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Case Study

Turkey's grand challenge: Disaster-proof building inventory within 20 years☆

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ABSTRACT

Turkey is located in a high seismicity region and has suffered extensive losses due to several major earthquakes that struck its various parts in the past two decades. While earthquakes are associated with damage and loss wherever they may occur, the destructive effects of those in Turkey are exacerbated by the large volume of code incompliant buildings constructed with poor materials and workmanship. As a large scale remedial initiative, Turkey has recently embarked upon a grand challenge of retrofitting or renewing all high-risk buildings within the next 20 years. This multi-million building and multi-billion dollar initiative has inevitably raised activity and debates in diverse disciplines regarding all aspects. This paper focuses on the methodologies and developing technologies for rapid condition assessment and structural evaluation of existing buildings in order to identify and prioritize high-risk buildings and for guiding decisions on retrofitting or renewal.

1. Background and introduction

Protection of people and the built environment from the destructive effects of natural hazards is a worldwide challenge that faces nations at various degrees of significance based on (1) the type of observed hazards; (2) the size of exposure, i.e. the number of people and structures affected by the hazards; (3) vulnerability of the exposure to the impinging hazards. The prediction and mitigation of damage and losses inflicted by natural hazards are among the most active and invested areas of research participated by all nations in proportion with their exposure and resources (Kidokoro et al., 2008).

A quick survey of the most damaging and deadly natural disasters recorded in history reveals that earthquakes occupy a prominent proportion, especially when followed by resulting hazards such as a large fire or a tsunami (Coburn and Spence, 2002). Indeed, earthquakes constitute a primary concern in any country located in a seismic zone. Despite the unceasing attempts to predict earthquakes in more than a hundred years, it is clear that seismic events cannot be predicted accurately enough to issue alarms of imminent damaging earthquakes (Geller, 1997). Nevertheless, significant progress made in fault modeling and probabilistic assessment of seismic hazard combined with performance based structural design and evaluation methods provide the necessary tools for engineers to be prepared for earthquakes (Kramer, 1996; Bozorgnia and Bertero, 2004) although cases of prominent skepticism regarding the validity of probabilistic hazard assessment should be noted (Gulkan, 2013). The meaning of preparedness may naturally differ for different nations based on the size of their economy, their level of investment in infrastructures, and their perception of acceptable risk for the population and

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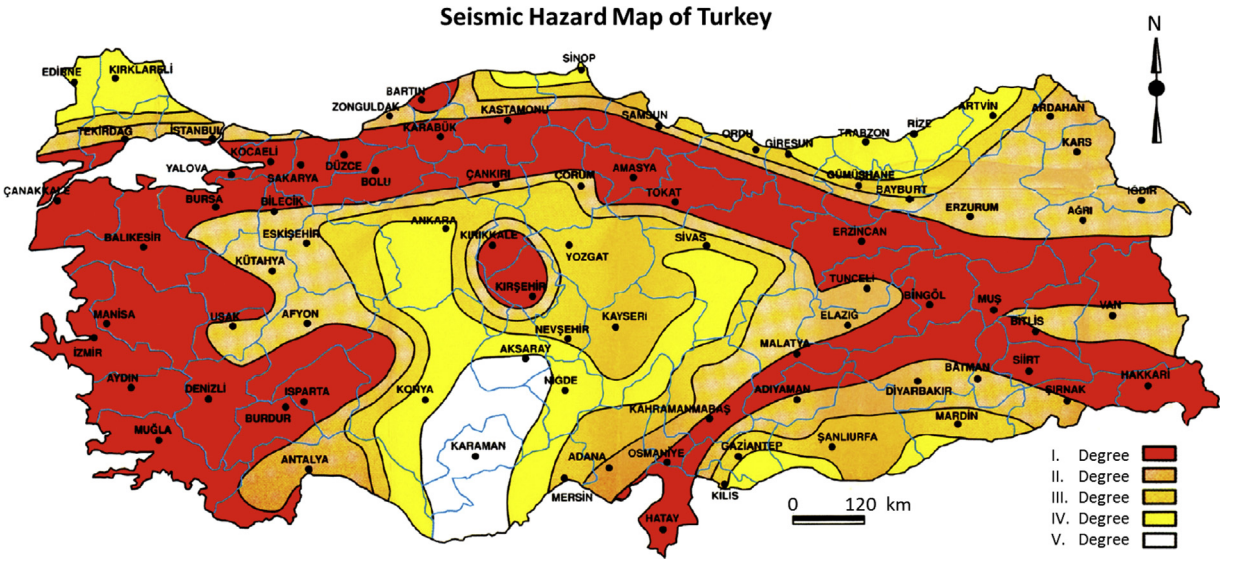

Fig. 1. The seismic hazard map of Turkey.
Source: Republic of Turkey, Prime Ministry Disaster and Emergency Management Presidency, AFAD.

infrastructure (Coburn and Spence, 2002). Although the level of confidence and conservatism used in the aforementioned tools for preparedness may differ in different codes, a generally accepted level of satisfactory performance is (a) for ordinary residential and commercial buildings to survive a design earthquake without collapse; (b) for essential buildings such as schools and hospitals to stay functional after a design earthquake and survive a rare earthquake; and (c) for critical facilities and lifelines to stay fully operational after a design earthquake and stay functional after a rare earthquake.

Turkey is a country known for its unique geography that bridges continents and cultures. It also bridges several tectonic plates including the Eurasian, African, and Arabian plates through the Anatolian plate (Bommer et al., 2002). Interactions between all surrounding plates and the Anatolian plate produce an active seismic region that encompasses most of Turkey as shown in Fig. 1. As a result, earthquakes have been by far the most significant natural hazards in the region. Based on available records, all natural disasters in Turkey since the beginning of the 20th century resulted in 87,000 casualties, 210,000 injuries, and 651,000 heavily damaged or destroyed homes. Earthquakes were responsible for 76% of the damaged or destroyed homes, followed far behind by landslides (10%) and floods (9%) (Ergunay, 2007). Several moderate to devastating earthquakes that occurred in Turkey in the past two decades have claimed nearly 20,000 lives and cost more than $17 billion in direct and indirect losses. The most significant one among these was Kocaeli Earthquake (August 17, 1999, Mw = 7.4) which caused more than 17,000 casualties and cost around $13 billion; and the most recent one was Van Earthquake (October 23, 2011, Mw = 7.2) which caused more than 600 casualties and cost $1–2 billion (Buyukozturk and Gunes, 2002, 2003; Ergunay, 2007; Erdik et al., 2012).

Table 1 shows the distribution of various elements such as land area, population, industrial installations and hydroelectric dams within the seismic zones shown in Fig. 1 (Ergunay, 2007). About half of each element is located in the first degree seismic zone and most of each is located in some degree of seismic zone other than V. Hence, earthquakes affect nearly the entire nation and unless effective mitigation strategies are developed and implemented in a timely fashion, seismic losses will continue to increase in the future.

The concerns highlighted in Fig. 1 and Table 1 are exacerbated by the fact that a very large portion of Turkey's building stock does not comply with either the structural/seismic codes that were effective at the time of their construction, or the ever more stringent modern seismic code enforced today. As a matter of fact, it is often reiterated in the daily press and accepted by the government officials that half to three quarters of existing buildings in Turkey lack the design documents and permits required for their construction. Referred to as illegal construction, these buildings are generally constructed with poor materials and workmanship due to insufficient or no supervision or inspections during construction.

An even more concerning development right after the devastating Kocaeli Earthquake in 1999 was the findings of a scientific study which indicated that the probability of occurrence of another severe and destructive earthquake along the

Table 1
Distribution of various elements within different seismic zones (Ergunay, 2007).

Seismic zone (Fig. 1)		Area (%)	Population (%)	Industry (%)	Dams (%)
I	(pga = 0.4 g)	42	45	51	46
II	(pga = 0.3 g)	24	26	25	23
III	(pga = 0.2 g)	18	14	11	14
IV	(pga = 0.1 g)	12	13	11	11
V	(pga < 0.1 g)	4	2	2	6