Organization for Development, Renovation and Equipping Schools of I.R.Iran (DRES)

A preliminary report on school buildings performance during M 7.3 Ezgeleh, Iran earthquake of November 12, 2017

Participants

Project Team

Mohammad Yekrangnia, DRES, Sharif University of Technology (m.yekrangnia@gmail.com)
Mahdi Eghbali, University of Zanjan (eghbali@znu.ac.ir)
Hamed Seyri, DRES
Mahdi Panahi, DRES
Saeed Y. Zanganeh, DRES
Mohsen Beyti, DRES
S. Vahid Hayatgheybi, DRES

Steering Committee

MohammadTaghi Nazarpour, DRES, Shahid Beheshti University
Hedayatollah Hasheminasab, DRES
Hamid Alyannezhad, DRES
Morteza Khebreh, DRES

Advisory Committee

Gholamreza Ghodrati Amiri, Iran University of Science & Technology
Abdoreza S. Moghadam, International Institute of Earthquake Engineering & Seismology

Prepared by: Technical and Supervision Deputy, Bureau of Technical and Research Engineering, Organization for Development, Renovation and Equipping Schools of I.R. Iran, No.6, Latifi Alley, Moosivand St., Shariati Ave., Tehran, Postal Code: 1933884883, Iran.

Introduction

On 12th November 2017, a magnitude 7.3 earthquake struck Kermanshah Province in Iran at 18:18 UTC (21:18 local time). Sarpol-e Zahab, Qasr-e Shirin and Eslamabade-e gharb counties have been the focus of most damages. Ezgeleh was the nearest city to the epicenter of the earthquake. More than 85% of the Iranian casualties were from Sarpol-e-Zahab County (www.tasnimnews.com), which have a population of over 80,000. Qasr-e Shirin and Islam Abade-e Gharb with the population of over 24,000 and 141,000 respectively suffered less than 20 losses. At least 440 people were reported to have died (http://www.entekhab.ir) and more than 9,400 others were injured (www.mehrnews.com). There are 7 cities and nearly 2000 villages which were affected by this earthquake. The total number of buildings exceeds 30,000 including at least 4,500 urban buildings and 11,500 rural settlements with severe daamges (www.tasnimnews.com).

According to the National Center of Broadband Seismic Network of Iran, the epicenter of the earthquake was located at 34.88°N and 45.84°E near the Iran–Iraq border with a local depth of 23 km. The focal mechanism solutions for this earthquake indicate a fault dipping shallowly to the east-northeast, or on a fault dipping steeply to the southwest [1]. The Kermashah province and its counties are shown in Fig. 1. The epicenter locations of the earthquake according to different reports are shown in Table 1 and Fig. 2 together with the faults in the area.

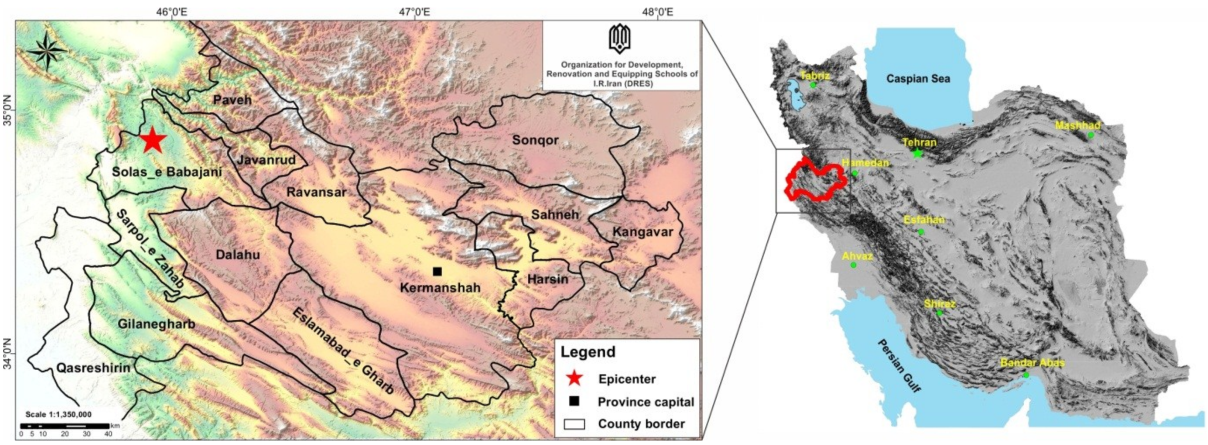


Fig. 1. Kermashah province and its counties in Iran

Table 1: Earthquake event characteristics

Reported by	Epicenter coordinates		Magnitude	Local depth, km
	Longitude	Latitude		
Institute of Geophysics University of Tehran (IGUT)	34.77	45.76	7.3	18
Iran Strong Motion Network (ISMN)	34.81	45.91	7.3	18
International Institute of Earthquake Engineering and Seismology (IIEES)	34.88	45.84	7.3	18
United States Geological Survey (USGS)	34.91	45.96	7.3	19
European-Mediterranean Seismological Centre (EMSC)	34.79	45.85	7.3	24

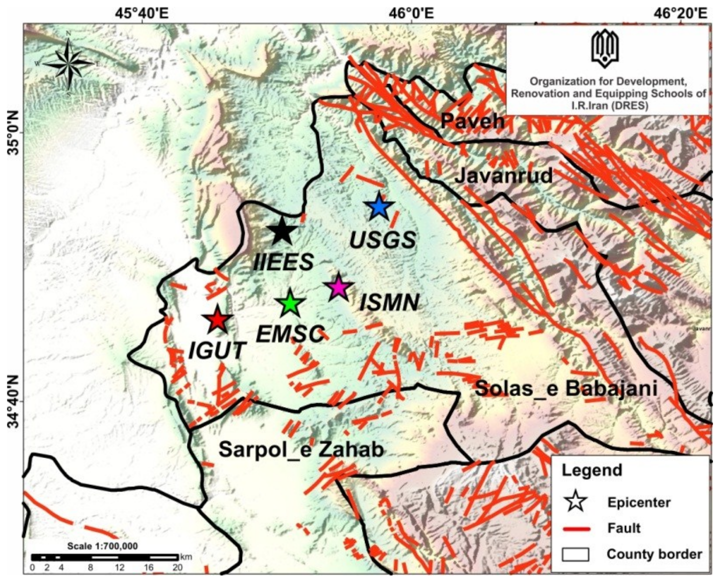


Fig. 2. Possible epicenter locations and the faults in the stricken area

The faulting mechanism of the event indicates thrust faulting, as a consequence of the Arabian plate moving northwards. In the area of this earthquake, the plate convergence occurs along a northwest-striking plate boundary and is related to the formation and uplift of the Zagros Mountains (Iran), which is a very seismic-prone area (https://www.egu.eu/news/373/iraq-iran-earthquake-what-we-know-so-far/).

This report presents the preliminary observations of the earthquake. Partial emphasis is made on the conditions of the affected school buildings evaluated by the reconnaissance teams from Organization for Development, Renovation and Equipping Schools of I.R. Iran (DRES). To the best of the knowledge by the authors of this report, the mentioned numbers and statistics are based on the authentic references which have been given full credit. Some photos used in this report were available in several public channels and groups; some of them are belonged to anonymous photographers. All the photos which were not taken by the authors of this report were credited to their photographers, unless the owners of the photos were unknown.

General information about the affected area

Cities and villages

Table 2 shows the total and student population of the affected counties in Kermanshah Province. It is estimated about 400,000 people including 56,000 students were exposed to a shaking intensity from VI to VIII (EMS98) during the earthquake.

Table 2: Total and student population of the affected areas

County	Total population (amar.org.ir)	Student population (dres.ir)
Islam Abad-e Gharb	141,000	20,400
Dalahou	36,000	5,800
Ghasr-e Shirin	24,000	3,000
Gilan-e Gharb	57,000	8,600
Salas-e Babajani	35,000	5,500
Sar-e Pol-e Zahab	80,000	13,500

Seismicity

The affected area witnessed several major seismic events, previously. An Ms=7.6 and mb=6.5 earthquake hit the Farsinaj region of Kermanshah province in 1957. The epicenter of the earthquake was located at 34.35°N and 47.67°E with about 35 km depth. This event resulted in heavy damages within an area of 2,800 km^2 with the 1,119 casualties, 900 injured and 15,000 homeless (http://www.tehrantimes.com/news/418596/7-3-magnitude-quake-in-Sarepol-e-Zahab). Also, the two earthquakes of year 958 and year 1150 with the magnitude of 6.4 and 5.9 near Sarpol-e Zahab caused vast number of collapsed buildings and heavy casualties [2]. The seismicity of the region is depicted in Fig. 3.

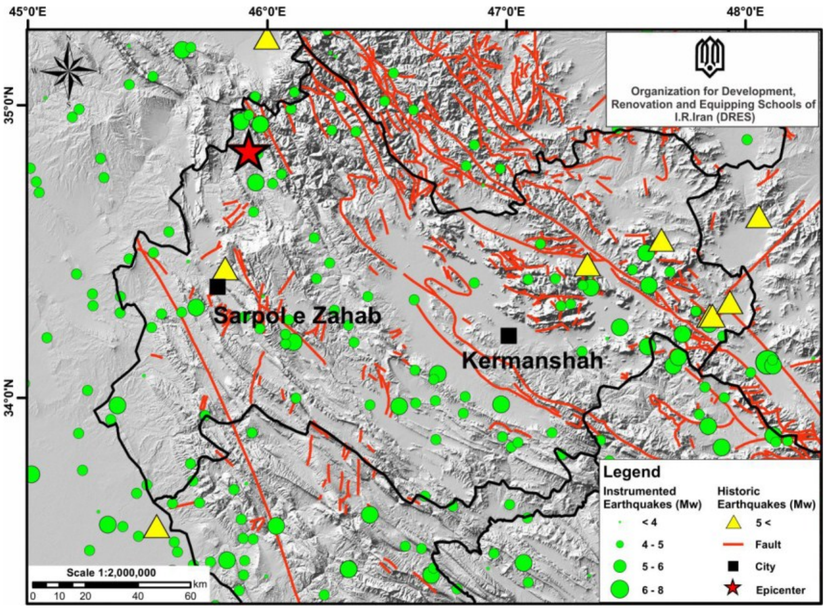
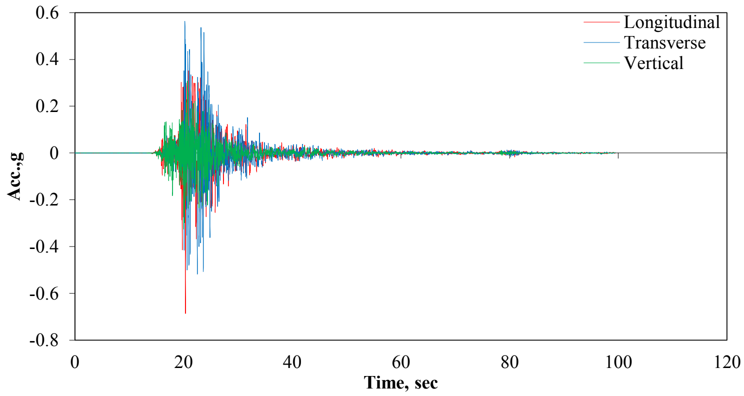


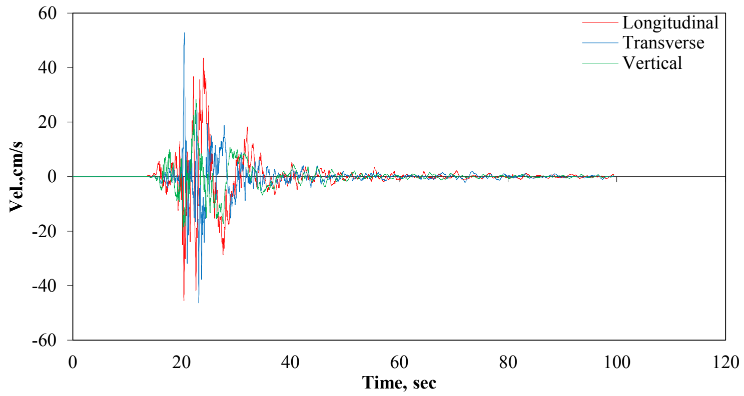
Fig. 3. Seismicity of the region

Main event

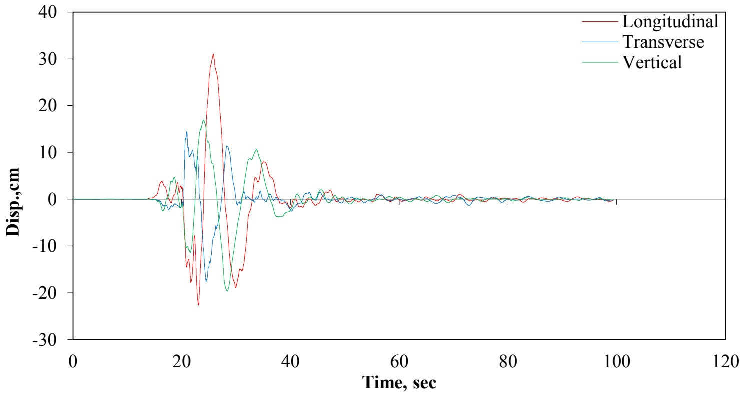
The strong motion of the main shock was recorded by 101 stations of the Iran Strong Motion Network. Among these records, the highest value corresponds to the station in Sarpol-e Zahāb with a corrected Peak Ground Acceleration (PGA) of 681 cm/s^2, 585 cm/s^2 and 358 cm/s^2 for N-S, W-E and vertical components, respectively (see Fig. 4) [3].



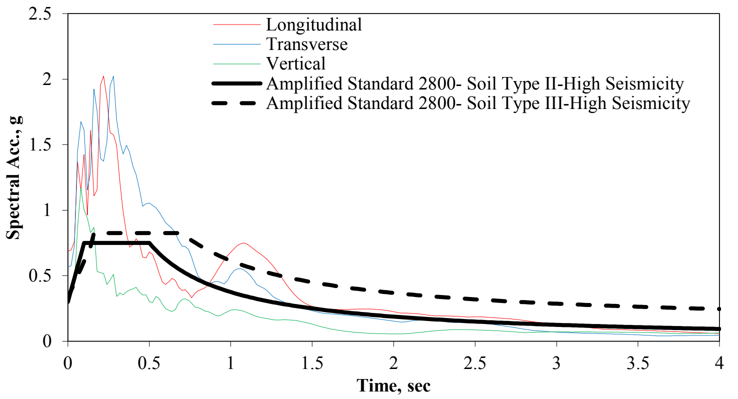
a) Acceleration time-histories



b) Velocity time-histories



c) Displacement time-histories



d) Spectral accelerations

Fig. 4. Time histories and spectral acceleration of the in Sarpol-e Zahāb station [4]

Foreshocks and aftershocks

The IIEES preliminary study reports that the earthquake had at least three foreshocks of 1.9~4.5 magnitude [1]. Based on the results of IGUT, there have been 1080 aftershocks with the 1.8~4.7 magnitude. Fig. 5 shows the location and magnitude of these foreshocks and aftershocks.

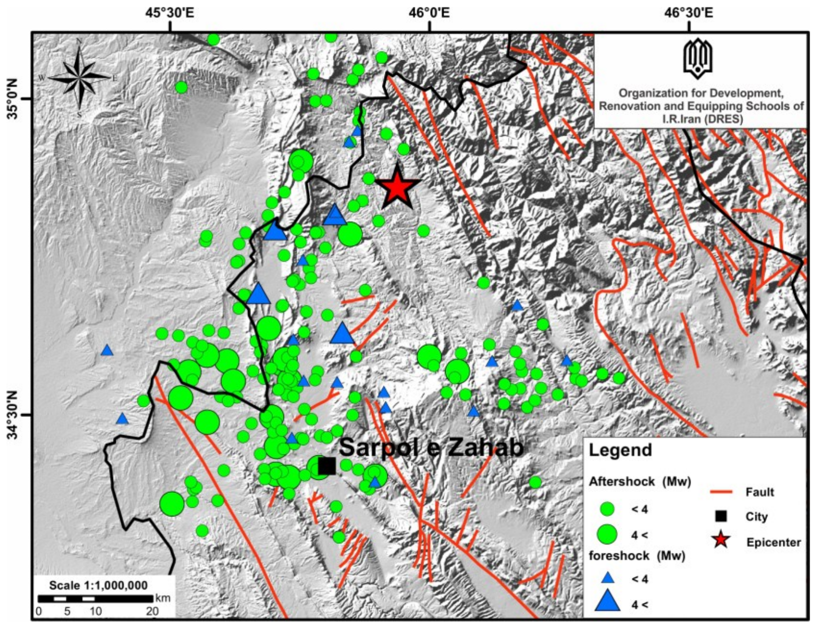


Fig. 5. Foreshocks and aftershocks (According to IGUT)

ShakeMap and PGA maps

The shakeMap of this earthquake in Modified Mercalli Intensity Scale according to USGS together with the distribution of the villages in the affected area is shown in Fig. 6. The variation of the recorded PGA in the region is shown in Fig. 7.

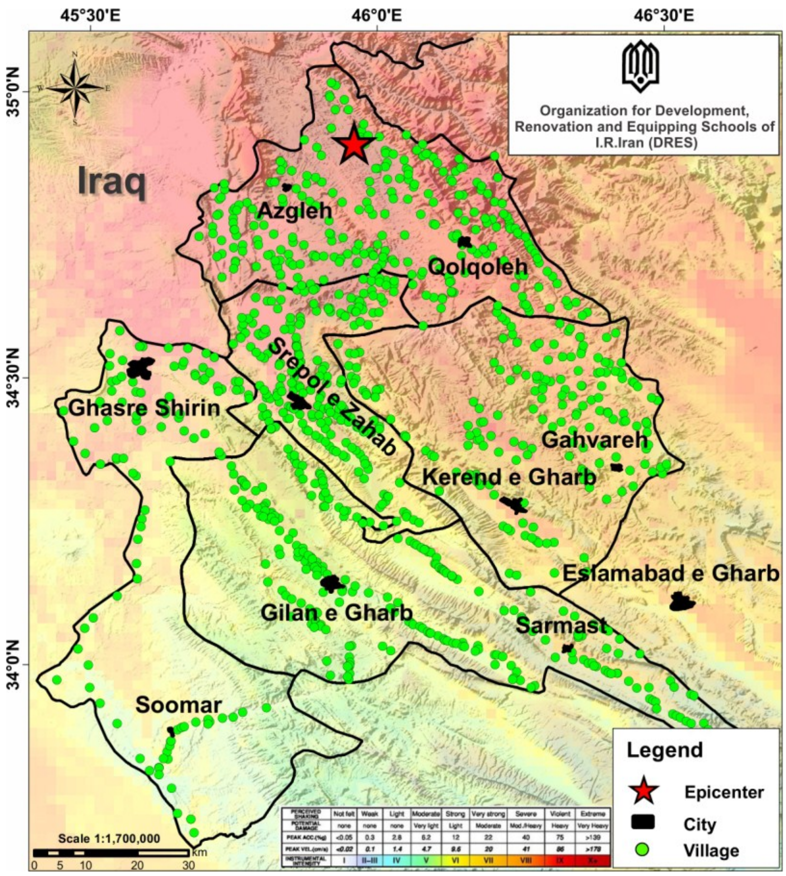


Fig. 6. Location of the villages together with the MMI map from USGS (usgs.gov)

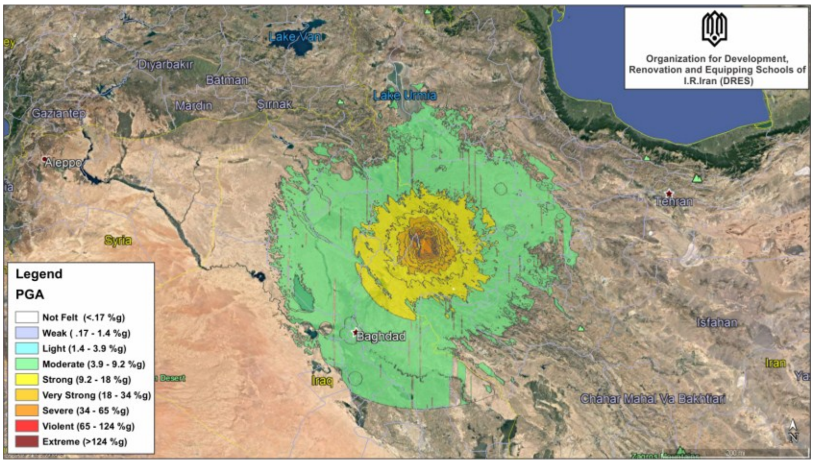


Fig. 7. Map of the variation of PGA (Classification in the legend is according to USGS)

Geotechnical hazards

According to the IIEES reconnaissance results, there have been several incidents of landslides with the approximate area of 4×4 km; also, at least 200 rock falls in an area of more than 2000 km^2 were reported by this team (see b)). Furthermore, few cases of liquefaction and surface rupture were observed [1].

a) Surface rupture (Photo from www.Mersadnews.ir)

b) Rock falls (Photo from IIEES)

Fig. 8. Examples of Geotechnical hazards

Buildings types

The taxonomy and distribution of the residential buildings in Kermanshah province and the buildings related to schools in Kermanshah province are shown in the affected counties in Fig. 9 and Fig. 10, respectively.

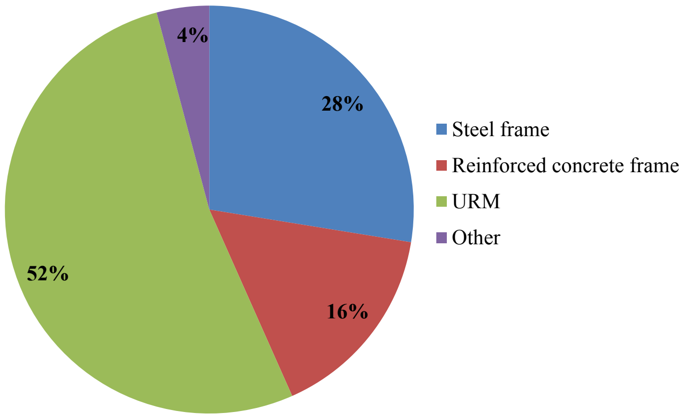


Fig. 9. Residential buildings taxonomy in Kermanshah province (amar.org.ir)

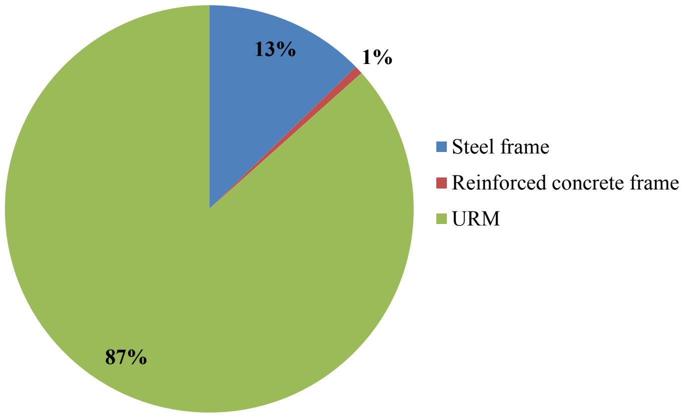


Fig. 10. Buildings related to schools in the affected counties in Kermanshah province (dres.ir)

The UNITAR-UNOSAT analysis identified 683 damaged structures by taking into account the pre-disaster footprints provided by approximately 9700 structures. The results show about 7 % of the total number of structures within Sarpol-e-Zahab. The damage density highlights that the neighborhood of Maskan-e Mehr and the area around the Post Office are amongst the most affected zones (see Fig. 11). An example of a collapse residential building is shown in Fig. 12.

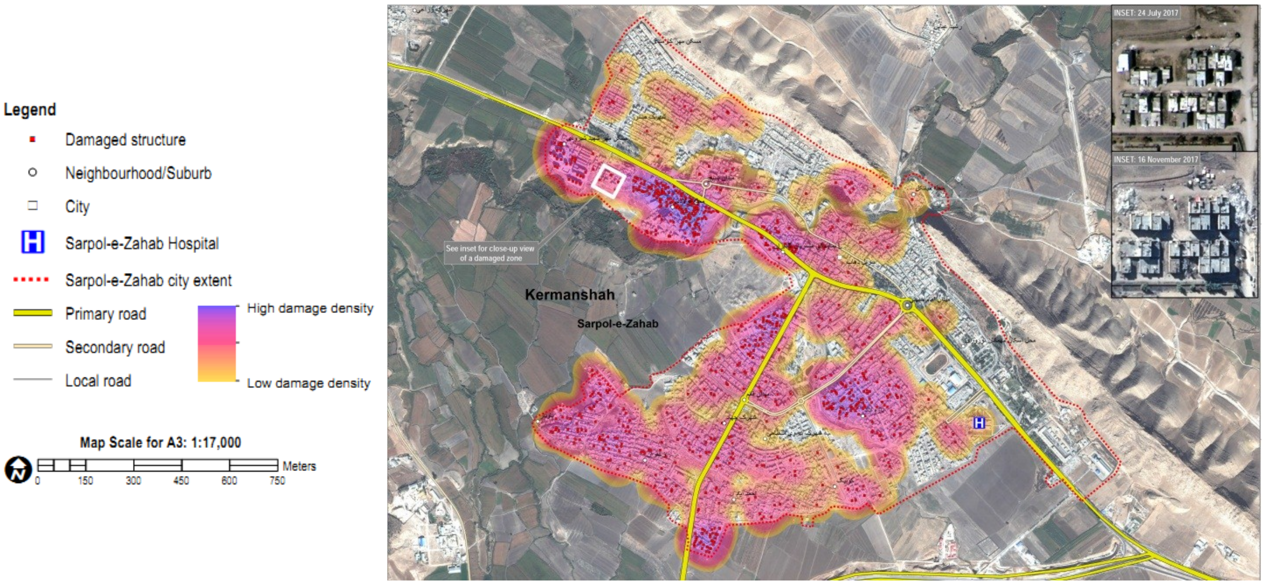


Fig. 11. Damaged structures and related density map in Sarpol-e-Zahab (https://unitar.org/unosat/)

Fig. 12. An example of a collapse residential building (www.tabnak.ir)

School buildings

In a preliminary rapid evaluation of all the school buildings by 17 teams from the provincial office of DRES, the post-earthquake conditions of all of the school buildings in Kermanshah were determined. Out of 787 school buildings (including 2854 classrooms) in the affected area, 709 schools having 2439 classrooms, constituting 89% of all the school buildings in the affected area, were remained intact and passed the level of Immediate Occupancy (IO). The majority of the damaged schools are URM with no confinement, which date back to more than 30 years ago. Examples of structural damages in URM school buildings are depicted Fig. 13 to Fig. 15. There are two URM school buildings which experienced collapse. In some cases, the infill walls with clay blocks showed brittle cracking, while those made of sandwich panels remained intact (Fig. 16). There were several cases of damages to nonstructural elements especially in the form of overturning of the fence walls, falling of the furniture and masonry/stone veneers (Fig. 17).

a) Collapse of school building

b) A partially collapsed school building

Fig. 13. Total and partial collapse of old URM school buildings with no confinement

a) A classroom with severe cracks in URM walls

b) Major shear-sliding cracks at the URM walls

c) A two-story building with some shear cracks at the corner of the opening

d) A confined masonry with severe cracking at the base level

Fig. 14. Severe cracks in URM school buildings

a) Slight damages in URM walls

b) Moderate shear-sliding damages in URM walls

Fig. 15. Slight to moderate damages in URM school buildings

a) Major cracks and crushing of an infill wall at the base level of a three-story steel frame with shear walls

b) Cracks in the infill walls of a single-story moment-resisting frame

Fig. 16. Examples damages to the infill walls with hollow clay blocks

a) Falling of walls' finishing

b) Collapse of fence walls

Fig. 17. Examples of nonstructural damages in school buildings

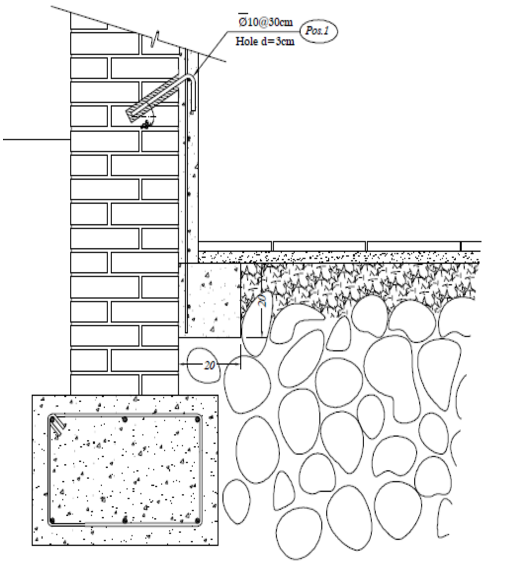
Some of the vulnerable URM school buildings were retrofitted by shotcreting of peripheral walls; these buildings showed satisfactory performance with very fine cracks at the corner of some of the walls (Fig. 18). Some details and construction phases of shotcreting of URM school buildings are shown in Fig. 19. By the way, the performance of retrofitted and recently-constructed school buildings was satisfactory compared to many other buildings in the affected area which in some cases led to their use as a temporary disaster management center. Based on the field observations, it can be concluded these buildings passed the Immediate Occupancy (IO) performance level [5-7]. Fig. 20

and Fig. 21 show examples of school buildings with acceptable performance. Generally speaking, all the school buildings including the URM buildings which were designed and constructed according to the Iranian Code of Practice for Seismic Resistant Design of Buildings (Standard 2800) [8], showed satisfactory performance with none to slight damages. These include but not limited to the recently-built school buildings. The recovery program consisting of construction of new school buildings has already begun.

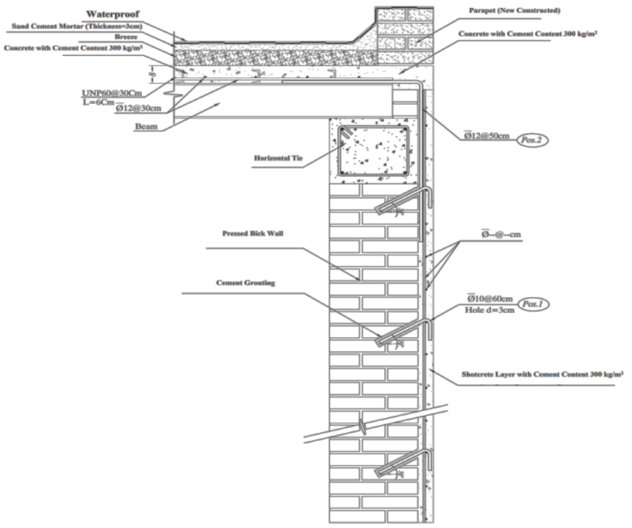
a) The building with few hairline cracks on some of the walls

b) The retrofitted single-story unconfined URM building adjacent to the appendant newly-constructed confined URM building; both of which experienced very fine cracks

Fig. 18. None to a few very slight cracks in the retrofitted school buildings by shotcreting of peripheral walls



a) Details of the connection of the shotcrete layer to the foundation



b) Details of the connection of the shotcrete layer to the wall the roof

c) Installed steel grid

d) Shotcrete

Fig. 19. Some details and construction phases of shotcreting of URM school buildings

a) A URM school in Sarpol-e Zahab; collapse of the adjacent residential buildings on the right is visible

b) A URM school in Sarpol-e Zahab; collapse of the adjacent residential buildings is visible

c) A complex of school buildings in Dalahoo; collapse of the adjacent residential buildings is shown on the left bottom

d) The undamaged school building in Sarpol-e Zahab which became the disaster management center

e) Using a school building as the immediate sheltering center

f) Unfinished school building with no damages

g) Using a school building by armed forces as one of the centers of command of task force

h) Using a playground in a school for storing the necessary supplies (mainly donated by people)

Fig. 20. Examples of school buildings with acceptable performance

a) External view

b) Internal view

Fig. 21. Examples of steel frame school buildings with acceptable performance

Conclusions

The 12th November 2017, magnitude 7.3 earthquake in Kermanshah Province can be regarded as a testimony to the importance of design and construction as per the regulations of the design codes. There were several cases in which poor design and/or construction deficiencies due to lack or insufficient supervision resulted in collapse or major damages to the newly-constructed frame buildings; whereas most of the URM buildings, widely regarded as one of the most vulnerable structural systems, which were constructed according to the codes regulations, responded satisfactorily against this major earthquake. All the retrofitted school buildings behaved satisfactorily. Few newly-constructed school buildings experienced damages in nonstructural parts and/or infill walls made of hollow clay blocks. In general, 11% of school buildings, mostly the old URM's, located in the affected areas experienced slight to severe damages. The remaining 89% of the school buildings in the affected area passed the immediate occupancy performance level. The preliminary results show that in some regions, the earthquake posed seismic demands which are considerably higher than those of the codified design-level earthquakes. As a result, severe damages in the buildings, including school buildings, located in those regions may be justified; though additional evaluations and analyses of the characteristics of the earthquake in different sites, soil conditions, structural materials and details are necessary to draw any further conclusions. The more frequently observed structural damages in some representative school buildings with their location in the stricken area are shown in Fig. 22.

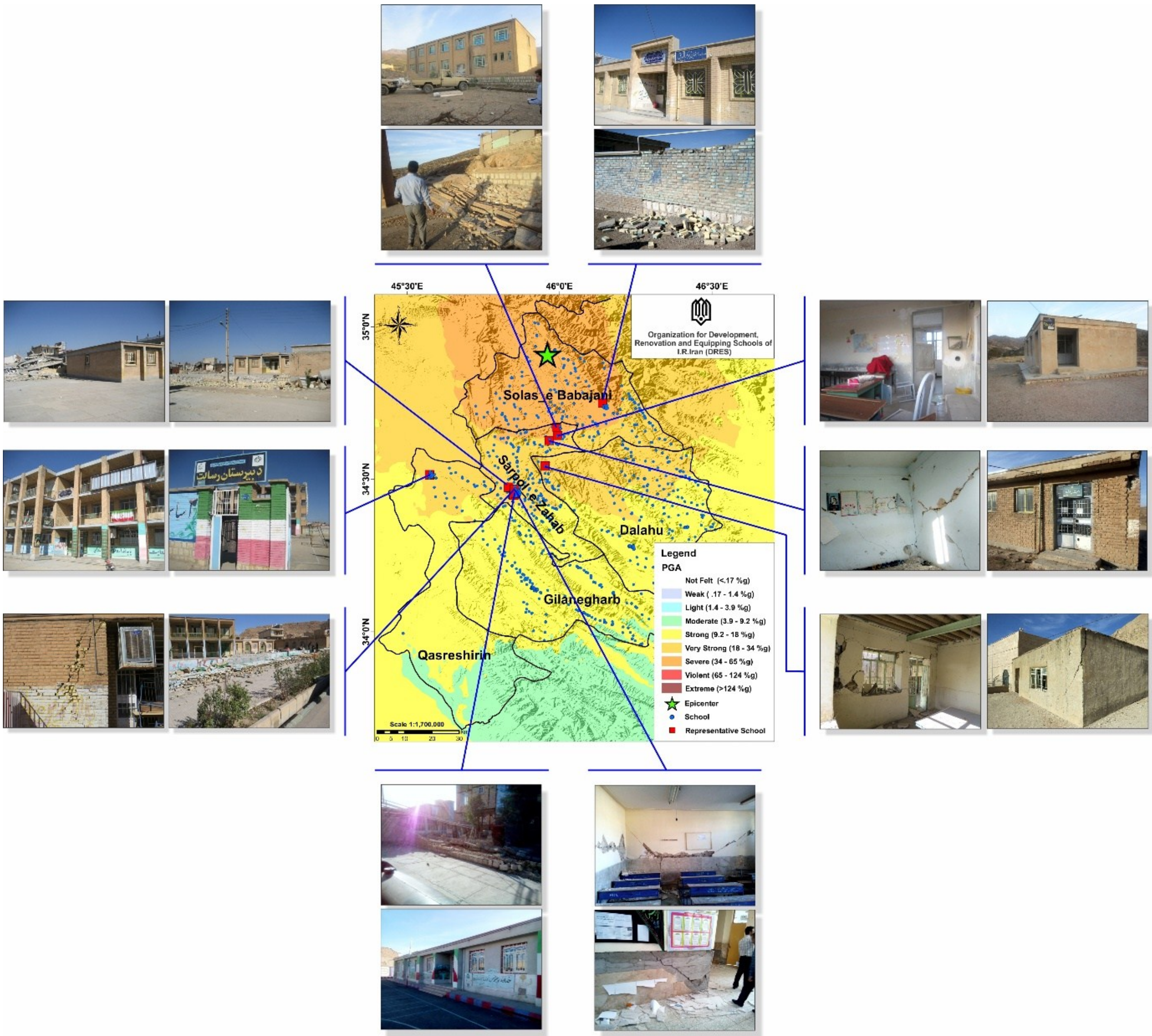


Fig. 22. Structural damages in some representative school buildings

Acknowledgments

The authors of this report would like to thank the DRES members in Kermanshah provincial office for performing post-earthquake rapid assessment of all the school buildings in Kermanshah province and their sincere cooperation with the reconnaissance team from the central office of DRES. Appreciation is also extended to the endeavors of all the people who contributed to the national effort in improving the seismic performance of Iranian school buildings since 2003.

References

[1] Preliminary report on 12th November 2017, magnitude 7.3 earthquake in Sarpol-e Zahab, Kermanshah Province, 3rd Edition, November 2017, International Institute of Earthquake Engineering and Seismology (IIEES), Tehran, Iran (in Persian).

[2] Ambraseys, N.N., & Melville, C.P. (2005). A history of Persian earthquakes. Cambridge university press.

[3] Immediate-preliminary report on 12th November 2017, earthquake in Sarpol-e Zahab, Kermanshah Province, November 2017, Road, Housing & Urban Development Research Center (BHRC), Tehran, Iran (in Persian).

[4] Iran Strong Motion Network, Building & Housing Research Center (BHRC)

[5] Rossetto, T., & Elnashai, A. (2003). Derivation of vulnerability functions for European-type RC structures based on observational data. Engineering structures, 25(10), 1241-1263.

[6] Council, B. S. S. (1997). NEHRP guidelines for the seismic rehabilitation of buildings. FEMA-273, Federal Emergency Management Agency, Washington, DC.

[7] American Society of Civil Engineers. (2014). Seismic Evaluation and Retrofit of Existing Buildings: ASCE Standard ASCE/SEI 41-13. American Society of Civil Engineers.

[8] Iranian Code of Practice for Seismic Resistant Design of Buildings (Standard 2800). 4th edition, 2015, Building and Housing Research Center, Iran (in Persian).