlinear dynamic analysis is carried out. The list of the acceleration time histories is shown in Table 1.

Table 1. Mainshock acceleration time histories.

NO.	Name	Year	Recording Station Name	Magnitude (Mw)
1	Northridge-01	1994	Beverly Hills	6.69
2	Darfield	2010	CSHS	7
3	Sarpol-e Zahab	2017	Sarpol-e Zahab	7.3

The next step is applying the fire. The resistance of the frame to fire is investigated in situation which steel sections are assumed not to be insulated. The fire scenario consists of the whole first floor whose temperature soars to over 900°C then returns to the ambient temperature. Heat is transmitted through the convection, radiation, and conduction to all beams and columns of the first floor. Before the fire, the mechanical properties of the members are proportional to the temperature of 20°C, but during the fire, the mechanical properties of the members change. Increasing the temperature causes reducing stiffness and strength of the steel (Jelinek et al., 2017). The last step is a nonlinear dynamic analysis, where the structure is subjected to the following aftershock. For this purpose, properties of the aftershocks are extracted. Although major structural damage occurs in the fire, the aftershocks could intensify devastation of the structure until its fully collapse.

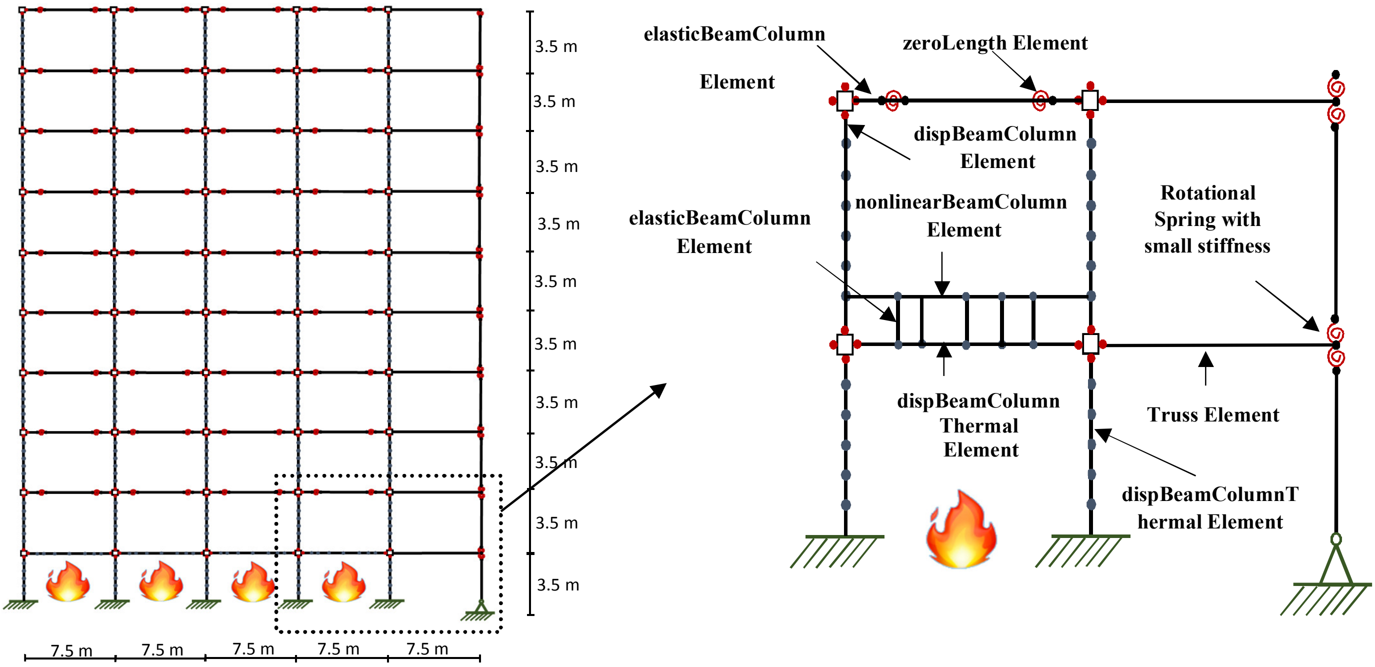

Figure 1. (Left): Case study building geometry, (Right): Analytical model in OpenSees.

A pushover analysis was performed after each step to evaluate the seismic behavior of the structure and obtain the structural capacity curve. Figure 2 shows the pushover analysis results after each step. As shown in this figure, ductility of the structure have declined, and it will endure smaller lateral displacements as a result of fire. Also, lateral stiffness and strength is reduced after implementation of the fire.

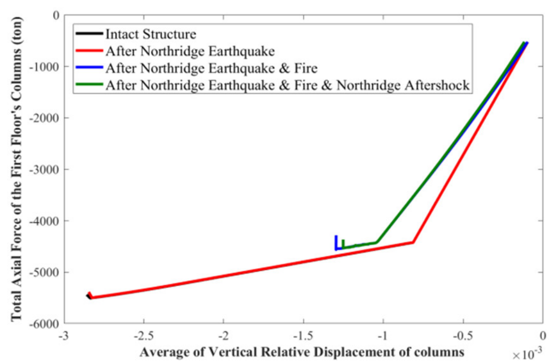

Figure 2. Total axial force versus average of downward relative displacement in the first floor's columns in the pushdown analysis after each step.

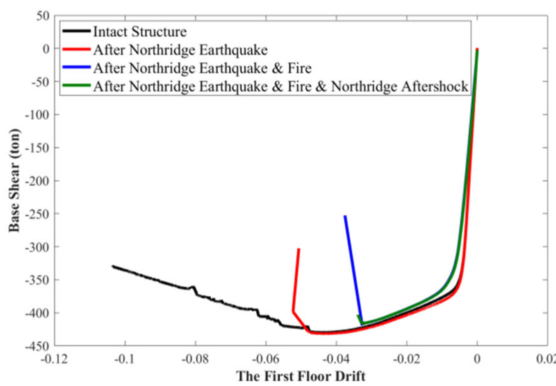

Figure 3. Base shear versus the first story drift in the pushover analysis after each step.

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