

Damages on reinforced concrete buildings due to consecutive earthquakes in Van



Sevket Ates^{a,*}, Volkan Kahya^a, Muhammet Yurdakul^b, Suleyman Adanur^a

^a Karadeniz Technical University, Department of Civil Engineering, 61080 Trabzon, Turkey

^b Bayburt University, Department of Civil Engineering, 69000 Bayburt, Turkey

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ABSTRACT

Consecutive earthquakes occurred on October 23rd, 2011 in Ercis and on November 9th, 2011 in Edremit that are townships located 90 km and 18 km far from Van city in Turkey, respectively. A total of 28,000 buildings were damaged or collapsed in the city center and the surrounding villages after the Ercis earthquake. This number reached 35,000 after the Edremit earthquake. In the area where the earthquakes occurred, almost all the reinforced concrete buildings were affected.

This study presents field observations of damages on reinforced concrete buildings due to the consecutive earthquakes that occurred in Van, Turkey. Damages appearing in the buildings may occur due to several reasons such as site effect, poor construction quality, poor concrete strength, poor detailing in beam-column joints, detailing of stronger beam than column, soft stories, weak stories, inadequate reinforcement, short lap splices, incorrect end hook angle, and short columns. Aftershocks also caused progressive damages on the buildings within 17 days after the earthquakes. According to the results of this study, most of the damaged buildings were not designed and constructed according to the Turkish earthquake code, the so-called Specification for Buildings to be built in Seismic Zones.

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1. Introduction

Substantial research efforts have been devoted to investigating the performance of engineering structures during earthquakes such as reinforced concrete buildings, minarets, masonry and wooden buildings. Watanabe et al. [2] introduced a study related to damages to steel structures during the 1995 Hyogoken-Nambu earthquake. Performance of reinforced concrete buildings during the 1999 Kocaeli earthquake was evaluated by Sezen et al. [3]. Dogangun [4] made a detailed observation on the reinforced buildings in the 2003 Bingol earthquake. Many structural deficiencies were observed in the epicentral area. Bayraktar et al. [5,6] presented the field investigations of masonry buildings during the March 25th and 28th, 2004 Askale in Erzurum and July 2nd, 2004 Dogubayazit earthquakes in Agri. Mondal and Rai [7] studied the performance of harbor structures in Andaman Islands during the 2004 Sumatra earthquake. Adanur [8] reported the performances of masonry buildings during the December 20th and 27th, 2007 Bala (Ankara) earthquakes. The March 8th, 2010 earthquakes that hit Kovancilar and Palu districts of Elazig province in Turkey and their impacts on masonry and concrete buildings were studied by

Celep et al. [9]. Saatcioglu and Bruneau [10] observed the performance of structures during the 13 March 1992 Erzincan earthquake in Turkey. Bruneau [11] described the damage of reinforced concrete, masonry, and steel structures during the 17 August 1999 Marmara earthquake in Turkey. Additionally, Arslan and Korkmaz [12] discussed the performance of reinforced concrete buildings during recent earthquakes in Turkey. Besides, theoretical researches have been also made by many researchers on the investigation of repeated earthquakes phenomena [15–23]. Some reports and studies were also published after the Van earthquakes [13,14,24,25].

Consecutive earthquakes occurred on October 23rd, 2011 in Ercis and on November 9th, 2011 in Edremit townships of Van city located in southeastern Turkey. A total of 28,000 buildings were damaged or collapsed in the city center and its vicinity after the Ercis earthquake. This number reached 35,000 after the Edremit earthquake. In the area affected by the earthquakes, almost all the reinforced concrete buildings were damaged/collapsed. It can be seen from the literature that the field investigation of engineering structures shortly after earthquakes to determine their performance is very important, and study about the performance of reinforced concrete buildings during the Van earthquakes in Turkey is not sufficient. In order to understand the behavior of collapsed/damaged reinforced concrete buildings and to observe their performance during the earthquakes, some evaluations based on the field observations are presented in this study.

* Corresponding author. Tel.: +90 462 377 26 61; fax: +90 462 377 26 06.

E-mail addresses: sates@ktu.edu.tr, sevket@hotmail.com (S. Ates), volkan@ktu.edu.tr (V. Kahya), myurdakul@bayburt.edu.tr (M. Yurdakul), sadanur@ktu.edu.tr (S. Adanur).

2. Seismological aspects

Turkey is located on one of the most active earthquake zones consisting of several tectonic plates approaching each other continuously. Turkey is on the Anatolian Tectonic Plate surrounded by the Arabian, the Eurasian and the African Plates (Fig. 1). Movement of these plates is still active today and results in hundreds of earthquakes each month.

The first main earthquake with $M_w=7.1$ occurred on October 23rd, 2011 at 10:41 UTC (Coordinated Universal Time) in Ercis township of Van (Fig. 2). The earthquake took place at shallow depth of 10 km on the shore of the Lake Van. The epicenter is about 30 km north of Van city center and its coordinates are reported as 38.68N–43.47E by the Earthquake Department of the Disaster and Emergency Management Presidency (AFAD) [26]. The depth of the earthquake is given as 19.02 km. Following the main shock, approximately 650 aftershocks occurred in the first 2 days. These aftershocks followed SW–NE direction. It was largely felt in Turkey and in the neighboring countries. The city of Ercis was particularly affected. Rescue teams struggled to help the population and to save victims from the rubbles (Fig. 3). The second main earthquake with $M_w=5.6$ occurred on November 9th, 2011 at 18:23 UTC in Edremit township of Van (Fig. 2). Coordinates of the epicenter of this earthquake are reported as 38.429N–943.234E by the Kandilli Observatory and Earthquake Research Institute [24], and its depth is given as 5 km. This earthquake has a dominantly strike–slip mechanism. Seven minutes later, an aftershock with $M_w=4.5$ occurred in the same area. The earthquake and its aftershocks destroyed 2 hotels and 25 buildings in Edremit.

According to Seismic Zone Map published by the Ministry of Public Works and Settlement of Turkey, the whole country is divided into five earthquake zones as shown in Fig. 4(a). As seen in the map given by Fig. 4(b), Van city is in the first and second zones, which are seismologically active. So far, many earthquakes over the magnitude 5.0 have thus been recorded in the city of Van and its vicinity. The distribution of the historical earthquakes that occurred from 1990 to present in these regions is shown in Table 1 and Fig. 5. According to the latest data (December 9th, 2011), a



Fig. 2. The location of Van, Ercis and Edremit.



Fig. 3. Rescue teams made every endeavor to save victims from the rubbles.

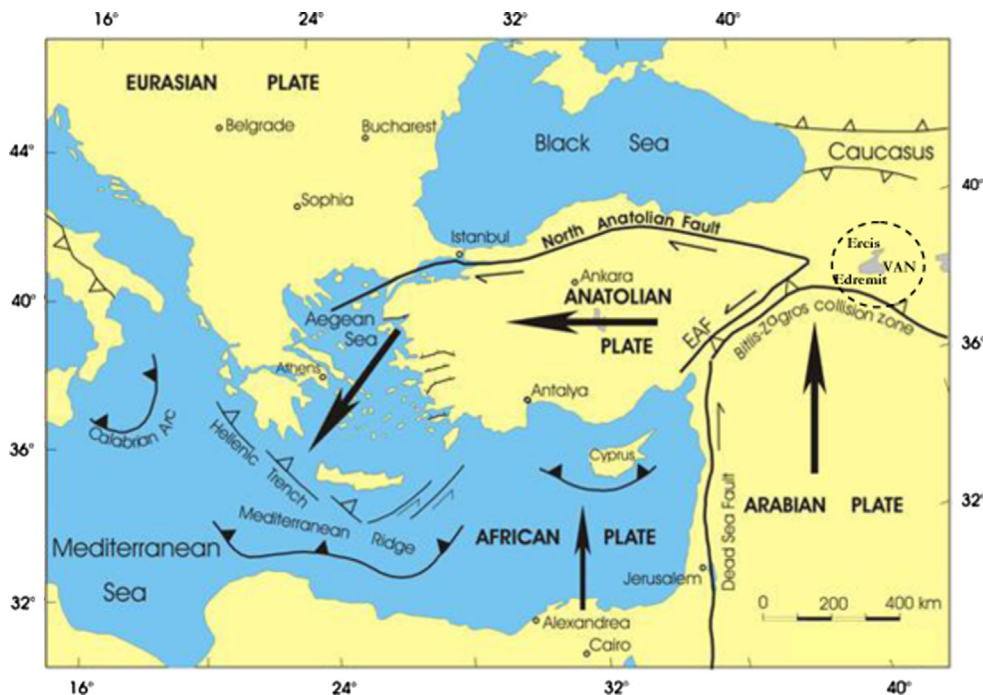


Fig. 1. Tectonic map of Turkey [1].

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