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Full-scale fire test on an earthquake-damaged reinforced concrete frame

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ABSTRACT

Fire, in the aftermath of an earthquake has evolved as a severely destructive force since the last century [1]. Codes and regulations exist in countries situated in seismically active regions of the world in order to ensure safety of buildings and their occupants in the event of an earthquake; it is however rare to find regulations that also require the consideration of fire following an earthquake, thereby leaving this possibility to be dealt with entirely by emergency responders on an ad-hoc basis with little preparedness. Fire following earthquake (FFE) events in the past, although rare, have sometimes been as destructive as the original earthquake. The aim of this study was to carry out a set of full-scale loading tests on an earthquake damaged, reinforced concrete frame subsequently exposed to fire. The sequential loading was devised in the form of a three phase testing procedure – simulated earthquake loading facilitated by cyclic quasi-static lateral loads; followed by a compartment fire; and finally by subjecting the earthquake and fire damaged frame to a monotonic pushover loading to assess its residual capacity. The reinforced concrete frame was well instrumented with numerous sensors, consisting of thermocouples, strain gauges, linear variable differential transducers (LVDTs) and pressure sensors. A large database of results consisting of temperature profiles, displacements and strains has been generated and salient observations have been made during each stage of loading. This paper describes the experimental investigation and serves as a vehicle for dissemination of the key findings and all the important test data to the engineering community which could be used for validating numerical simulations for further advancing the knowledge and understanding in this relatively poorly researched area.

1. Introduction

The risk of fires in the aftermath of earthquakes is well known. Two largest peacetime fire disasters, regarded as the worst ever fire disasters for mankind in the twentieth century: San Francisco (1906) and Tokyo (1923) were essentially triggered by earthquakes. Major conflagrations and widespread devastation were reported in both the events resulting in far greater damage attributed to the fires than that caused by the earthquakes on their own. In the 1906 San Francisco earthquake and fire, about 28,000 buildings were destroyed whereas in 1923 earthquake and fire, about 447,000 houses were destroyed by the blazing fire. The majority of buildings those days were constructed using timber. The modern cities of San Francisco and Tokyo are completely surrounded with reinforced concrete (RC) tall buildings and structures. Fortunately, the scales of these events have not been repeated; though there have been many major earthquakes, which have led to fires in their wake. Nearly all major Californian earthquakes were followed by multiple ignitions, most notably the 1989 Loma Prieta and the 1994 Northridge earthquakes, both of which were followed by over 100 ignitions each. After the 1995 Hanshin, Kobe (Japan) earthquake, over 100 ignitions were recorded in Kobe City. The 1999 earthquake of Marmara (Turkey) was followed by many local fires in buildings and industrial premises which were classified as uncontrollable. Collapse of reinforced concrete structures were predominantly reported in the

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two latter fire following earthquake (FFE) events. In the 1995 Hanshin FFE event, a 90 m high RC heater stack collapsed whereas in the 1999 Marmara FFE event, many mid-rise non-ductile RC frames were reported to be damaged in the earthquake and further affected by fire [2]. It is also important to note that many recent earthquakes, viz., Haiti (2010), Fukushima (2011) and Chile (2014) were followed by many conflagrations that damaged lifelines and critical facilities such as hospitals, oil refineries, and city

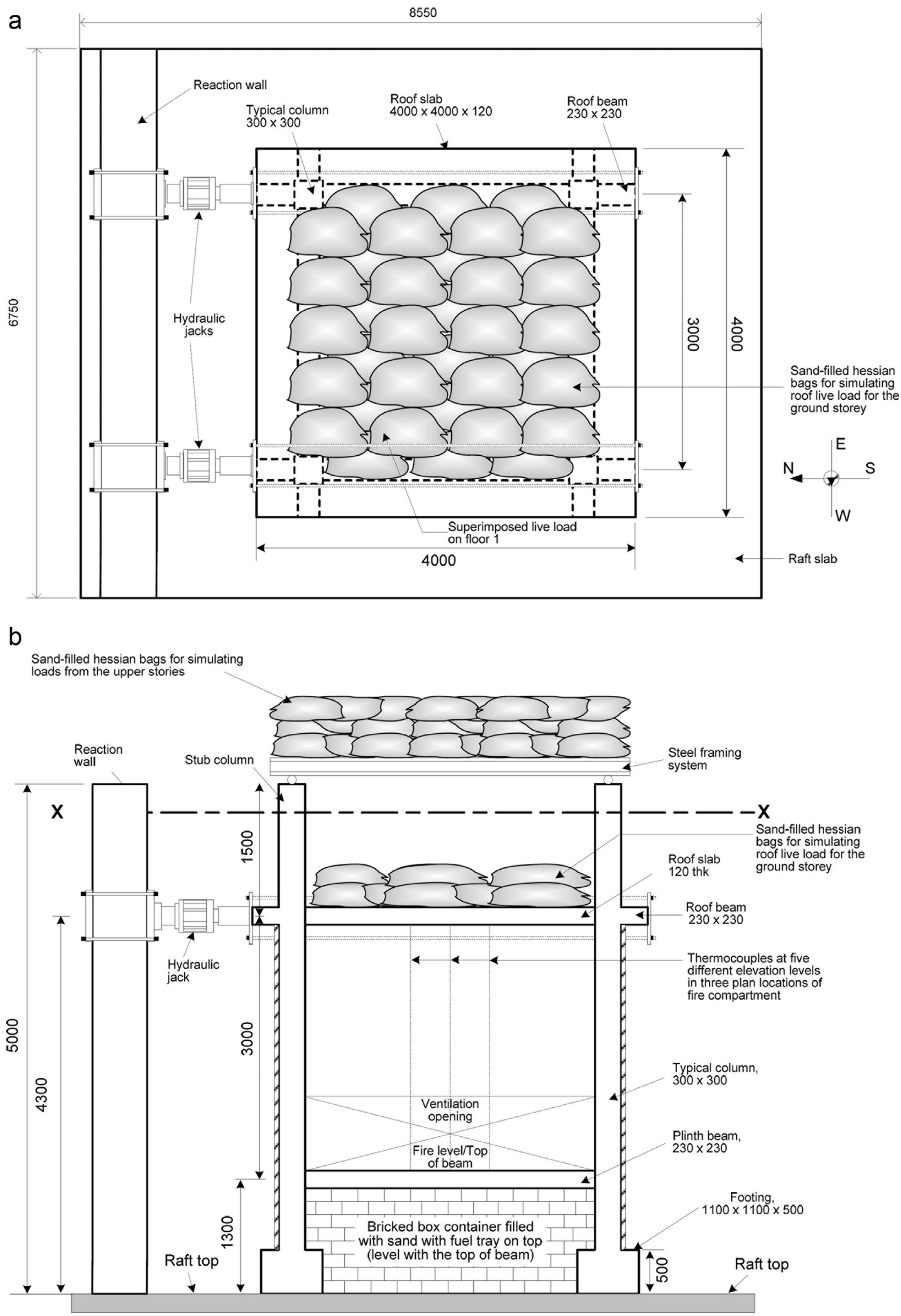

Fig. 1. Schematic of the test setup (a) plan and (b) elevation.