©2018 Published in 2ND International Symposium on
Natural Hazards and Disaster Management 04-06 MAY 2018 (ISHAD2018 Sakarya Turkey)

Performance of Masonry Buildings during the February, 2017 Ayvacık (Çanakkale) Earthquakes

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Abstract

Performance of masonry buildings during the February 2017, Ayvacık (Çanakkale) earthquakes are evaluated in this study. Ayvacık is a township located 68 km south from the province of Çanakkale in Turkey. A majority of the buildings in the affected region are built in masonry. Most of the masonry buildings were formed with random or coursed stone without any reinforcement. Many of such buildings were damaged or collapsed. The cracking and failure patterns of the buildings are examined and interpreted relative to current provisions for earthquake resistance of masonry structures. The damages are due to several reasons such as the poor construction quality and poor workmanship of the buildings. In addition to these reasons, the five earthquakes hit the buildings within seven days, causing progressive damage.

Keywords: Earthquake, masonry building, performance, damage, failure

1. Introduction

Five moderate earthquakes (Mw≥5.0) occured in Ayvacık (Çanakkale), Turkey between February 6 and 12, 2017. During the earthquakes, about one thousand masonry buildings were damaged, four people were injured, but fortunately no casualties in the rural area of Ayvacık. Most of the structures in the rural area of Ayvacık were masonry building.

The performance and failure mechanisms of masonry buildings during the moderate earthquakes previously occurred in Turkey have been carried out by several researches in the literature. Bayraktar et al. [1] carried out damages of masonry buildings during the July 2, 2004 Dogubayazit (Agri) earthquake in Turkey. Bayraktar et al. [2] evaluated performance of masonry stone buildings during the March 25 and 28, 2004 Askale (Erzurum) earthquakes in Turkey. Adanur [3] investigated performance of masonry buildings during the 20 and 27 December 2007 Bala (Ankara) earthquakes in Turkey. Celep et al. [4] reported failures of masonry and concrete buildings during the March 8, 2010 Kovancılar and Palu (Elazıg) Earthquakes in Turkey. Inel et al. [5] stated observations on the building damages after 19 May 2011 Simav (Turkey) earthquake. Sengel and Dogan [6] described failure of buildings during Sultandagi Earthquake. Sayin et al. [7] carried out failures of masonry and adobe buildings during the June 23, 2011 Maden-(Elazig) earthquake in Turkey.

In this study, performance of masonry buildings during the February 2017 Ayvacık, Çanakkale

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earthquakes were investigated. In order to understand the structural behaviour of the masonry buildings and to observe their collapse mechanisms during the earthquakes, it was visited the affected region on a reconnaissance. Observations and assessments were presented below.

2. Seismological Aspects

A moderate earthquake, measuring 5.3 on the Richter scale, hit the township Ayvacık of the southern province of Çanakkale, Turkey at 06:51 a.m. local time on Monday, February 6, 2017. The same day at at 01:58 p.m. local time, a second moderate earthquake of 5.3 on the Richter scale struck the same province. Only one day later, at 05:24 a.m. local time on Tuesday, February 7, 2017 a third moderate earthquake of 5.2 on the Richter scale crashed into the same province. And than, at 11:55 a.m. local time on Friday February 10, 2017 and at 04:48 p.m. local time on Sunday February 12, 2017; a fourth moderate earthquake of 5.0 on the Richter scale and a fifth moderate earthquake of 5.3 on the Richter scale bump into the Ayvacık [8].

Ministry of Public Works and Settlement published Seismic Zoning Map of Turkey in 1996 based on maximum acceleration. The whole country is divided into the five zones and Çanakkale province is in the first degree hazard zone in accordance with this map [8].

According to the information (February 13, 2017), a total of 982 aftershocks occurred after the Ayvacık earthquakes. Views of the earthquakes and their aftershock distributions are shown in Fig. 1 [8].

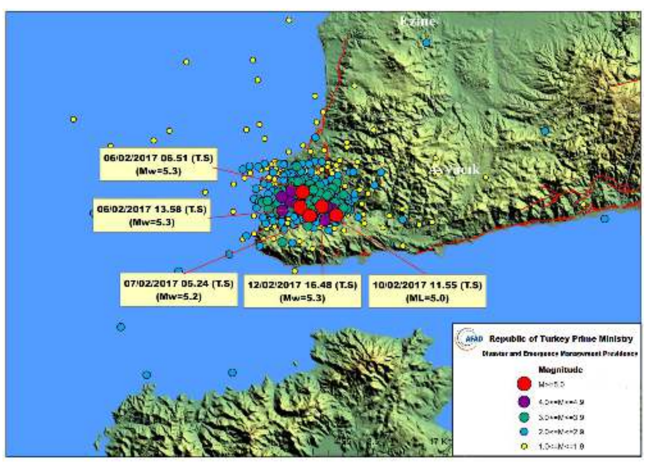

Figure 1. Ayvacık earthquakes and aftershock distribution [8].

The parameters and the three components of the ground acceleration records of the Ayvacık (Çanakkale) earthquakes taken at 1716 station are given in Fig. 2 and Table 1, respectively. Peak ground accelerations of the three components vary between 14.3880 cm/s^2 and 103.1696 cm/s^2 [8].

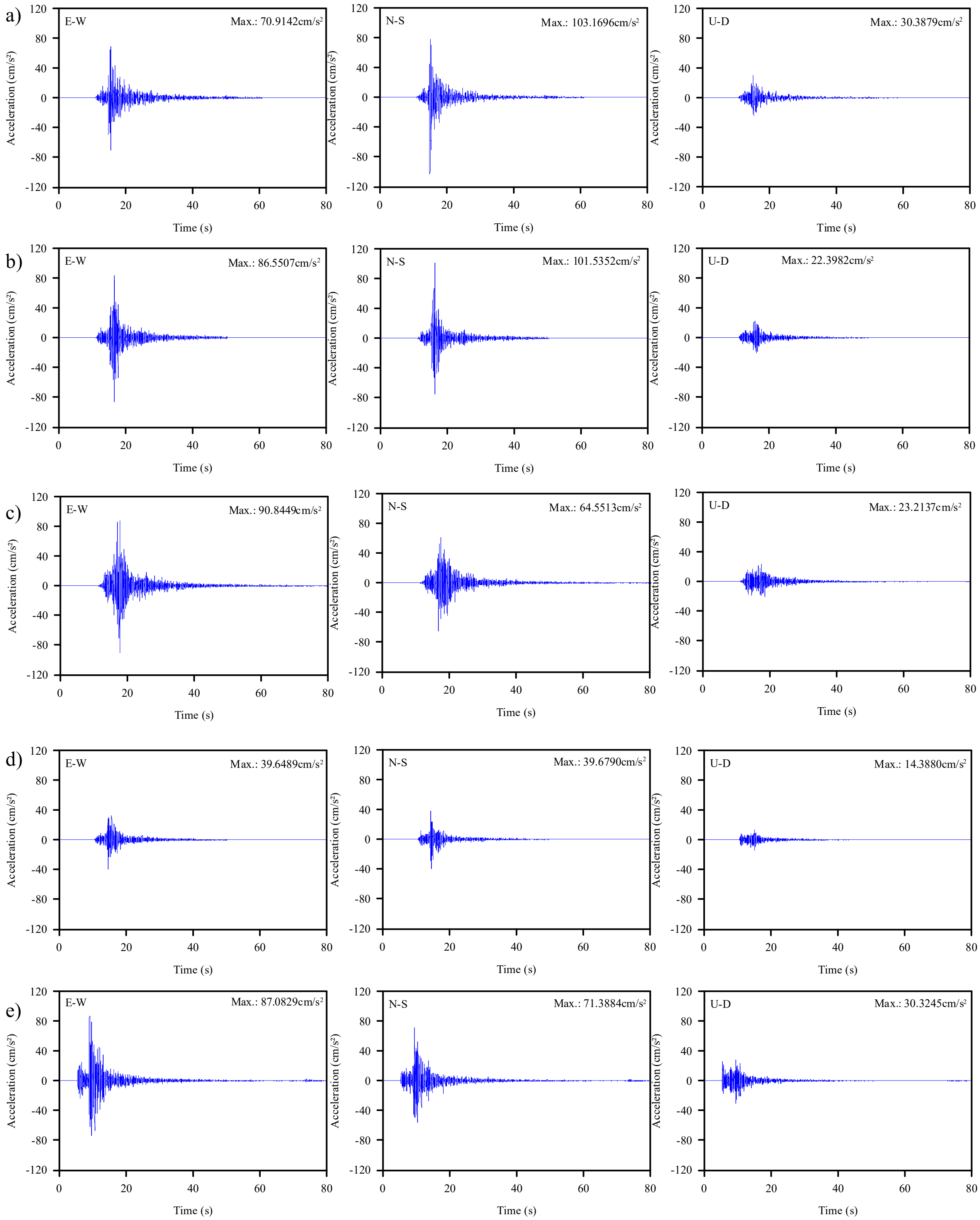

Figure 2. Acceleration records of the February, 2017 Ayvacık Earthquakes [8].

Table 1. Parameters of the February 2017, Ayvacık (Çanakkale) Earthquakes [8]

Date	Local Time	Magnitud (M_w)	Depth (km)	N-S (cm/s^2)	E-W (cm/s^2)	U-D (cm/s^2)	Latitude (N)	Longitude (E)	Location
February 6, 2017	06:51:40 a.m.	5.3	9.00	103.17	70.91	30.39	39.54950	26.13700	Ayvacık
February 6, 2017	01:58:02 p.m.	5.3	8.72	101.54	86.55	22.40	39.53030	26.13510	Ayvacık
February 7, 2017	05:24:04 a.m.	5.2	6.24	64.55	90.84	23.21	39.52050	26.15100	Ayvacık
February 10, 2017	11:55:26 a.m.	5.0	7.01	39.68	39.65	14.39	39.52360	26.19460	Ayvacık
February 12, 2017	04:48:16 p.m.	5.3	7.00	71.39	87.08	30.32	39.53360	26.17000	Ayvacık

Significant fault systems located near the epicenter of the Ayvacık earthquakes are Kestanbol Fault, Gülpınar Fault, Evciler Fault and Edremit Fault Zone [9]. Earthquakes that have occurred in the last century in the tectonically active region were 1900 Ayvacık-Çanakkale (M=5.2), 1912 Şarköy, Mürefte-Tekirdağ (M=7.4), 1912 Gelibolu-Çanakkale (5.2), 1935 Biga-Çanakkale (M=6.3, M=5.2), 1953 Yenice-Çanakkale (M=7.2), 1968 Ezine-Çanakkale (M=5.2), 1983 Ayvacık-Çanakkale (M=5.2), 1983 Biga-Çanakkale (M=5.8), 2013 Aegean Sea (M=6.2) Earthquakes [8].

3. Characteristics of Masonry Buildings in Affected Area

Most of the structures in the rural area of Ayvacık were masonry building. According to the post earthquake building damage survey of the Republic of Turkey Prime Ministry, Disaster and Emergency Management Presidency, about 1000 masonry buildings collapsed or damaged in the rural area of Ayvacık. About 600 of them were completely collapsed or havely damaged and the others were medium or minor damages [8]. Most of these buildings have been built by local builders without any engineered rules and any construction technique.

Masonry buildings were usually built in the affected area: (1)Stone masonry buildings with walls made of natural shaped stones, (2)Stone masonry buildings with walls made of cut stones, (3)Brick masonry buildings with walls made of bricks. These buildings were commonly constructed by their own residents without any engineering knowledge. Most of the stone masonry buildings have clayey mud mortar, whereas some have sand–cement mortar.

4. Damages to Masonry Buildings in the Affected Area

The February, 2017 Ayvacık (Çanakkale) earthquakes caused significant damage to Ayvacık and its vicinity. The five earthquakes hit the buildings within a week. A large proportion of the nonengineered stone masonry buildings completely collapsed or heavily damaged as shown in Figs. 3 and 4.

Figure 3. Examples of completely collapsed masonry buildings

Figure 4. Examples of heavily damaged masonry buildings

According to the Turkish Earthquake Code [10], natural stone load-bearing walls shall be used only in the basement and ground stories of masonry buildings. There were several two-storey stone masonry buildings in the affected area. Most of these buildings heavily damaged as displayed in Fig. 5.

According to the Turkish Earthquake Code [10], the ratio of the total length of masonry load-bearing walls in each of the orthogonal directions in plan (excluding window and door openings), to gross floor area (excluding cantilever floors) shall not be less than ($0.20I$) m/m^2 where I, represents building importance factor. $l_d/A \geq 0.20I$ m/m^2, where l_d is length of hatched area (m), A is gross floor area (m^2) and I is building importance factor. I=1.0 for residential buildings. There were many stone masonry buildings where this condition was not provided in the affected area. Most of these buildings damaged in the earthquakes as shown in Fig. 6.

According to the Turkish Earthquake Code [10], plan length of the solid wall segment to be set between the corner of a building and the nearest window or door opening to the corner shall not be less than 1.50 m in the first and second seismic zones. There were several stone masonry buildings where this condition was not provided in the affected area. Most of these buildings damaged in the earthquakes as demonstrated in Fig. 7.


Figure 5. Examples of heavily damaged two-storey stone masonry buildings


Figure 6. Examples of stone masonry buildings with inadequate load-bearing walls in each of the orthogonal directions in plan


Figure 7. Examples of masonry buildings which the nearest window or door opening to the corner was less than 1.50m

According to the Turkish Earthquake Code [10], unsupported length of any load-bearing wall between the load–bearing wall axes in the perpendicular direction in plan shall not exceed 5.50 m in the first seismic zone. There were many masonry buildings whose outer walls were stone and the inner walls were brick or wood in the area affected by the earthquakes. There was not any bond between inner and outer walls of these buildings. The outer walls of these buildings were the load–bearing, while the inner walls are not load–bearing. Therefore, unsupported length of any load-bearing wall between the load–bearing wall axes in the perpendicular direction in plan exceed 5.50 m in the affected area. Many of these buildings heavilly damaged in the earthquakes as illustrated in Fig. 8.

Figure 8. Examples of masonry buildings whose outer walls were stone and the inner walls were brick or wood

According to the Turkish Earthquake Code [10], construction of partial basement shall be avoided. There were a lot of masonry buildings with partial basements in the affected area. Many of these buildings broken in the earthquakes as shown in Fig. 9.

Figure 9. Examples of masonry buildings with partial basements

According to the Turkish Earthquake Code [10], minimum thicknesses of the load–bearing walls of natural stone masonry buildings shall not be less than 50cm. The wall thickness was reduced during construction of fireplace in masonry buildings in the affected area. Most of these buildings damaged in the earthquakes as displayed in Fig. 10.

Figure 10. Examples of masonry buildings whose wall thickness was reduced during construction of fireplaces

The corners were seriously cracked and the stones collapsed in the affected area. Fig. 11 illustrates the collapse of the building corners. This is owing to the deficiency of connection between orthogonal walls and between walls and floors or roofs.

Figure 11. Examples of failure of masonry building corners

Usually, it is seen that the structural performance of the masonry buildings in the affected area was not adequate during the earthquakes. However, there were also some observations of good performance as given in Fig. 12. This was mainly because of proper care and good workmanship during the construction.

Figure 12. Examples of undamaged masonry structures

Conclusions

The performance of the masonry buildings affected by the February, 2017 medium magnitude earthquakes in Ayvacık (Çanakkale) was presented in this paper. It was shown from the field investigation that the reason of the damages and failures of the masonry buildings can be described as: poor construction quality and poor workmanship in the affected area, five moderate earthquakes occured in the area in a week, the earthquakes were shallow focus earthquakes, and the area were nearly epicenter of the earthquakes.

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