Proceedings of the International Symposium on Engineering Lessons Learned from
the 2011 Great East Japan Earthquake, March 1-4, 2012, Tokyo, Japan

REPORT ON 2012 VAN (TURKEY) EARTHQUAKES

Mustafa ERDIK[1], Yaver KAMER[2], Mine B. DEMIRCIOGLU[3], and Karin SESETYAN[4]

[1] Professor, Department of Earthquake Engineering, Kandilli Observatory and Earthquake Res. Institute,
Istanbul, Turkey, erdik@boun.edu.tr, erdikm@gmail.com
[2] Chair of Entrepreneurial Risks, Swiss Fedrral Institute of Technology,
Zurich, Switzerland, ykamer@ethz.ch, yaver.kamer@gmail.com
[3] Research Associate, Department of Earthquake Engineering, Kandilli Observatory and Earthquake Res. Institute,
Istanbul, Turkey, minebd@gmail.com
[4] Research Associate, Department of Earthquake Engineering, Kandilli Observatory and Earthquake Res. Institute,
Istanbul, Turkey, ksesetyan@gmail.com

ABSTRACT: An earthquake of Mw7.2 on 23 October 2011 occurred in the Van region of Eastern Turkey. The mainshock and long series aftershocks caused significant damage and claimed 644 lives. Particular features of the earthquake, damage, losses, rehabilitation and the lessons learned are covered.

Key Words: Van Earthquake, strong ground motion, earthquake damage, earthquake losses

INTRODUCTION

A magnitude Ml6.6 - Mw7.2 earthquake struck the Van province in eastern Turkey at 10:41 GMT (13:41 Local) on Sunday, October 23rd, 2011. Kandilli Observatory and Earthquake Research Institute (KOERI, www.koeri.boun.edu.tr/sismo/indexeng.htm, www.kandilli.info) reports that the earthquake originated at a depth of about 5km at the epicenter was located at 43.36 N 38.76 E, at the village of Tabanli, between the major cities of Van and Erciş.

On the basis of the data from Turkish Statistical Institute (http://www.turkstat.gov.tr), the Van province has 2011 population of 1.022.532 (1.4% of the population of Turkey) with a population density of 55 per km2 and average household size of 7. The major cities are Van with a population of 363,419 (municipal) / 526.725 (total) and Erciş with a population of 76,473 (municipal) / 159,450 (total). Both cities have doubled their population during the last 25 years, during which the major building population took place.

This earthquake caused significant damage in the cities of Van, Erciş as well as in many villages. According to the information provided by Prime Ministry Disaster and Emergency Management Presidency (AFAD, www.afad.gov.tr) this earthquake caused 604 fatalities and 2,608 injuries. Significant aftershock has been associated with this earthquake. The M5.6, Nov. 9, 2011 earthquake resulted in additional damage and collapses in Van city with 40 additional fatalities. The earthquake is estimated to have caused around 1 – 2 billion USD in total economic losses.

SEISMO-TECTONICS

Ambraseys (2009) reports that Van province was exposed to major damaging historical earthquakes in 1276, 1648, 1715, 1896. The 1941 M5.9 Van-Erciş earthquake caused 192 casualties.

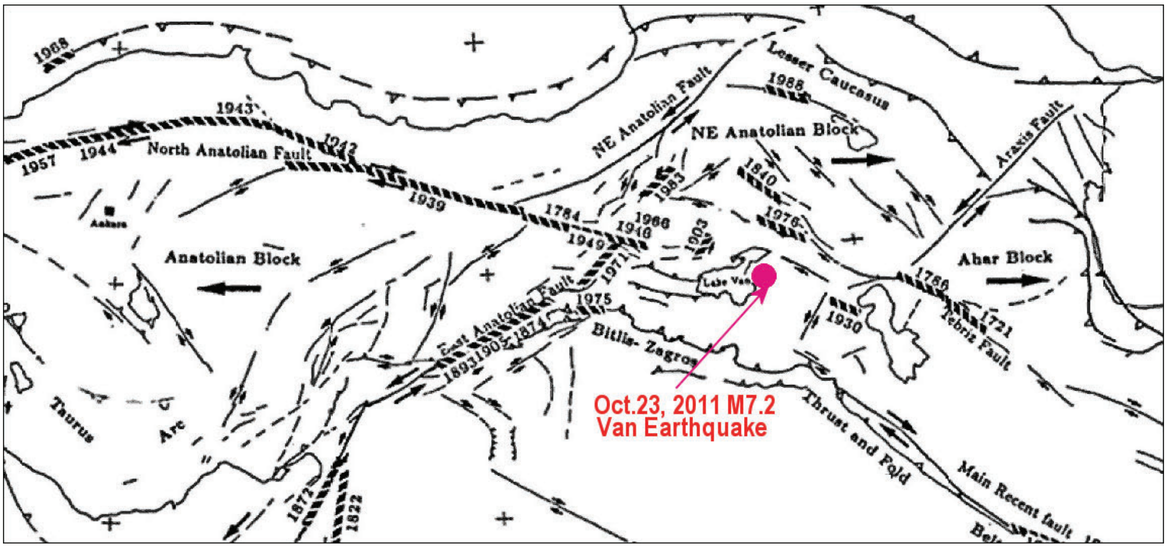

Fig 1. Earthquake located on the neo-tectonic map of Barka and Reilinger (1997)

The Mw7.2 (seismic moment Mo=1020 Nm) earthquake in Eastern Turkey on Sunday 23.10.2011, 13:41 local time hit the Eastern Turkey. The epicenter of the main shock was located in between Van and Erciş (about 30km, respectively, north of Van and south of Erciş). The focal region of the earthquake and much of easternmost Turkey lie towards the southern boundary of the complex zone of continental collision between the Arabian Plate and the Eurasian Plate. Part of the convergence between these two plates takes place along the Bitlis-Zagros fold and thrust belt at a rate of approximately 2.4cm/yr. As reported by KOERI, the earthquake rupture started as 38.75 E 43.36 N, and propagated in Northeast and Southwest directions. The focal mechanism indicates oblique thrust faulting, consistent with the expected tectonics in this region, with a fault surface area of about 60 km x 30 km, as confirmed by the aftershock sequence.

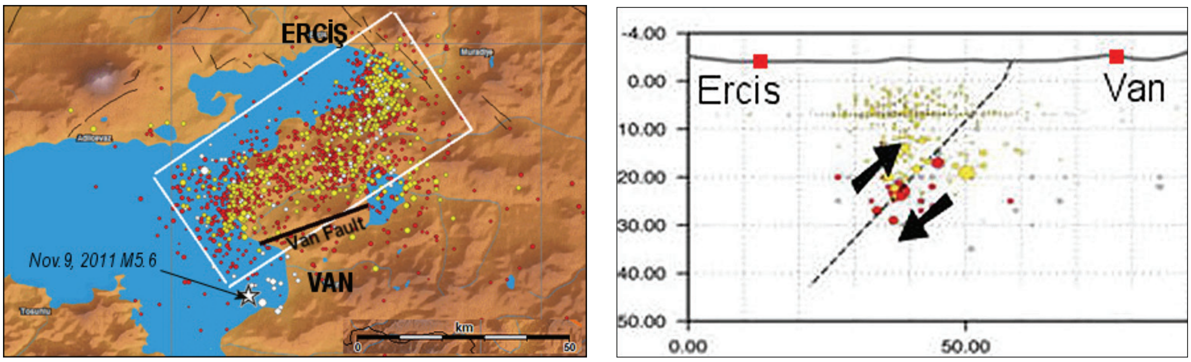

Fig 2. (a) and(b)Van fault, aftershock distribution (KOERI) and simplified fault model

The finite fault model developed by Dr.Gavin Hayes of USGS (Fig 2b) (http://earthquake.usgs.gov/earthquakes/eqinthenews/2011/usb0006bqc/finite_fault.php) indicate a north-dipping fault plane at 45-51 degrees and with a strike of 241 degrees. These findings correlate well with the InSAR results, and information from geologists mapping surface rupture in the field. The rupture surface is 20 km along strike and 20 km down-dip. The peak fault displacement is at about 4m at 16km depth. The moment rate indicates rupture duration of about 30s with a peak rate at 4s.

Focal mechanism solution and the fault model of the Van earthquake reveals an east-west trending reverse fault with a" north-dipping fault plane. East-West oriented thrust fault mechanism. Since there were no evidence of thrust faulting in the field as only very small (in centimeters) surface rupture has been observed. The Van earthquake was associated with fault that was not previously recognized as active. Morphological indicators, point the east-west oriented thrust fault, so called Van or Everek Fault, as the primary source of this event. Similarly, Nov. 9, 2011, M5.6 earthquake on another previously unrecognized active fault.

Van earthquake is associated with intense aftershock activity compared to the similar magnitude strike-slip earthquakes that took place in Turkey. The number of aftershocks above M4.0 and M5 are respectively 80 and 10. So far the largest aftershock had a magnitude of 5.7 (Ml). The reason of the relatively intense post-earthquake activity appears to be the tectonically complexity of the affected area and the existence of several faults with different characteristics. The main shock could have also served to activate this system of small scaled faults.

Following the main shock KOERI have deployed 16 additional seismic instruments to the earthquake area to enable recording of the strong ground motion and the determination the accurate fault geometry. This deployment will enable KOERI scientists better locate the aftershocks and to determine the fault geometry more accurately. KOERI is continuously monitoring the aftershock activity and updated evaluations are disseminated (www.koeri.boun.edu.tr, www.kandilli.info).

GEOTECHNICAL EFFECTS

Site response and ground failure are the two major geotechnical effects that could aggravate the damage to buildings, infrastructure and lifelines.

Both in Van and Erciş cities there exist pockets of severely damaged areas that may be taken as manifestation of site amplification. However, the lack of properly classified building damage distribution, lack of adequate strong ground motion data and site specific geotechnical data does not allow for any conclusion at this stage. The data from the post-earthquake deployment of strong motion recorders in the field by KOERI and AFAD can serve to quantify the site response effects associated with aftershocks.

Limited slope failures, mostly in the form cracks in natural slopes and road embankment failures were observed in the epicentral region of the Van earthquake. Some of these failures may also be associated with clay softening (Çelebi et al. 2011).

Small scale liquefaction took place at several locations along the river beds and at the delta of the Karasu Creek. Liquefactions were associated with sand boils and lateral spreading. The damaged the water line supplying Yüzüncü Yıl University, located in the northern outskirts of Van, is associated with liquefaction (DM&AYE (2011).

STRONG GROUND MOTION

Distribution of Intensities

Fig 3a and Fig 3b provides shake maps of the Oct. 23 and Nov.9 earthquakes in terms of EMS'98 intensities using the ELER routine (Erdik et al., 2010). As it can be assessed the cities of Van and Erciş are located in VII+ in Oct. 23 and in VIII and IV calculated intensity zones in Nov.9 events.

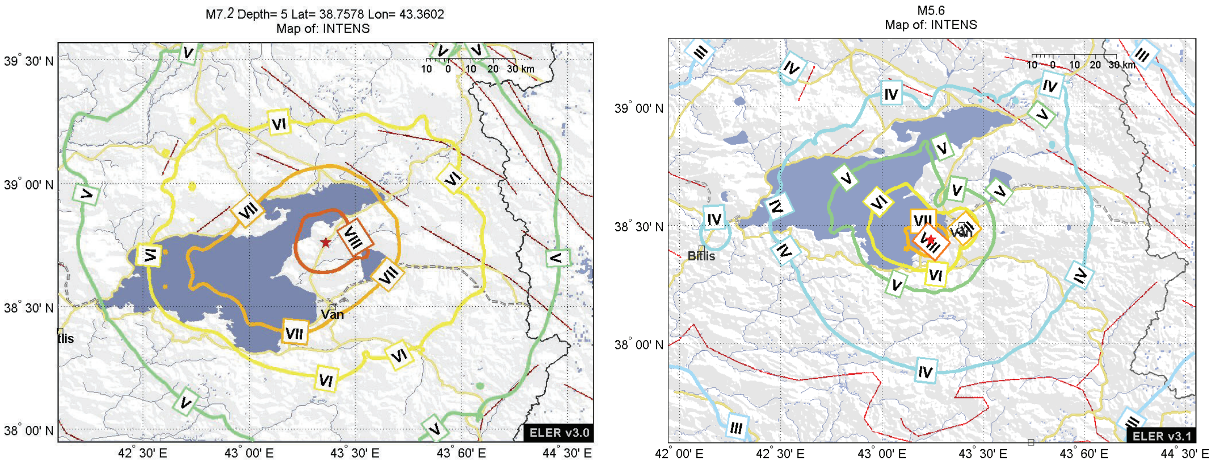

Fig 3. (a), (b). Shake maps of the Oct. 23 Mw7.2 and Nov.9 Ml5.6earthquakes

Accelerometric Data

The strong motion stations operated by AFAD have produced 22 strong motion records for the Oct. 23, 2011, Mw7.2 Van earthquake most of them at large distances beyond 100km. Unfortunately, no strong motion data is available for the cities of Van and Erciş (EQE-KOERI, 2011; METU-AFAD, 2011),.

The peak ground acceleration at Muradiye Station in Oct. 23, 2011 earthquake is 0.18g. Since Muradiye City is about at the same distance from the epicenter at least the same ground motion levels can also be assumed for the cities of Van and Erciş. It should also be noted that Erciş City is located on the moving block of the thrust rupture that may imply higher levels of ground motion than Van City. This fact is also manifested by the somewhat greater damage in Erciş compared to Van city.

Strong motion data from the existing and the additionally installed stations exist for the post-earthquake activity. The peak ground acceleration value recorded at Van Station in Nov. 09, 2011 earthquake is 0.25g. It appears that during the Nov. 09 earthquake the Van City was in the forward directivity of rupture and as expected, the fault normal motion is dominant.

Fig 4 illustrates the peak ground acceleration distribution map obtained from shake maps with bias adjustment with recorded ground motion. Fig 5 provides a comparison of peak ground accelerations with the NGA ground motion prediction relationships (EQE-KOERI, 2011).

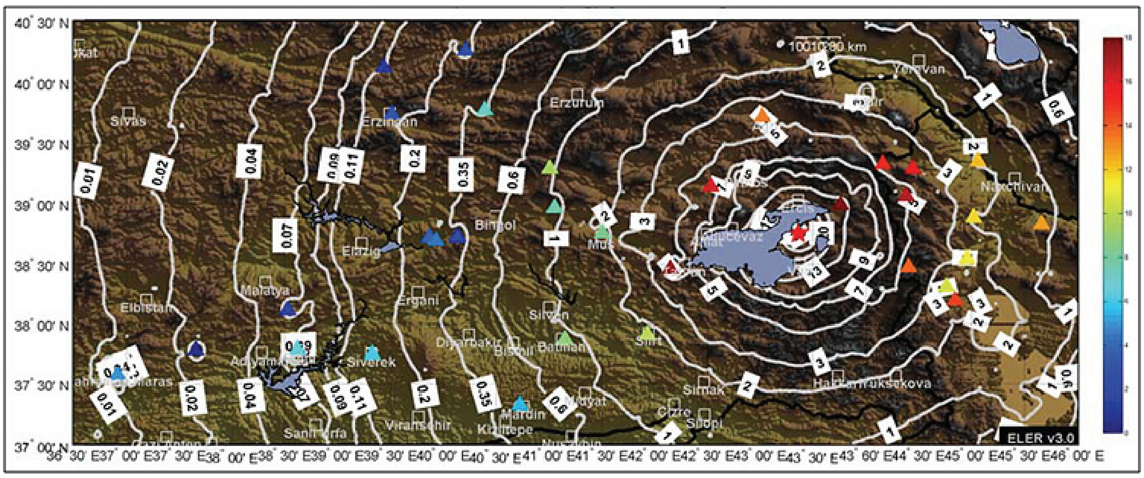

Fig 4. PGA shake map with bias adjustment with recorded motion. (EQE-KOERI, 2011)

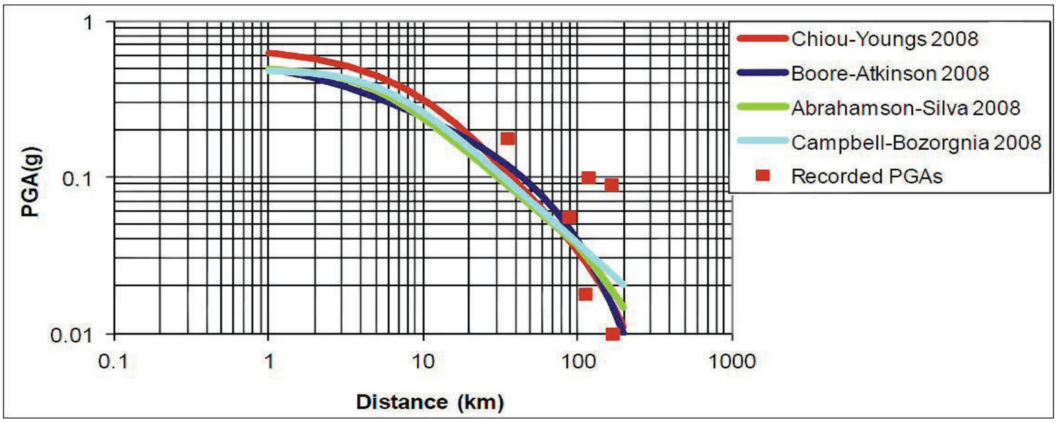

Fig 5. Comparison of recorded PGA with the NGA-GMPEs (EQE-KOERI, 2011).

LOSSES

Building Damage

Van earthquake caused considerable damage to buildings and to public facilities with substantial casualties. The building stock in the major cities of Van, Erciş and vicinity consists mainly of non-engineered low rise buildings and engineered mid-rise reinforced concrete framed buildings with infill walls. The predominant structural system used for reinforced concrete buildings in Turkey consists of reinforced concrete frames with a symmetric floor plan and with unreinforced masonry infill walls. Except for some industrial plants or assemblages steel construction is rare.

In villages, the dominant building type consists of adobe and stone masonry buildings minimally reinforced with timber lintel beams. The roofs are constructed mostly with galvanized steel sheets. Livestock shelters generally have heavy earthen roofs. Those buildings with heavy earth roof experienced heavy damage and collapse as it has also been experienced in previous rural earthquakes in Turkey.

Many modern buildings in urbanized areas did quite well but typically older ones collapsed. There have been weak first storey collapses (soft storey collapse) as well as pancake collapses that have been seen. Many buildings that appeared undamaged outside, revealed signs of critical structural damage once inspected carefully. Some reinforced concrete framed buildings have been constructed with sufficient earthquake resistance (tunnel-form construction, shear walls and post tensioning) performed well. It should also be noted that these damage observations in Van and Erciş relate to a building stock that has been exposed only to about 50% of the reference (or design) acceleration of 0.3g -0.4g level. As such, any nearby aftershock (M5.5+) that can create ground motion above 0.15g-0.2g level can cause additional damage and collapses as evidenced in Van City by the Nov.9, 2011 M5.7 Edremit earthquake.

KOERI estimates for the distribution of buildings in the Van Province are provided in Table 1 (www.koeri.boun.edu.tr/News/23%20October%202011,%20Mw=7.2%20Van,%20Turkey%20Eq._16_204.depmuh)

Table 1 Building Inventory in Van Province

	Van City	Erciş City	Van Province
Number of Buildings	35,200	10.700	78,000
Reinforced Concrete Percentage	5%	27%	12.7%
Unreinforced Masonry Percentage	82%	63%	75%
Adobe Percentage	9%	8%	9.5%
Rubble Stone Percentage	4%	2%	2.8%

KOERI has provided the following estimations of the building damage in terms of geo-cell based distribution of buildings in EMS’98 (Grünthal, 1998) damage states, immediately after the earthquake using the ELER routine (Erdik et al., 2010).

- Damaged beyond repair (EMS’98 damage states: D3+D4+D5) = 3,927 (Fig 6)
- Medium Damage (EMS’98 damage state D2) = 9,956
- Light Damage (EMS’98 damage state D1) = 24,582

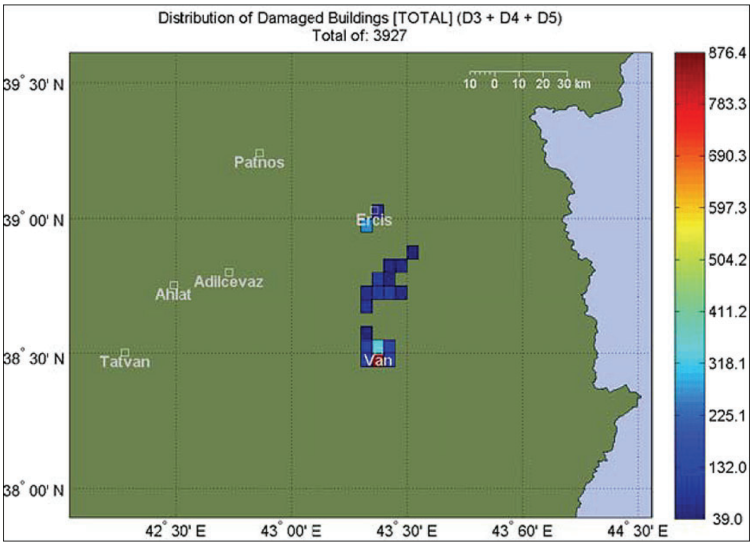

Fig 6. Estimated Distribution of buildings damaged beyond repair (EQE-KOERI, 2011)

Past earthquakes in Turkey have shown that at computed EMS’98 intensity levels of VII (as is the case in Van and Erciş) about 10% of the mid-rise R/C buildings and about 5% of low-rise R/C or masonry buildings receives damage beyond repair. These statistics are in conformity with the figures provided in Table 1.

On the basis of UN Situation Report No. 7, October 30, 2011 (http://reliefweb.int/) AFAD declared that in the Province of Van 861 buildings collapsed (probably EMS’98 damage states: D4+D5) and 3713 buildings (5270 housing units) are damaged-uninhabitable (probably EMS’98 damage states: D2+D3). It is furthermore reported (AFAD) that in the October 23, 2011 Mw7.2 main shock the numbers of heavily damaged and totally collapsed (D4+D5) buildings in Van and Erciş are respectively 36 (6 total collapse) and 1095 (65 total collapse). After the November 9, 2011 M5.6 earthquake this number increased 100 (27 total collapse) in Van. As it can be assessed the rapid estimations of building damage provided with KOERI are in agreement with the field observations.

The official damage assessment conducted by AFAD refers to housing units (instead of buildings) and is essentially conducted to sort out families (rather, property owners) that the government will legally provide housing units (to ones with damage beyond repair, at very low interest levels) and credit for repair (to ones with medium damage) and cash assistance (to those with light damage). The results of this damage assessment are summarized in Table 2.

Table 2 Official Household Based Damage Assessment

Locality	Total Inspected Housing Units	Housing Units Beyond Repair	Repairable Housing Units	Housing Units with Light Damage
Van Province	117, 700	28,532	11,317	43,403
City of Van	67,738	13,250	9,308	25,920
City of Erciş	14,482	4,547	1,503	6,607

It should be noted that, these damage assessments are not tied to the EMS'98 damage classes and incorporate the subjective opinion of about 1000 inspectors. Please compare that the number of housing units beyond repair was only 66,441 at 1999 M7.4 Kocaeli earthquake which has effected a population of about 10 times more than the Van earthquake and caused 17,480 fatalities.

Leaving, if any, the site response problems aside, poor earthquake performance of most buildings is essentially due to the noncompliance with the earthquake resistant design codes. The contrasting performance between similar buildings that survived and those that failed provides evidence that conformity with the design code and good construction practices can limit damages during strong earthquakes. The damage to reinforced concrete buildings can be attributed to one or more of the following reasons:

- Poor building material quality: The strength of the concrete was in general well below the values specified in the building codes. The use of smooth reinforcing bars (as opposed to the deformed bars) was also common.
- Soft stories: Soft stories increased deformation demands, P-Delta effects and forced the first-story columns to dissipate the all the energy. This effect has caused a large portion of the building collapses. Although, there were many cases where the first story collapsed and the upper stories remained relatively undamaged.
- Strong beams and weak columns: Deep beams used with flexible columns have contributed to the early failure of columns.
- Poor detailing: Insufficient anchorage, splice lengths and confinement have severely limited the ductile response of the reinforced concrete frames.
- Short Columns: In many cases improperly designed infill walls limited the height of the columns, leading to shear failures.

For R/C buildings typically hollow clay tiles are used with inadequate mortar at the joints. Although not intended, these walls form the first line of resistance against the earthquake forces and, in many cases, control the lateral drift. Once the infill walls fail, the lateral resistance is to be provided by the reinforced concrete frames alone, with usually have low concrete quality, inadequate reinforcement and poor detailing. Extensive inelastic action at the critical regions has caused varying degrees of building damage that, in extreme cases, lead to formation of hinge mechanisms and pancake-type collapses. As such the effect of infill wall performance to the structural performance of the building is of importance and should reflect in the future revisions of the earthquake resistant design codes.

Due to (now outdated) heat insulation regulations the infill walls were constructed in two unconnected layers with insulation sheets located in between. Such a construction has created even weaker infill walls that become easily dethatched and collapsed in Van earthquake. Although, there was no structural damage the loss of walls in a cold climate rendered the buildings inhabitable and caused great strains for the supply of emergency accommodation. This would necessitate the development of construction guidelines for proper infill walls.

There were several earthquake retrofitted school buildings in the region. One of those has been inspected (METU, 2011) revealed adequate earthquake performance with limited damage. Apart from cracks in the infill walls, there was localized minor structural damage consisting of some shear cracks in shear walls (imparted to the existing frame for retrofit) and at doweling interface under the first floor beam. These damages highlight the importance of shear wall and shear wall anchorage designs and construction in retrofit applications.

Fig 7 to Fig 8 provides a general illustration of damages in the cities of Erciş and Van and in the Tevekli village.

Fig 7. Damaged Reinforced Concrete buildings in Erciş (AA Press)

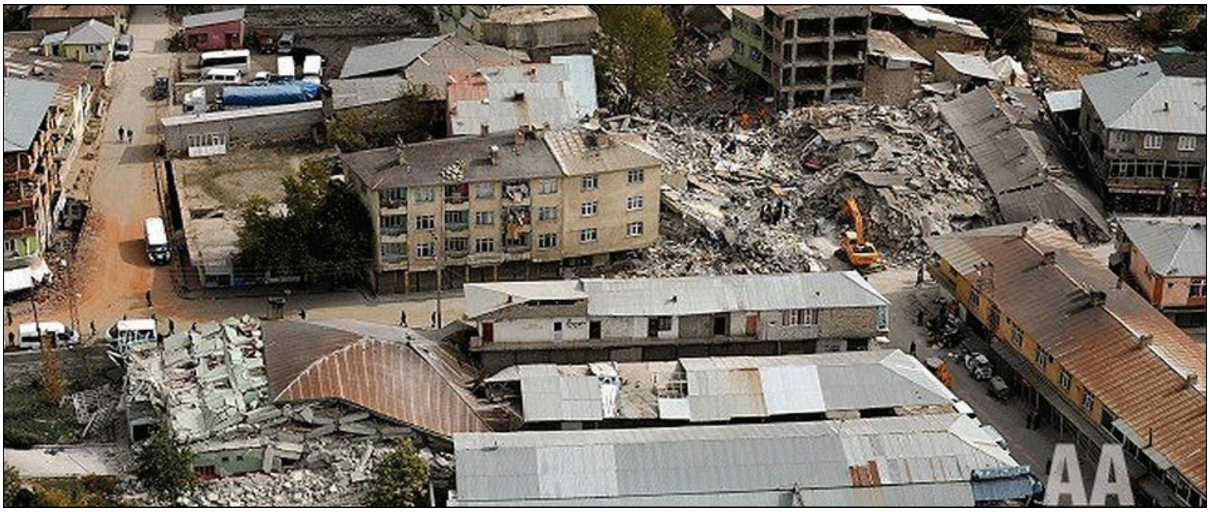

Fig 8. Damaged Reinforced Concrete buildings in Erciş (AA Press)

Fig 9. Damaged Reinforced Concrete buildings in Erciş (AA Press)

Fig 10. Damaged Reinforced Concrete buildings in Van (AA Press)

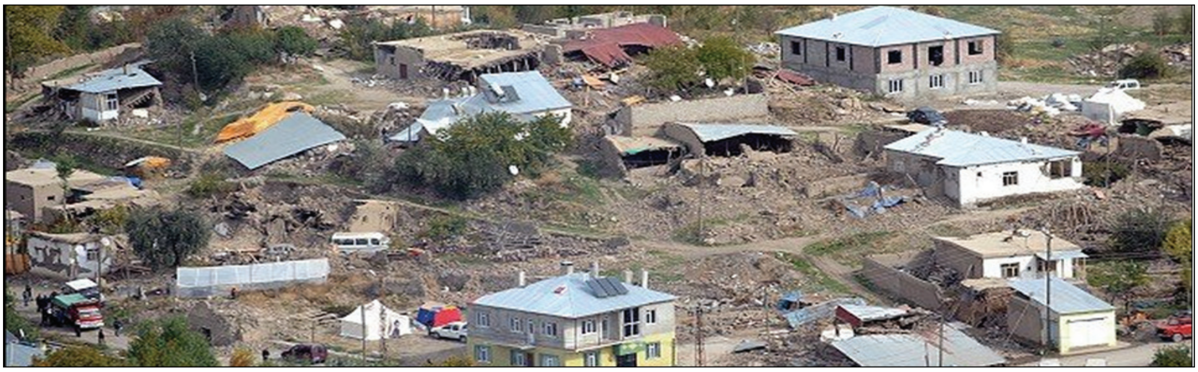

Fig 8. Damaged rural buildings in Tevekli village (AA Press)

Hospitals and Schools

In past earthquakes the performance of public hospital and school buildings has been on the average much better than the general building stock. The main reason behind this is the 50% increase in earthquake design loads for these buildings (i.e. importance factor=1.5) and simple symmetric structural layout with no soft stories.

Several hospitals were damaged (structural, non-structural and equipment) in the Van earthquake both in the cities of Van and Erciş. Due to severely limited hospital capacity, temporary field hospitals were deployed in the region. Yüzüncü Yil University – Faculty of Medicine Hospital, Maternal Health and Pediatric Hospitals, İpekyolu State Hospital and Erciş State Hospital are closed (or partially operating for emergency cases).

The Ministry of Education has terminated the educational activities in the affected region for about 70 days since many schools in the area collapsed or were seriously damaged. On the basis of the investigations conducted by the Ministry of Education, it has been announced that about 2000 classrooms out of the total 7100 classrooms in primary and high schools were unusable due to the damage. It should be noted that, although the damage was widespread, as no children were at school on Sunday (day of earthquake), a high death toll of students were avoided. The lacking class space was cared for by the deployment of prefabricated buildings and the education has restarted in the beginning of January 2012

Historical and Cultural Property

There are important historical monuments in Van, such castles, mosques and churches. In Oct. 23 and Nov.9 earthquakes several mosques were damaged in Ercis and Van and the minaret damage was widespread in cities and throughout the villages. In addition, the Van Museum and its famous Urartu collections were damaged. Damages to Sheikh Abdurrahman Mosque and Hüsrev Pasha Mosque, located on the outskirts of Van Castle, were light. The minaret of the Kaya Çelebi Mosque (also located nearby the Van Castle) collapsed on the dome causing extensive damage. The historical church (Yedi Kilise or Vank Monastery), located in Bakraçlı village of Van, was partly damaged and the front entrance has collapsed. Except a renewed crack in the dome of Akdamar Church (a 10th century Armenian monument), no damage was reported.

Lifelines

Van earthquake caused limited damage to electric and water systems. There was almost no damage to the transportation network and the natural gas supply network (Van city).

Damage to electric distribution networks was mostly due to transformer damage. About 80% of the Van city received power after 2 hours. The restoration period for Erciş city was about 2 days for %70 of the consumers.

The water supply at Van city was interrupted for about a week due to the repair of damages at some pumps and pipes. Significant damage to water supply system to Yüzüncü Yıl University, to the north of Van City, took place due to liquefaction induced settlement.

With the exception of minor cracks on the Van-Erciş highway (that was repaired almost immediately) the transportation system (including railroads) fared wary well. Field studies indicate that the damage in to highway bridges in the epicentral generally consists of limited movement (few cms) of elastomeric bearings under the deck beams. Very limited cracks in few piers and stopper blocks were also observed. No damage was reported in the regional dams and hydro-electric facilities.

Casualties

Stemming from the poor earthquake performance of the buildings, past earthquakes in Turkey have shown that the death rate in earthquakes has been about an order of magnitude higher than those in California. This was no exception also in the Van earthquake.

KOERI has successfully provided the rapid estimation fatality as 714 and their geo-cell based distribution (Fig 9) using the ELER routine (Erdik et al., 2010). In contrast, the median fatalities reported by the first issue of the USGS-PAGER system stood in excess of 10,000 and 32% were assigned to fatalities between 10,000 and 100,000. This was possibly due to the USGS location earthquake epicenter (CEDIM reports at www.cedim.de and http://earthquake-report.com).

The actual number of fatalities was 604 in the October 23, 2011 Mw7.2 main shock. The serious injuries were about 2000 and about 230 people were saved alive from the collapsed buildings, due to the much improved and developed search and rescue efforts. After the November 9, 2011 M5.6 earthquake 40 people have lost their lives in the collapsed Bayram Hotel in Van, bringing the total number of fatalities to 644. About 75% of the fatalities were in urban areas.

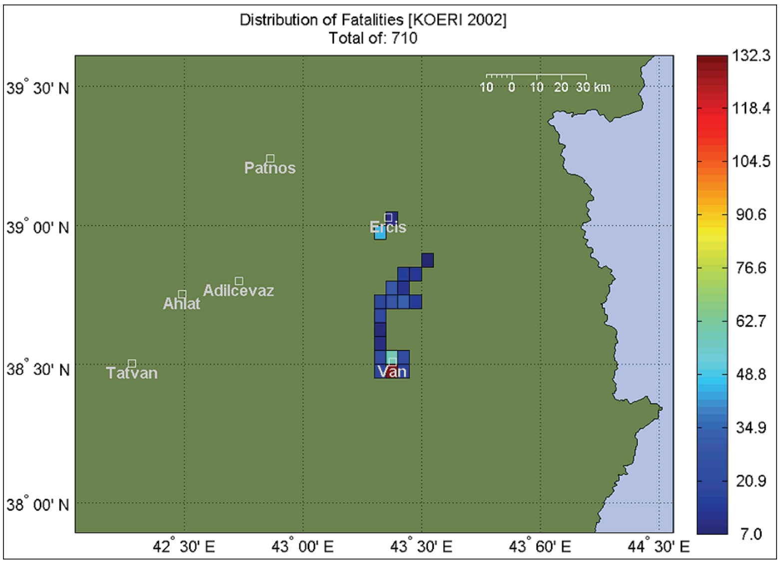

Fig 9. Estimated distribution of fatalities (EQE-KOERI, 2011)

Economic Losses

Total economic loss is estimated about 1-2 billion USD (CEDIM reports at www.cedim.de and http://earthquake-report.com/). Our economic loss estimate amounts to about 1.5 billion USD, consisting of 1.2 billion USD physical damage and 0.3 billion indirect losses. On the basis of the data from Turkey's Statistical Yearbook 2010 (Turkish Statistical Institutute, www.tuik.gov.tr), the gross value added (GVA) of Van Province can be assumed to be around 3 billion USD (2011), this loss would represent around 1/3 of the GVA of Van (and about 0.2% of the national GVA). Although this loss is about 5% to 10% of the losses suffered in 1999 Mw7.4 Kocaeli earthquake in Turkey. However, it should be noted that this earthquake is in a region about 4 times poorer than the Kocaeli region.

Micro and small enterprises will eventually be the hardest hit group by the earthquake, losing most of their customers due to outmigration and government subsidies of food and other items to earthquake effected population. The loss of capacity in small and micro enterprises has additional adverse socio-economic effects due to loss of unemployment, production and economic linkages with larger firms. However, the job losses especially for the self-employed are expected to recover in the near future with government credit incentives, debt rescheduling and assistance for re-building.

REHABILITATION

Several NGO's, Turkish Red Crescent-American Red Cross, FEMA and other concerned agencies are working with local offices of emergency management, universities, neighborhood groups and business partners to increase community preparedness levels through training and education. The number of search and rescue teams amounted to 476 encompassing 3503 persons. 222 people were rescued alive from the collapsed buildings. This evidences the highly improved SAR system after the 1999 Kocaeli earthquake.

As reported by Emergency Appeal Operation Update Turkey: Van Earthquake – Jan. 9, 2012 (www.ifrc.org), due to damaged housing and fear of aftershocks about two hundred thousand people are residing in temporary shelters (Fig 10), consisting of about 3,800 prefabricated Mevlana houses, about 2700 container houses and tents (14 tent cities and individual tents amounting to 72,500). Heath services are provided by about 3000 medical personnel in the sound hospitals and in 11 mobile field hospitals.

About 16,500 container houses (9000 in Erciş City, 2500 in Van City and rest in villages) are planned to be deployed as part of the shelter phase before the permanent reconstruction is realized. The reconstruction activities in the affected areas have already started in November. The preparations of foundations for the permanent reinforced concrete buildings that would eventually encompass about 30,000 housing units are currently en route and the reconstruction is foreseen to be completed within a year, at a cost of about 1 billion USD. For the total physical rehabilitation of Van Province the government plans to spend about 2 billion USD.

Earthquake Insurance

Total insured loss estimates made by EQECAT (www.eqecat.com) and by AIR Worldwide (www.air-worldwide.com) varied respectively between 100 - 200 million USD and between 55- 170 million USD.

A government-sponsored Turkish Catastrophic Insurance Pool (TCIP) is created in 2000 with the essential aim of absorbing the government's financial burden of replacing earthquake-damaged housing (www.tcip.gov.tr). As of January 2012, the number of sold policies is 3.757.000 that represents about 23% annual penetration. The annual average premium is USD 57 for an average insurance coverage of about US$36,000 per house, with 2% deductible. In Van province the number of policies sold was 7,318 (about 9% penetrations). The TCIP payment is expected to amount about 40 million USD.

Fig 10. Post earthquake temporary housing

REFERENCES

EQE-KOERI (2011), The October 23, 2011 Van, Turkey Earthquake (Mw=7.2), www.koeri.boun.edu.tr/News/23%20OCTOBER%202011,%20Mw=7.2%20VAN,%20TURKEY%20EARTHQUAKE_16_204.depmuh

Özden, Ş., E.Akpınar and H.M.Atalay (2011), Reconnaissance Report on Van Earthquake of October 2011, Kocaeli University.

Barka, A. and R. Reilinger, Active Tectonics of Eastern Mediterranean region: deduced from GPS, neotectonic and seismicity data, Annali Di Geofisica, X2(3), 587–610, 1997.

Erdik,M., K.Sesetyan, M.B.Demircioğlu, U.Hancılar and C.Zulfikar (2010), Rapid earthquake loss assessment after damaging earthquakes, Soil Dynamics and Earthquake Engineering.

DM&AYE (2011), 23 Ekim 2011 M7.2 Tabanlı - VAN Depremi, İTÜ Deprem Mühendisliği ve Afet Yönetimi Enstitüsü

Grünthal, G., (ed.), (1998). "European Macroseismic Scale 1998", Cahiers du Centre Européen de Géodynamique et de Séismologie Volume 15, Luxembourg.

METU-AFAD (2011), Processed Mainshock Accelerometric Recordings of the 23 October 2011 Van Earthquake, Report prepared by Earthquake Engineering Research Center (EERC)-Middle East Technical University and Earthquake Department Disaster Management and Emergency Presidency (AFAD), Ankara Turkey.

Çelebi, M., T.L.Holzer and K.M.Scharer (2011), Van, Turkey, M7.1 Earthquake of October 23, 2011, Report to USAID/OFDA, USGS, Dec., 2011.

AFAD (2011), Van Depremi (23 Ekim 2011) Raporu, Deprem Dairesi Başkanlığı, Aralık 2011

Koçyigit, A., Yilmaz, A., Adamia, S. ve Kuloshvili, S. (2001). “Neotectonics of East Anatolian Plateau (Turkey) and Lesser Caucasus: implication for transition from thrusting to strike-slip faulting,” Geodinamica Acta, 14, 177–195.

Akyüz, S., C.Zabcı and T.Sancar (2011), Preliminary Report on the 23 October 2011 Van Earthquake, İstanbul Technical University.

Ambraseys N. (2009), Earthquakes in the Mediterranean and the Middle East, Cambridge University Press, 947 pp.

Erdik, M. and N.Aydınoğlu (2004), Earthquake Performance and Vulnerability of Buildings in Turkey, The World Bank Group - Disaster Management Facility

Utkucu, M., E. Budakoğlu, H. Yalçın, H. Durmuş, H. Kalkan And L. Gülen (2011), 23 Ekim 2011 Van Depremi (Mw=7.2) Hakkında Ön Rapor, Sakarya Üniversitesi, Ekim, 2011

METU (2011), 23 Ekim 2011 Mw7.2 Van Depremi Sismik ve Yapisal Hasara İlişkin Saha Gözlemleri, Middle East Technical University, Earthquake Engineering Research Center, Kasim 2011 Ankara).

CEDIM (2011), Comparing the current impact of the Van Earthquake to past earthquakes in Eastern Turkey. CEDIM Forensic Earthquake Analysis Group – Report #4.

Emre, Ö., D.Y.Duman, S.Özalp and H.Elmacı (2011), 23 Ekim 2011 Van Depremi Saha Gözlemleri ve Kaynak Faya İlişkin Ön Değerlendirmeler, MTA, Ankara.