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Damages of Masonry School Buildings on 2010 Karakocan - Elazig Earthquake

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ABSTRACT

Masonary school buildings were damaged very heavly or coolapsed in Karakocan-Elazig-Turkey earthquake with M=6.0 occurred on 08 March 2010 at 04:32 a.m. (local time) at eastern Turkey and caused the loss of life and heavy damages, as well. The majority of the damaged structures were seismically deficient unreinforced masonry structures.. In this paper, results of the site survey of Earthquake region -the damaged masonary school buildings are presented and the reasons behind the damages are discussed.

One of the most common reasons was the use of wrong material. Red bricks, Rubble stone, shaped soft stone blocks and very low guality mortar as binding material were the wall materials commonly used in the damaged buildings. Red brick, Soft stone blocks have low strength values. Another common reason is lack of interlocking element to connect the inner and outer leaves of the masonary walls to each other. Because of this deficiency, the unsupported length of the outer leaf of the wall was doubled, but its effective thickness was decreased to the half of the wall thickness.

Insufficient connection of the walls to each other was also a common reason of the damages . As a result of this deficiency the free span of the external wall was too much to resist aganist out of plane failure.

Wrong placement of the openings in the walls was among the most common damage reasons.

Insuffucient bond beams along the walls and a heavy – inclined roof were also important reasons.

Topography of the region was also effective in the damages. Many of the damaged buildings were located on the hills with a high slope.

INTRODUCTION

08 March 2010 Karakocan-Elazig earthquake of magnitude 6.0 occurred at a region where masonry and adobe construction is very common. Most of these masonry structures are seismically deficient. Karakocan- Elazig is located in a high seismicity region on Eastern Anatolian Fault System (EAFS) which is one of the most active fault systems of the world. (Fig. 1). This earthquake was related to the faults at the eastern end of Palu segment.

Due to the earthquake, 42 people were died and 14113 buildings were damaged [1]. Many of the damaged buildings were unreinforced masonry with low construction quality.

Most of the heavily damaged school buildings have been located on the hills with high slope. Therefore, the topographic amplification was effective on the severity of the damages similar to some of the previously reported cases. Some researchers reported that ground accelerations could increase up to 2.5 times on the hills [2-4].

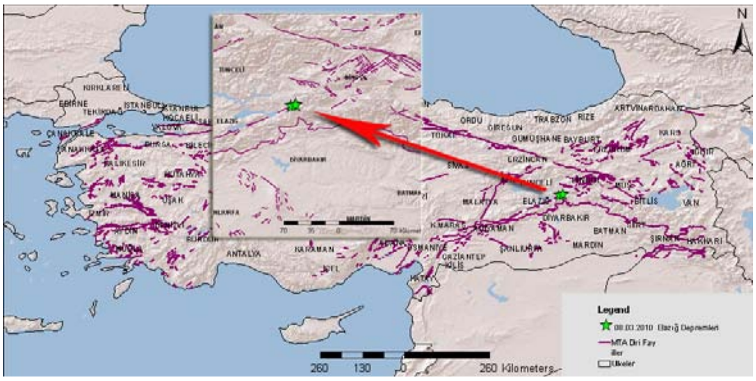

Figure 1 Karakocan-Elazig earthquake [5]

Peak acceleration values recorded by five stations for the earthquake are given in Table 1. The nearest station to epicenter was Palu station having an epicentral distance of 12 km. The corrected components of the record are shown in Fig. 2. The epicentral distances of the buildigs with heavy damages were ranging from 4.8 km to 10.0 km.

Table 1 Peak acceleration values [5]

Recording station	Epicentral Distance (km)	Peak Ground Acceleration (cm/s²)		
		N-S Compo.	E-W Compo.	Vertical Compo.
Palu	12	62.00	66.50	30.00
Bingöl	43	55.31	34.26	25.50
Elazığ	74	5.56	4.76	3.84
Solhan	90	28.50	29.00	12.00
Diyarbakır	95	3.44	5.10	3.59

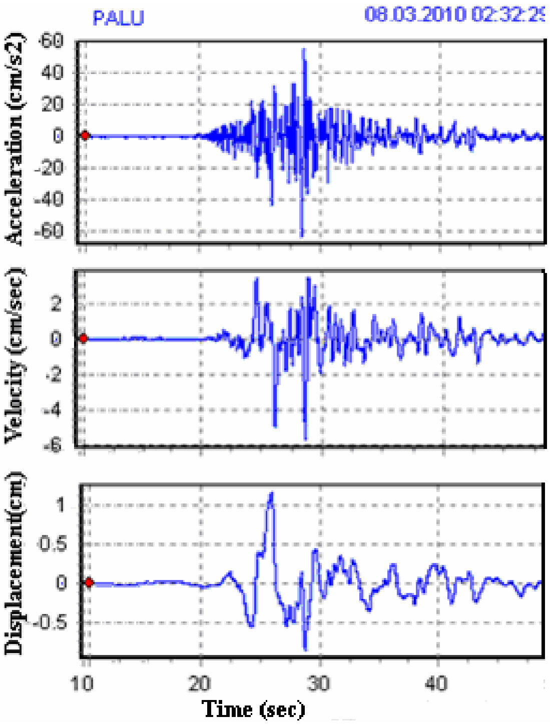

Figure 2 Palu station acceleration records [5]

Maximum soil amplification value obtained from Palu strong motion station is about 5 and it is seen from dominant frequencies that soils are generally in the stiff soil classification [5].

According to the Palu station records, the earthquake lasted for 13.77 sec in EW and 15.52 sec in the NS direction.

Damping ratios between 2% and 10% are proposed for masonry structures [6,7]. Damping in masonry walls is achieved by the friction forces in the cracks [8]. However, nonlinear damping characteristics of the unreinforced masonry structures are not well known at the moment.

DAMAGES AT MASONRY SCHOOL BUILDINGS

The masonry school buildings in the region affected by the earthquake were constructed by using stones collected from the river beds, soft natural stone blocks and lime hollow/solid blocks. Most of them were one-storey with a very heavy saddle shaped roof (Fig. 3). These buildings were not earthquake resistant according to previous or existing Turkish seismic codes [9]. Although the magnitude and spectral acceleration values of the Earthquake were not so high, many masonry school buildings were heavily damaged due to the above mentioned construction practice. The disaster area was surveyed and detailed studies were carried out on the damaged buildings to understand the reasons of the poor performance of the masonry school buildings. The main reasons are discussed in detail with the examples of damaged buildings.

Figure 3 Heavy -saddle shaped roofing systems

One of the most common reasons was the use of wrong material. Rubble stone and shaped soft stone blocks were the wall materials commonly used in the damaged buildings(Fig. 3 and 4). Soft stone blocks have low strength and ductility values. The rubble stone blocks selected from the river beds used as wall material do not have a proper shape for the use in the masonry walls. They have smooth and oval surfaces with irregular sizes. It is not possible to construct an overlapping wall section using this kind of material without cutting into proper sizes and shapes. Poor quality of bonding mortar as it is observed in most of the figures is another important reason for the damages.

The stone masonry walls were constructed as inner and outer leaves with a total thickness of 50 cm in general. There was no interlocking element to connect the inner and outer leaves to each other (Fig.5). Because of this deficiency, the unsupported length of the outer leaf of the wall was doubled, but its effective thickness was decreased to the half of the wall thickness. So, the out of plane failure risk was increased considerably.

Figure 4 Rubble stone and shaped soft stone blocks used as the wall materials

Figure 5 No interlocking element to connect the inner and outer leaves to each other

Another common reason of the damages was the insufficient connection of the walls to each other. There was either no connection or the connection was not constructed properly to transfer the loads. This kind of damage is shown in Fig. 6. The construction of the exterior walls was completed without any connection to partition walls. For this reason, the free span of the external wall was too much to resist aganist out of plane failure.

Figure 6 Damade due to the insufficient connection of the walls to each other

Wrong placement of the openings in the walls was among the most common damage reasons. Since the masonry walls are the only lateral load bearing structural elements of the masonry buildings, seismic design codes restrict the distance between the two openings and the distance between opening and corner of the walls [9]. The minimum distance between two openings should be 1 m and the minimum distance between an opening and a building corner should be 1.5 m. The damage due to the insufficient distance between two windows is shown in Fig. 7. Irregular shape of the masonary units in Fig. 7 is also as important as the insufficient wall length. Besides, it should be noted that the damage level in that wall could be higher if the bonding beams at the mid-height and the top of the walls were not. The damage shown in the Fig. 8 was due to the insufficient distance between the opening and the building corner.


Figure 7. Damage due to insufficient distance between two openings

Figure 8 Wall opening close to the building corner

A heavy saddle shape roof which does not provide a proper rigid diaphragm effect is also important reason for the damages (Fig. 9). Interior walls and the walls in the inclined direction and the roof were not connected to each other to transfer the seismic loads. Therefore, the exterior long wall was subjected to the most of the seismic load coming from the heavy saddle type roof.

Figure 9 A heavy saddle shape roof

Topography of the region was also effective in the damages. Many of the damaged buildings were located on the hills with a high slope. According to Kramer topographical irregularities on ground surface may affect ground acceleration significantly [10]. Because of the amplified ground accelerations, the number of the damaged buildings increased significantly. The damages on the buildings located on a hill are shown in Fig. 10. Due to the concentration of seismic energy and amplification of the ground acceleration at the top of the hill, the damage level of the building becomes heavier than those located on the foot of the hill.

Figure 10 Many of the damaged buildings were located on the hills with a high slope

CONCLUSION

The damages mostly occurred in the rural areas with one-storey unreinforced masonry structures. Most important defects of the damaged masonry structures were the lack of interlocking units between external and internal leaves of the wall sections and lack of connection between crossing walls. Both of them cause an increase in the possibility of out-of-plane failure, as their formation increases net length of the walls or leaves.

Heavy saddle shape roof was not behaving as a proper diyaphgram on the walls. Therefore the roofing increased the seismic demands and caused the damages.

Improper placement of openings was also a common reason of damage. Cracks were concentrated around the openings.

Soil amplification due to slope hill effect and local soil conditions increased ground accelerations and the damages.

The masonry buildings, especially in rural areas of Turkey similar to the ones in the developing countries all over the World, are under high risks of significant damages in the future earthquakes. Therefore, it is very urgent to take necessary precautions to reduce seismic damage risk in the masonry structures. Economical and applicable strengthening techniques for the existing masonry structures must be developed.

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