# Site Investigation of the Ahar-Varzeghan Earthquake in NW Iran of Auguest 11, 2012

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**Key facts:**

- Hazard type: Earthquake
- Date of disaster: August 11, 2012
- Location of the survey: East Azarbaijan County, Iran
- Date of the field survey: August 26th - 31st, 2012
- Key findings:
    1) The two earthquakes occurred as a result of oblique strike-slip faulting in the shallow crust of the Eurasian plate. These earthquakes lay as inter plate type.
    2) The maximum peak ground acceleration of the first event was 478 cm/s/s on horizontal component recorded in Satarkhan dam and it of the second event was 532 cm/s/s on horizontal component recorded in Varzaghan.
    3) The deaths were more than 330 persons. The significant amount of the death toll and structural damages are from adobe and stone buildings.
    4) Electricity network of 25 villages were totally damaged. Electricity rafts located on fault have fallen but rest of them in further distance from the fault was undamaged.
    5) Earthquake caused gas network cut off for 18 thousand domestic users in stricken areas.
    6) No significant damage was reported on water network.

***Key Words :*** *the Ahar-Varzaghan Earthquake, field investigation, damage to houses and buildings, damage to lifelines*

## 1. INTRODUCTION

On the late afternoon of Saturday August 11, 2012 the northwest of Iran was shaken by two of the strong earthquakes in Iranian history (See **Fig. 1**). First was hit by 6.4 *Mw* at 16:54 local time (12:23 GMT), and about 11 minutes later, a 6.3 *Mw* struck 10 km to the west. Preliminary estimates placed, and the deaths were more than 330 persons and the number of injured persons was about 26,000 and overall, more than 50,000 persons have been resettled. As many as 365 villages, out of total of 537 in the affected area, are heavily damaged (between 50% and 90%) and 46 villages are completely devastated. Successively Varzeghan-Ahar earthquakes are the cluster ones or "earthquake sequence", and involved more than hundreds moderate and small temblors and are centered on Varzeghan area.

Japan Society of Civil Engineers has decided to dispatch an advance team of reconnaissance of this earthquake and pointed Prof. Miyajima of Kanazawa University as a team leader. The advanced team has done field investigation between 26th and 31st of August, 2012. This report outlines the findings obtained through the quick survey. Some descriptions in this report are not fully evidenced yet, and therefore, some comments are not yet the conclusions reached after through discussions among the members.

## 2. SEISMISITY AND EARTHQUAKES

Actually earthquake occurred in narrow belts. Azarbaijan is the site convergent plate collisions along the Alpine-Himalayan active mountain belt.

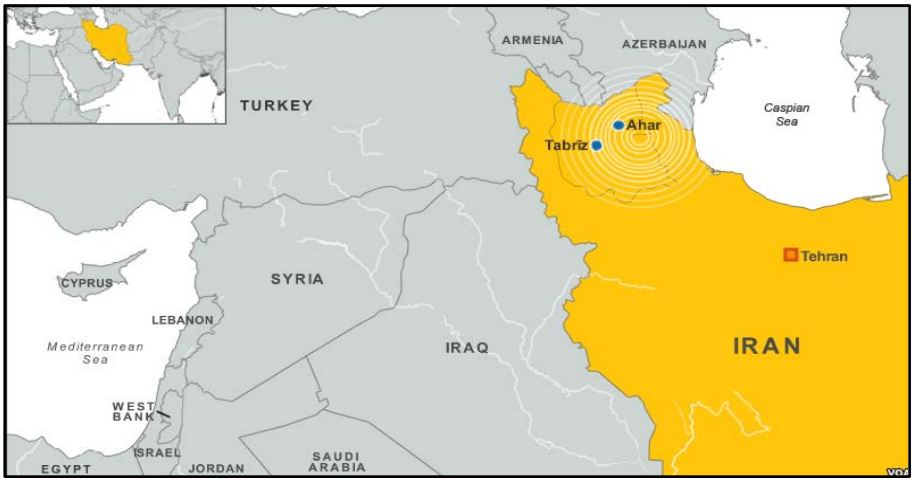


**Fig.1** Location of Ahar and Tabriz

Brittle faults in Azarbaijan belong mostly to Cenozoic of younger in Quaternary Age. Geological setting of the area consists of sedimentary, volcanic-sedimentary, plutonic and volcanic, and terrestrial deposit embracing almost entire stratigraphic range beginning from early Mesozoic through Quaternary time.

In fault zones, an earthquake causes rocks to expand and become more porous. The two earthquakes in NW of Iran occurred as a result of oblique strike-slip faulting in the shallow crust of the Eurasian plate, approximately 300 km east of the plate boundary between the Eurasia and Arabian plates. The earth's crust thickness in Azarbaijan region is in the range from 38 km to 55 km, and the earthquakes depth was around 10 km. Varzeghan-Ahar earthquakes lay as inter-plate type and earthquakes of this type account for more 90% of the total seismic motions around the world. The relatively tight distribution of aftershocks within 20 km of the second event, leads me suggest that there is no migration towards the main fault (North Tabriz Fault).

Several local and international seismological centers have determined the position of these earthquakes as shown in **Figs.2**, **3** and **Tables 1**, **2**.

The total number of aftershocks larger than 2.5 on the Richter scale was recorded by the Institute bandwidth seismic network before 14 August 2012 was equal to 300. The two aftershocks greater than magnitude 5, 15 aftershocks 4.1 to 5 magnitude, 114 aftershocks 3.1 to 4 magnitude, 169 aftershocks between 2.5 to 3 magnitude, have been estimated. The number of aftershocks greater than magnitude 3 in first three days after earthquake was 105, whereas earthquake was not expected in this region, and it shows that the different regions of the country has the potential of seismicity. **Fig.4** indicates the total number of aftershocks greater than 3.0 in relation to the days after the main shock.

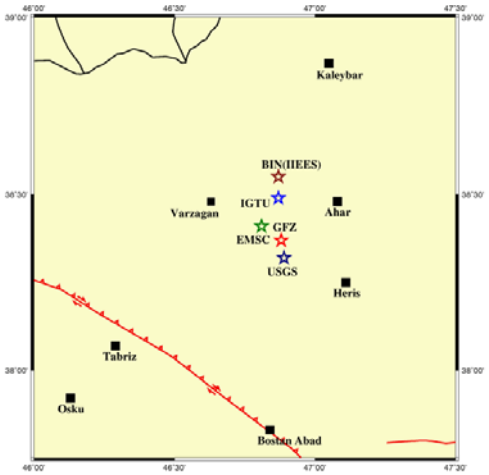


**Fig.2** Epicenter of Ahar- Varzaghan first earthquake determined by the various seismological centers[1)]

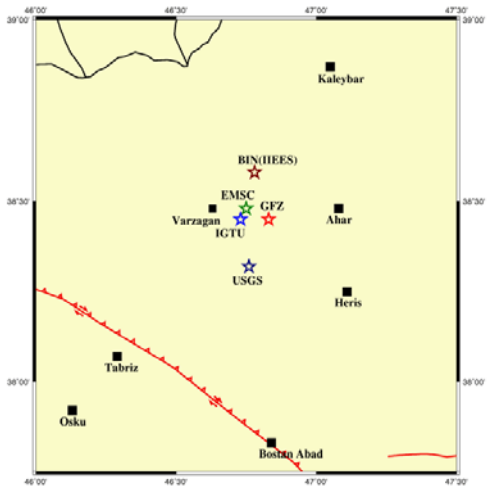


**Fig.3** Epicenter of Ahar- Varzaghan second earthquake determined by the various seismological centers[1)]

## 3. SEISMOGRAPHS

Epicenters of these events based on registered

seismographs in the national broadband seismic network of the Institute is in the coordinate of 38.55 degree of northern latitude and 46.87 degree of eastern longitude for the first earthquake, and in the coordinate of 38.58 degree of northern latitude and 46.78 degree of eastern longitude for the second earthquake. This event was registered by national broadband seismic network of the International Institute of Seismology and Earthquake Engineering. Ahar's and Varzeghan's earthquake occurred at a depth of 10 km, which the acceleration of the first earthquake was 0.4 g and the acceleration of the second earthquake was 0.5 g. **Figs.5**,**6**,**7**, and **8** show seismographs of both earthquakes in the stations of Varzeghan and Ahar according to Housing and Building Research Center (BHRC) website.

According to these seismographs, the maximum peak ground acceleration of the first event was 478 cm/s/s on horizontal component recorded in Satarkhan dam and it of the second event was 532 cm/s/s on horizontal component recorded in Varzaghan.

## 4. DAMAGE TO HOUSES AND BUILDINGS

### (1) Adobe and stone buildings

Most of the existing buildings in the villages of the earthquake hit area are from the adobe and few are form stone. Since the mortar used in these two classes of buildings is from mud, so they are brought here together. The other common characteristic of these buildings is the cover of the roofs. The roofs are composed of wood lumbers that normally are laid on the surrounding wall about 60 to 90 cm from each other. The lumber working as main beams are covered by woods or wicker mats. Thereafter, the roof is covered by a thick layer of mud for isolation. The process is sometimes completed by a bituminous insulator.

These types of buildings are very brittle and weak against earthquakes. And the significant amount of the death toll and structural damages are from these buildings. The mechanism of the damages that mostly in total is that the walls occurring across the earthquake waves are separated from the rest of the building and the roof that has lost its support collapses(**Photo.1**). The field observations showed that the main reasons of the collapse of these buildings are:

(a) Lack of any kind of connection between cross walls.
(b) Use of lumbers as the main beam in the roof without any effective connection between themselves and the supporting walls. The used lumbers are sometimes very heavy.
(c) Decay of the lumbers that are very potential for collapse even under the weight of the roof alone.

There is an exemption that may be referred to as the Jame Mosque of Varzegan that was from stone but with cement mortar. The roof of this building also was different and made from steel beams filled by brick arches, a roof type that was very common in masonry buildings in Iran before about 20 years ago. The building that has suffered moderate damages had not collapsed.

**Table 1** AHAR- Varzaghan First earthquake profile, reported by various seismological centers[1)]

| Date & Time (UTC) 2012/08/11 12:23:16 | | | | | |
|---|---|---|---|---|---|
| Date & Time (Local) 1391/05/21 16:53:16 | | | | | |
| | Latitude | Longitude | Depth (Km) | M | Type |
| BIN | 38.55 | 46.87 | 15 | mb | 6.1 |
| IGTU | 38.49 | 46.87 | 10 | $M_N$ | 6.2 |
| EMSC | 38.41 | 46.81 | 10 | $M_w$ | 6.4 |
| USGS | 38.32 | 46.89 | 10 | $M_w$ | 6.4 |
| GFZ | 38.37 | 46.88 | 10 | $M_w$ | 6.4 |

**Table 2** Ahar- Varzeghan Second earthquake profile, reported by various seismological centers[1)]

| Date & Time (UTC) 2012/08/11 17:34:35 | | | | | |
|---|---|---|---|---|---|
| Date & Time (Local) 2012/08/11 17:04:35 | | | | | |
| | Latitude | Longitude | Depth (Km) | M | Type |
| BIN | 38.58 | 46.78 | 16 | mb | 6.1 |
| IGTU | 38.45 | 46.73 | 10 | $M_N$ | 6 |
| EMSC | 38.48 | 46.75 | 10 | $M_w$ | 6.3 |
| USGS | 38.32 | 46.76 | 10 | $M_w$ | 6.2 |
| GFZ | 38.45 | 46.83 | 10 | $M_w$ | 6.3 |

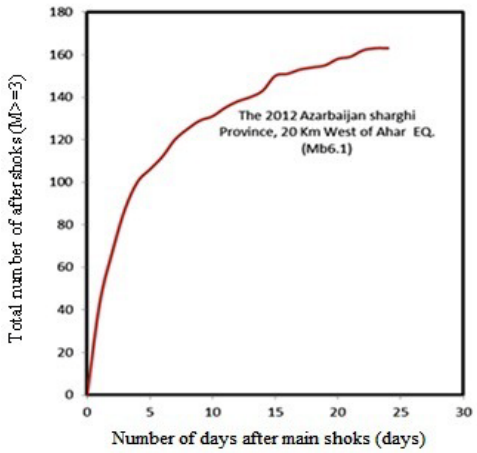


**Fig.4** Number of aftershocks (IIEES[1)])

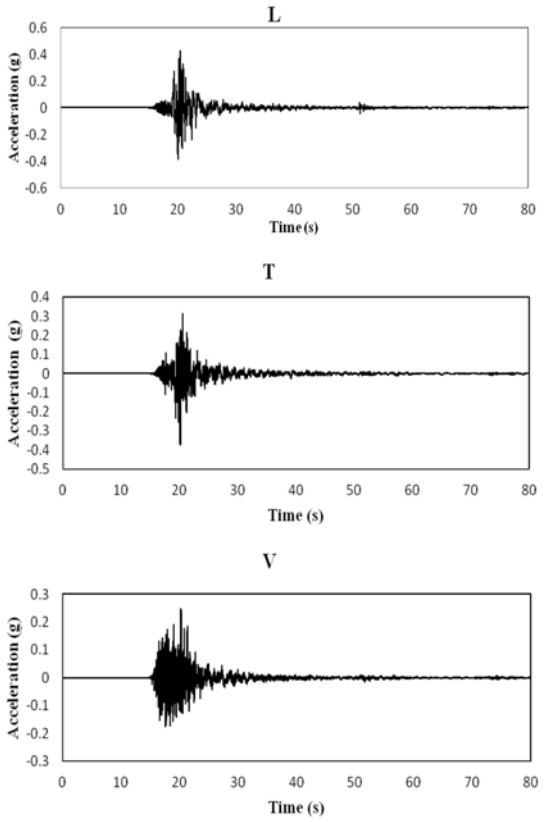


**Fig.5** First earthquake records at Varzeghan station 2012/08/11- 12:23:15 (BHRC[2)])

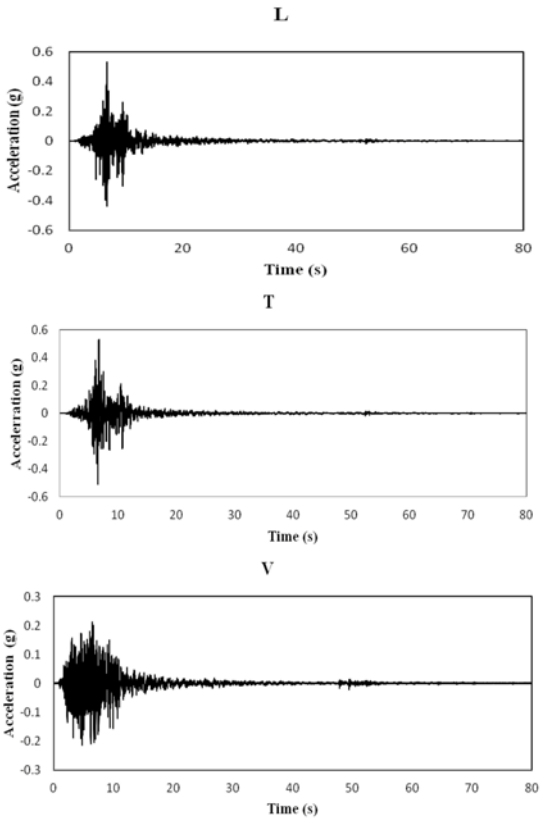


**Fig.7** Second earthquake records at Varzeghan station 2012/08/11- 12:34:35 (BHRC[2)])

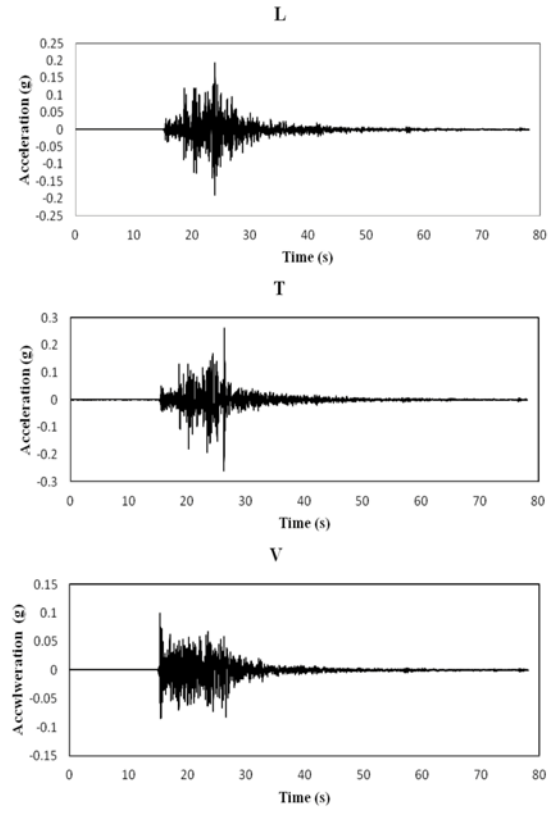


**Fig.6** First earthquake records at Ahar station 2012/08/11- 12:23:15 (BHRC[2)])

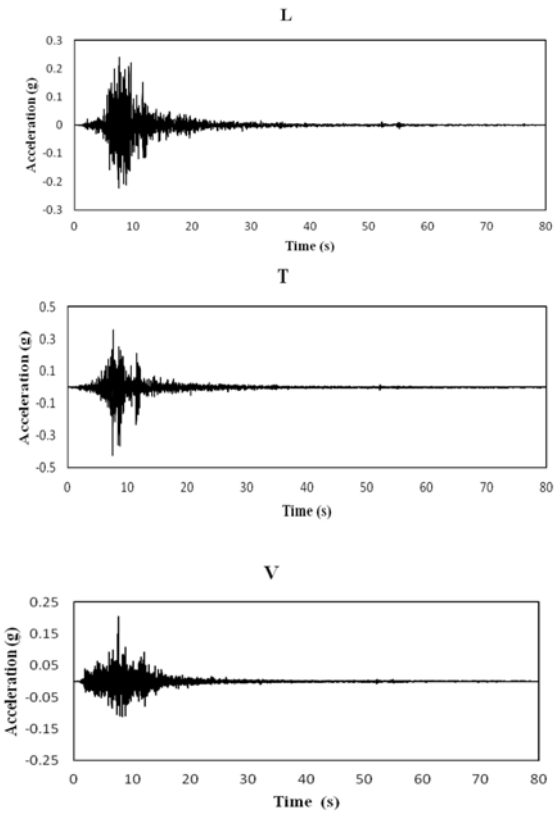


**Fig.8** Second earthquake records at Ahar station 2012/08/11- 12:34:35 (BHRC[2)])

**(2) Brick buildings**

In this report brick building is referred to buildings that comprise of surrounding brick masonry walls and some internal steel columns. The roofs of these buildings are built with steel rolled beams filled in between by brick arches. This type of building was very common in Iran before about 20 years and at the moment is not allowed by the building authorities in Iran. The mortar is from sand and cement. The beams of roof are sometimes connected transversally to each other by bars to ensure their integral action. However, there is not an effective connection between the wall and the roof in this method of construction.

The observations showed that this type of building has not experienced total collapse. But the large amount of serious cracks in walls and wall and roof connections are apparent (**Photo.2**). The quality of bricks used in these buildings is very different. However, it was observed that this item has not effective parameter in the behavior of the building and rather the details of connections of walls to each other and to the roof or details around the openings are more important.

Observations showed that in the case of lack of bracing of roof beams, some major damages are encountered, likely:

(a) Fall of some part of arches between the steel beams.
(b) Break of arches near the supporting steel beams.
(c) Cracking of the roof and falling of covering gypsum.

There existed huge amount of shear cracks in this type of building. Wall collapse also was visible. Bending mode cracks were also observed, however, this type of crack was suppressed by falling off the walls.

**(3) Half reinforced masonry buildings**

Half reinforced buildings are comprised of tie columns and bond beams filled with masonry walls and covered by ordinary joist concrete beams shown in **Fig.9**. This type of buildings has grown to be used in villages after promotion by the Housing Foundation of Iran.

These buildings showed much better behavior in the course of the recent earthquake and there was not observed any total collapse in them. However, most of these buildings tolerated some minor damages and few of them even involved serious damages (**Photo.3**). The main reason for the damages can be mostly attributed to the following factors:

(a) Lack of construction of suitable connection detail of tie columns and bond beams. Or missing some tie columns amid long walls.

**Photo.1** Damage to adobe buildings

**Photo.2** Damage to brick buildings

**Photo.3** Damage to half reinforced masonry buildings

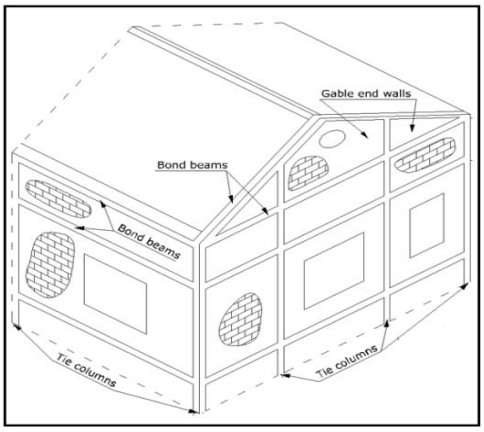


**Fig.9** Structure of half reinforced masonry building

(b) Use of poor quality concrete and providing low diameter reinforcement. Also, compaction of concrete during construction is not done as appropriate.
(c) Construction of a specified map required by the Housing Foundation for use of loan according to the code of practice of Iran (Code No 2800) and addition of some rooms without tie columns and bond beams later.
(d) Lack of a proper connection of surrounding beam and columns to the filling walls. This factor is responsible for the utmost of the damages in these buildings.

Factors (b) and (d) are the major damages amount in the earthquake hit areas. However, it seems that if some more attention to be paid for the supervising the construction of these buildings and also a book of commented details are provided by the authorities for the connections, the future damage statistics would decrease significantly.

**(4) Concrete buildings**

Concrete buildings are mostly constructed in cities like Ahar, Heris and Varzegan. These buildings are designed and constructed under supervision of engineers. The observations showed no serious damages in these buildings. This is expected in an earthquake intensity of 6.3. However, the most considerable damage for the concrete buildings could be mentioned as crack and collapse of in-filled walls (**Photo.4**). The other type of damage was throwing out of windows because of lack of proper connection of them to the surrounding walls, pour of façade also because of lack of connection of the façade material to the main wall body. It seems that a major reason for the existing damages of the half reinforced and concrete buildings is the lack of a qualified detail handbook specified by the authorities that should be used in the course of construction.

The other weakness of the concrete building is use of clay voided blocks which are very dense and brittle. These blocks do not provide proper bond with the poor quality mortar which is provided normally in construction of walls and therefore they crack or move during ground motion. The other factor is brittleness of the clay blocks which is not adaptable with the ductility of the concrete frames and with any draft of the frames the infilled clay walls. Eventually the walls crack or break and some time jump out in the transverse direction or tolerate serious diagonal shear cracks which cause spalling of gypsum in the walls.

The case of the Hospital of Varzegan was different. In addition to the aforementioned damages, there were signs of structural damage in the concrete columns of the last story of the building.

**(5) Steel buildings**

Steel buildings are also confined to the cities and are constructed under supervision of engineers. There were not observed serious damage in these buildings. However the same vulnerability discussed for the concrete buildings are seen for steel buildings. Except that in some of the steel buildings the necessary bracing was not provided.

A case that worth of being considered specifically is a two story braced steel building. There was a

**Photo. 4** Damage to reinforced concrete buildings

**Photo. 5** Damage to steel buildings

buckling in one of the bracings of the building and also a rupture in the connection of the gusset plate to the web of the column. Also the main column had buckled because of pounding of a part of stair ramp connection to the column (**Photo.5**).

## 5. DAMAGE TO HISTORICAL BUILDINGS

According to province bureau of historical and cultural heritage, earthquake has caused 30 to 35 percent damage on Ahar Bazaar due to ceiling fall in some parts of it. Ahar Bazaar is similar to Tabriz Bazaar and is one of the Iranian national monuments. This Bazaar is the second largest roofed bazaar in East-Azarbaijan after Tabriz Bazaar. Due to this earthquake, “Atayi House” as one of most famous monuments is damaged 50 percent. Dome of literature and spirituality museum, tomb of “Sheykh Shahab-al-Din”, is damaged 20 to 30 percent in which a fracture is happened. Caravanserai of “Goyja-Bel” is damaged 10 to 15 percent. Another famous building of Ahar, “Dr. Qasem-Khan” home is damaged 10 to 15 percent. Another famous building of Ahar, “Amir arshad” home is damaged 25 to 30 percent, including some cracks in walls and ceiling.

## 6. DAMAGE TO BRIDGES

In general, structural damage was not considered in the bridges of the earthquake hit region. The slab bridges that are very common for low span bridges were all safe and ready for use. However, it was apparent that some soil settlement had occurred in both sides of these bridges. The reason for this is the poor compaction of the adjacent soil to the abutments.

The masonry arch bridges also were safe and the reason is that they get low spans. From three major bridges that were investigated in the region, one was in the road of Ahar to Varzegan. This bridge is a 5-span concrete bridge (No. 1), the second was an old 6-span composite bridge in Varzegan and the last one was a new 3-span integral composite bridge. In all of the above mentioned bridges the expansion joints have become active during the ground motion. And all of the spans of the bridges adjacent to the joints have experienced some minor or moderate movements. In the case of the bridge No.1, some lateral movement was observed in the first span of the bridge (**Photo.6**). This movement was restricted by the shear block of the pier. However, some cracks have been induced in the shear block as a result.

In bridge No. 2, the movement was clear and almost all the spans had lateral movement (**Photo.7**). The main reason for this fact was that no shear block was provided for the bridge and only the friction between the beams and pile has overcome the exceeding movement.

In bridge No. 3, no lateral movement was observed (**Photo.8**). Since this bridge was integral and the main beams was continuous composite beams, there was not any lateral or transverse movement in the body of the bridge. However, there were apparent cracks both in the beginning and at end of the bridge in the joint locations in the asphalt.

**Photo.6** Damage to 5-span concrete bridge (No.1)

**Photo.7** Damage to 6-span composite bridge (No.2)

**Photo.8** 3-span integral composite bridge (No.3)

## 7. DAMAGE TO LIFELINES

Electricity network of 25 villages (under control of Tabriz head office) are totally damaged. Electricity rafts located on fault have fallen but rest of them in further distance from the fault was undamaged. According to Tabriz bureau of electricity power, damages to electrical power networks in 25 villages, under control of Tabriz head office, was estimated about 12 billion Iranian Rials (0.6 million Dollars). The highest damages to Tabriz electrical power network relates to "Oola-Kandi" village, located in suburb of Tabriz city. Some of electrical feeders were gone out of circuit and reconnected after half an hour and most damaged feeder was "Sattar-Khan" feeder of Tabriz city.

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Earthquake caused gas network cut off for 18 thousand domestic users in stricken areas. Most of damages to gas distribution network have occurred in residential areas because of building collapse and rest of networks was undamaged. Gas systems back to use for undamaged areas including for 37 out of 38 villages of Varzeqan and 60 out of 74 villages of Ahar and 15 out of 18 villages of Heris County. A fire, also, was reported due to gas leakage in "Vali-lu" village, suburb of "Khaju".

Some insufficiencies are reported in telecommunication antennas due to the earthquake. There were some difficulties in phone contact to the area because of heavy traffic in calls. No significant damage was reported on water network.

## 8. CONCLUDING REMARKS

This report outlines the findings obtained through the quick survey at the affected sites. Results and findings of the reconnaissance activities on the Ahar-Varzeghan Earthquakes are as follows:

(a) The two earthquakes occurred as a result of oblique strike-slip faulting in the shallow crust of

the Eurasian plate. These earthquakes lay as interplate type.

(b) The maximum peak ground acceleration of the first event was 478 cm/s/s on horizontal component recorded in Satarkhan dam and it of the second event was 532 cm/s/s on horizontal component recorded in Varzaghan.

(c) The deaths were more than 330 persons. The significant amount of the death toll and structural damages are from adobe and stone buildings.

(d) Electricity network of 25 villages were totally damaged. Electricity rafts located on fault have fallen but rest of them in further distance from the fault was undamaged. Earthquake caused gas network cut off for 18 thousand domestic users in stricken areas. No significant damage was reported on water network.

**ACKNOWLEDGEMENT**: All the members of the advanced team of reconnaissance of JSCE are much indebted and thankful to the faculties and staffs of Azarbaijan Shahid Madani University, Tabriz, Iran, for their kind supports and assistance to the survey activities in the affected sites. Lastly all the members would like to express hereby their sincere sympathy to the people affected the devastating earthquake.

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