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Performance and damages of reinforced concrete buildings during the October 23 and November 9, 2011 Van, Turkey, earthquakes

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ABSTRACT

In this paper, it aimed to investigate the performance and damages of reinforced concrete buildings during October 23 (Erciş) and November 9 (Edremit), 2011 Van earthquakes in Turkey. A total of 28,000 buildings are damaged or collapsed in the city center and surrounding villages after the Erciş earthquake. This number increased to 35,000 after the Edremit earthquake. Large proportion of non-engineering reinforced concrete buildings completely collapsed or were damaged heavily. Most of the reinforced concrete buildings in the affected area are not designed and constructed in accordance with Turkish Earthquake Resistant Design Code. The cracking and failure patterns of the reinforced concrete buildings are examined. Seismic code requirements are discussed and compared with observed details. It is seen that the damages are due to several reasons such as site effect, location, and length of the fault, the poor construction quality, the poor concrete strength quality and unribbed reinforcement steel, poor detailing in beam column joints, strong beam–weak columns, soft stories, weak stories, inadequate transverse reinforcement, existence of short lap splices and incorrect end hook angle, short columns, weak walls, inadequate safe distance between buildings, unconfined gable walls, concrete slab failures, insulation materials, broken staircase slab and cracks at the corners of the windows and doors. Also, it is emerged that 26% of the buildings have no building license, 66% of the buildings' ground floor is used as a shop, 36% of the buildings have no static project, building (static) projects of 57% of the structures are insufficient, 57% of the buildings are not constructed in accordance with their static project, 74% of the static projects have no detail drawings and hoops densifications, the majority of the buildings have not got sufficient compressive strength according to the related earthquake code, aggregate dimensions are larger than maximum aggregate diameter for concrete, 60% of the building was constructed using unribbed reinforcement steel, and the majority of the buildings (85%) have not got any soil report. In addition to these reasons, the two earthquakes hit the reinforced concrete buildings within 17 days, causing progressive damage.

1. Introduction

Release of energy waves called seismic waves in the crust of earth leads to the creation of a natural disaster called earthquake [1]. Turkey is one of the most active earthquake zones because it is located in an area where several tectonic plates are converging, and are actively in motion. Turkey consists of the Anatolian Tectonic Plate which is surrounded by the Arabian Plate, the Eurasian Plate, and the African Plate (Fig. 1) [2]. The movement of these plates, which are still active today, results in hundreds of earthquakes each month. So, performance of the constructed structures (especially for buildings) must be determined carefully considering earthquakes in the design phase and must be controlled during life time.

Reinforced concrete is one of the most widely used modern building materials. Concrete is obtained by mixing cement, sand, and aggregates with water. Fresh concrete can be molded into almost any shape, which is an inherent advantage over other materials. However, its limited tension resistance prevented its wide use in building construction. To overcome this weakness, steel bars are embedded in concrete to form a composite material called reinforced concrete [3].

The worldwide use of reinforced concrete construction stems from the wide availability of reinforcing steel as well as the concrete ingredients. Concrete construction requires a certain level of technology, expertise, and workmanship, particularly in the field during construction. The extensive use of reinforced concrete

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construction is due to its relatively low cost compared to other materials such as steel. The cost of construction changes with the region and strongly depends on the local practice [3].

Reinforced concrete buildings consist of horizontal elements called beams and vertical elements called columns connected by rigid joints. These structures are cast monolithically in order to act in unison. Reinforced concrete buildings provide resistance to both gravity and lateral loads through bending in beams and columns [3].

Considerable research efforts have been devoted to investigating the performance of engineering structures such as reinforced concrete buildings, minarets, masonry and wooden buildings, steel and harbor structures during earthquakes. Watanabe et al. [4] introduced a study related to damages to steel structures during the 1995 Hyogoken-Nanbu earthquake. Performance of reinforced concrete buildings during earthquakes is illustrated by many authors [5–8]. Seismic code requirements are discussed and compared with observed details. Bayraktar et al. [9,10] presented the field investigations of masonry buildings during the March 25 and 28, 2004 Aşkale and July 2, 2004 Doğubayazıt earthquakes in Ağrı, Turkey. Mondal and Rai [11] carried out the performance of

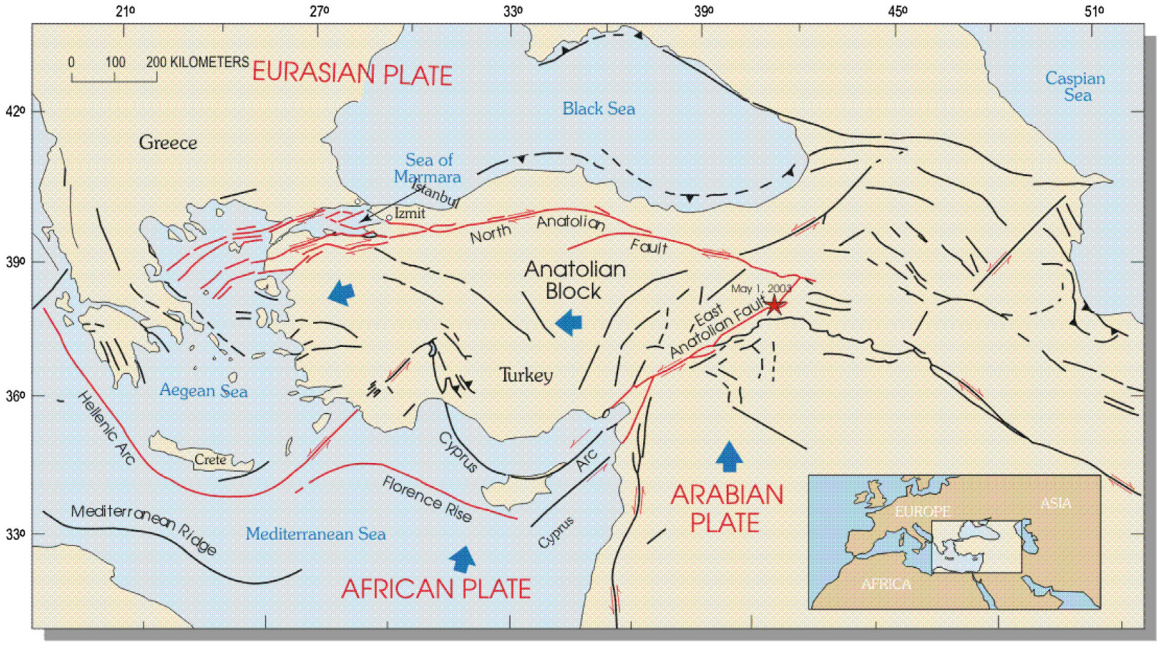

Fig. 1. Tectonic map of Turkey [2].

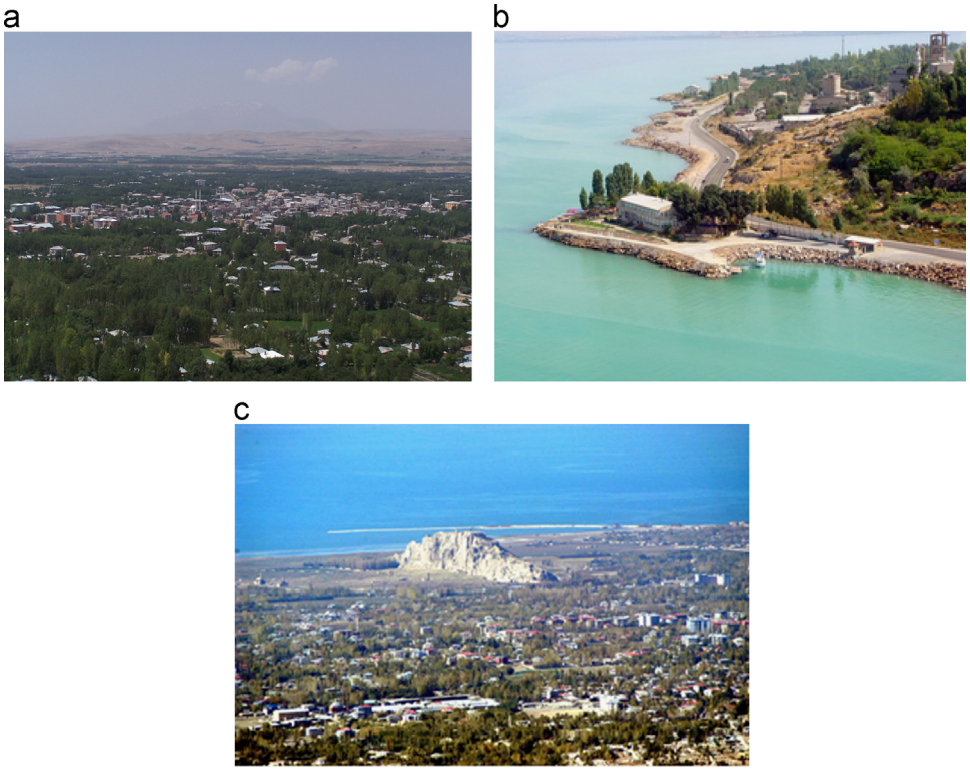

Fig. 2. A view of (a) Erciş Township [URL-2], (b) Edremit Township [URL-3] and (c) Van city [URL-4].