Chapter 15
Simulating Post–Earthquake Fire Loading in Conventional RC Structures

Behrouz Behnam
Amirkabir University of Technology (Tehran Polytechnic), Iran

ABSTRACT

Post-earthquake fire (PEF) is one of the most complicated problems resulting from earthquake, presenting a serious risk to urban buildings. As most standards and codes ignore the possibility of PEF, buildings are too weak under PEF loads. This chapter is to investigate the effects of PEF loads on partially damaged RC buildings located in urban regions. To do that, a methodology named sequential analysis is introduced here via which the structural performance at various performance levels is evaluated under fire and PEF scenarios. Numerically, in order to simulate the earthquake loads, conventional pushover analysis is employed, with an explanation presented in the chapter to introduce the pushover analysis, its advantages and its limitations. To simulate the fire loads, standard fire curve (ISO 834) is used for simplicity.

INTRODUCTION

Strong earthquakes may bring about significant damage to all kinds of infrastructure, including buildings in urban areas. In addition to the damage caused by the earthquake itself, post-earthquake events resulting from the shock, such as fire, can potentially create even more significant damage than the earthquake itself. Past events have proven that lack of adequate attention paid to post-earthquake fire (PEF) can result in significantly increased fatalities and casualties. The 1906 San Francisco PEF is considered one of the largest urban disasters in human history. The fire swept over nearly a quarter of the city, including the entire downtown area. Over 3,000 people died as a result of the disaster. It is estimated that the economic value of the damage was more than US$524 million (in 1906 dollars) (Fitzpatrick, 1914). The fire accounted for 80% of the total damage. The 1923 Kanto PEF in Japan is also said to be one of the largest urban disasters, resulting from a strong earthquake. More than 140,000 people lost their lives.
and around 447,000 houses were destroyed. It is estimated that 77% of the total damage was due to the fire. The fire following the 1989 California earthquake (known as the Loma Prieta Earthquake) caused more than US$6 billion damage to the Bay area of California. The fire displaced more than 12000 people and caused 3700 casualties. The strong 1995 Kobe (Japan) earthquake resulted in significant damage to the city. It is recorded that more than 100 fires broke out within a few minutes of the earthquake, in both residential and commercial buildings. Two hours after the earthquake, several conflagrations had developed. It is estimated that over 6,500 buildings burnt, in an area of nearly 700,000 square meters. The most recent serious earthquake (with a magnitude of 8.9 on the Richter scale) happened in the north of Japan in 2011. This earthquake caused a tsunami, which created one of the worst disasters in the history of Japan. Thousands of people were killed or injured, and more than 150,000 people became homeless, many being forced to evacuate their homes and leave their possessions. The city of Kesennuma in the northern part of Japan was completely engulfed in flames following this earthquake, the biggest on record in the country.

The devastating effect of PEF on buildings arises mainly because the majority of structural elements are not designed for extreme loading events combined with gravity loads, lateral loads and fire loads. Consequently, even those structures only moderately damaged by an earthquake can be rapidly destroyed in a subsequent fire. PEF is a high-risk load, which needs to be scrutinized further and allowed for in the codes of design. This scrutiny and modification to codes should include providing sufficient time under PEF, during which the building remains gravity load bearing, until the building’s inhabitants can safely evacuate. The time would naturally not only depend on the building’s structural properties, the severity of earthquake, and the extent of fire load, but also on the availability and response time of fire brigades. The first priority is thus to simulate the PEF loading in a building a structure. This priority is further highlighted with this reality that there are currently limited user-friendly computer packages capable of performing a coupled analysis, i.e. considering seismic analysis and its subsequent fire, allowing for the variation of material properties at elevated temperature. Sequential analysis would be an alternative to this limitation. Sequential analysis is a functional tool that considers the loads and corresponding changes in geometry in a number of steps. It allows the effects of residual deformations, as well as degradation in stiffness and strength from the earthquake, to be used in the fire analysis. Utilizing a commonly used structural analysis software package, and following the simple application of gravity loads, for which the structure mostly remains in the elastic region, the seismic analysis is performed and the equivalent seismic loads are derived. These loads are transferred into the second software package, which is capable of performing the structural fire analysis. There is often a degree of programming involved in connecting the two software packages together so that the process becomes automatic.

**SEISMIC ANALYSIS**

Structural seismic analysis can be performed through static or dynamic methods, which can be linear or non-linear. Although most static and linear methods are simple to use, they cannot entirely demonstrate the inelastic deformation or damage in structures, which is an important deficiency of these methods. On the other hand, earthquake forces have a dynamic nature and therefore, only a dynamic analysis (as the most rigorous approach) can meet a realistic assessment. Nevertheless, dynamic analyses are not routinely employed in everyday designs, mostly because of the complex nature of the analysis, in particular with