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Failures of structures during the October 23, 2011 Tabanlı (Van) and November 9, 2011 Edremit (Van) earthquakes in Turkey

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ABSTRACT

The October 23, 2011 Tabanlı and November 9, 2011 earthquakes that hit Tabanlı and Edremit districts of Van province in Turkey and their impacts on different types of structures are studied in this paper. According to United States Geological Survey (USGS), the magnitudes of these earthquakes, which caused partial or total collapse of numerous buildings and more than 600 casualties, were 7.1 and 5.6, respectively. Other than negatively impacting all aspects of daily life, the earthquakes remarkably disrupted the economical activities in the area. This paper summarizes the seismological characteristics of the affected region, the general characteristics of the strong ground motion and the types of structural damage observed during site investigations. Emphasis is given to the failures and seismic performance of different types of structures, through detailed explanation of damage mechanisms. The structural damage levels are observed to be directly related to the extent of irregularities of the structural system, level of the insufficient quality in the workmanship, and usage of inadequate building materials. It was also clearly observed that if a minimum amount of engineering attention had been paid during the construction stages, and the requirements of design and construction codes had been satisfied, most of the existing buildings could have sustained the earthquakes without considerable damage.

1. Introduction

Van Province is located in the eastern part of Turkey, quite close to the border between Turkey and Iran. The population of Van city is slightly above one million, according to 2009 census. About half of this population lives in urban areas, while other half lives in villages. Being one of the most seismically-active zones in Turkey, Van settles close to junction of East Anatolian Fault (EAF) and North Anatolian Fault (NAF), Fig. 1 (left). In addition to these main faults, there are also numerous minor faults around Van. An extensive summary of the faults around Van city can be found elsewhere [2]. On October 23, 2011, an earthquake of magnitude M_w = 7.1–7.2 hit the Tabanlı district of Van province at 13:41 (10:41 GMT) local time. Tabanlı is approximately 30 km way from the center of Van city. Magnitude and source characteristics of this earthquake, as defined by various institutions, are given in Table 1. In this table, M_L is the local magnitude and M_w is the moment magnitude. This earthquake affected particularly the Erciş district, whereas it also caused structural damages, structural collapses and

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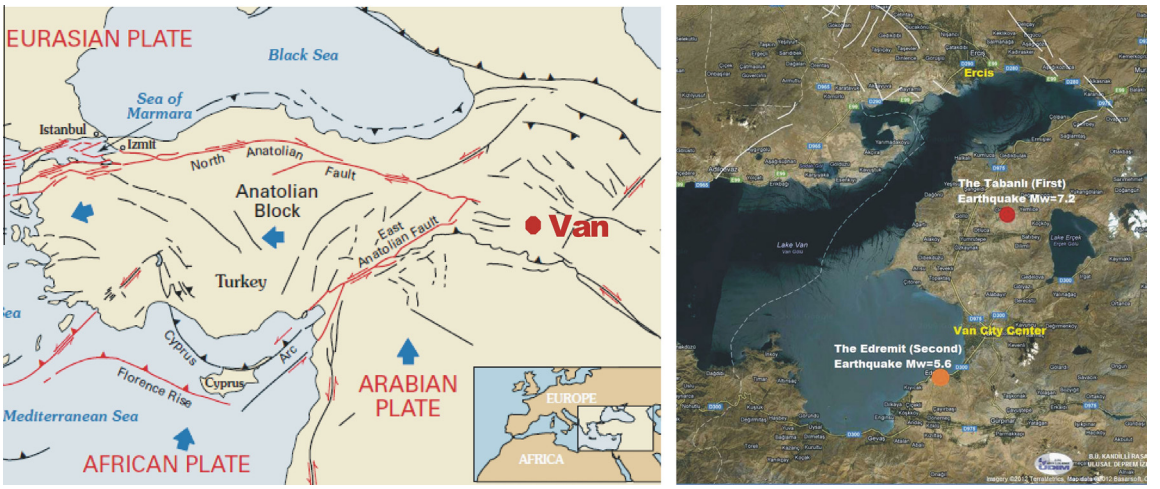

Fig. 1. Seismotectonics of Turkey (modified from [1]) and region affected by the earthquakes [3].

Table 1
Characteristics of October 23, 2011 Tabanlı (Van) earthquake.

Institution	KOERI[a]	USGS[b]	EMSC[c]	DEMP[d]
Date	10/23/2011	10/23/2011	10/23/2011	10/23/2011
Time	13:41:21 (Local)	10:41:21 (GMT)	10:41:22 (GMT)	10:41:20 (GMT)
Latitude	38.757N	36.628N	38.86N	38.689N
Longitude	43.3602E	43.486E	43.48E	43.465E
Depth	5 km	20 km	10 km	19 km
Magnitude	6.6 (M_L), 7.2 (M_w)	7.1 (M_w)	7.2 (M_w)	6.7 (M_L), 7.0 (M_w)

[a] Kandilli Observatory and Earthquake Research Institute.
[b] United States Geological Survey.
[c] European-Mediterranean Seismological Centre.
[d] Turkish Prime Ministry – Disaster and Emergency Management Presidency.

Table 2
Death toll after Tabanlı (Van) earthquake.

Location	Deaths
Van – City center	100
Erciş	351
Other	153
Total	604

fatalities at the center of Van city. It should be noted that the Erciş district is approximately 35 km way from the epicenter (Tabanlı). The death toll distributed among settlement areas is summarized in Table 2.

Following the first earthquake, another earthquake of magnitude $M_w = 5.6$ hit the Edremit district of Van province on November 9, 2011. While Tabanlı is to the north of Van city center, Edremit is located approximately 15 km southwest of Van city center. Although the magnitude of the second earthquake was smaller than the first one, its impact on structural damages was extensive, due to relatively high acceleration components in the center of Van city. The damages experienced during the first earthquake were further increased during the second earthquake. Furthermore, many buildings, which experienced heavy damage during the first earthquake in Van city center, collapsed totally during the second earthquake. The characteristics of this earthquake are presented in Table 3. It should be noted that this earthquake caused 40 casualties at the center of Van city. A map showing the epicenters of two earthquakes, Van city center and the Erciş district is presented in Fig. 1 (right). It is important to note that the earthquakes were caused by two different fault ruptures. While the faulting mechanism of the first earthquake was thrust type, the second one was caused by strike-slip faulting [2]. According to the Governorship of Van, a total of 28,512 buildings were damaged heavily or collapsed during Tabanlı and Edremit earthquakes [4]. The distribution of damage to buildings in Van province is presented in Table 4 [4].

On the day of the second earthquake, our reconnaissance team arrived in the region to carry out site investigation and damage assessment. Subsequently, the affected area was visited five more times to examine the damages and the seismic performance of different types of structures, such as school buildings, hospitals, hotels, prefabricated structures, historical