

# Civil engineering features of damage on June 20, 1990 Manjil-Rudbar earthquake, Iran

F.Jafarzadeh

International Institute of Earthquake Engineering and Seismology, Iran

**ABSTRACT:** This paper reports a summary of the civil engineering features of the June 20, 1990 Manjil-Rudbar earthquake ( $M=7.6$ ), which left 37000 dead and caused widespread damage in the north of Iran. Seismological and geotechnical aspects of this earthquake and also damage to buildings and special structures in the affected area have been reviewed briefly.

## 1 INTRODUCTION & SEISMOLOGICAL ASPECTS

The northern part of Iran was shaken at 0:30 a.m. (local time) on June 20, 1990 by a strong earthquake. According to the report of USGS, the magnitude of this earthquake, named the Manjil-Rudbar earthquake, was 7.6 on Richter scale ( $M_s=7.6$ ,  $M_b=6.8$ ), and the epicenter was south-west of Caspian sea (north of Iran), latitude 36.96N and longitude 49.41E, with a focal depth about 10 km.(Fig.1). It has been estimated that more than 37,000 persons lost their lives, about 400,000 persons became homeless, more than 100,000 homes and commercial buildings damaged and hundreds of towns and villages destroyed. The most intense aftershock occurred 12 hours after main shock on June 21 ( $M=6$ ), which was decisive in provoking collapse of many previously damaged structures. Since 1905, six earthquakes of magnitude 6 or larger have been recorded in this area, which the June 20, 90 Manjil-Rudbar

earthquake is the most severe one. It shock about 10 provinces in north and north-west of Iran and some parts of Azarbayjan republic in CIS (former USSR). The intensity of this earthquake was more than III (MMI) in about 45 cities and towns of Iran. The most severe damage was concentrated in Gilan and Zanjan provinces. In two cities, Manjil and Rudbar, located in Gilan province the intensity of the earthquake was X and IX, respectively. The isoseismal map of this earthquake has been presented in Fig. 1.(IIIES 1991)

## 2 GEOTECHNICAL ASPECTS

Due to high intensity of Manjil-Rudbar earthquake and extent of the damaged area, almost all aspects of geotechnical damages were obvious.

In several cases rockfalls caused damage of roads (Fig. 2), retaining walls and extended into villages which were built at the base of the mountains. A few villages completely or partially were buried by landslides. The dimensions of some landslides were more than one kilometer. Low resistance layers and high water content were two most important reasons for these slides. There were also a lot of slop failures in weathered parts of marl and clay slopes (Fig. 3). Foundation of many factories and buildings were collapsed by differential settlements. Liquefaction was reported in widespread silty sand areas (about 70 km. far from epicenter) that caused damage to roads, water towers, water canals and wells (Fig. 4). This phenomenon was also one of the main reasons for

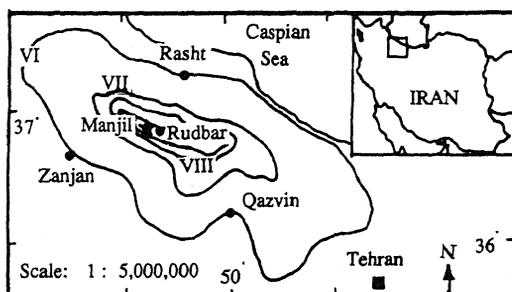


Figure 1. Isoseismal map of the Manjil-Rudbar earthquake.(IIIES 1991)

differential settlements. Sometimes the settlement of one-story buildings was more than one meter. Local site effects were also obvious during this earthquake. For example in Rasht city, capital of Gilan province and about 70 km. far from the epicenter, most of the damaged buildings were between 4 and 8 stories (IIIES 1991). Concerning the seismicity and probability of occurrence of severe earthquakes following with amplification and liquefaction, microzonation studies should be carried out in this agricultural and industrial populous area.

### 3 DAMAGE TO BUILDINGS

Concerning the structural systems and materials which have been used in the buildings of shaken area, it is possible to categorize them in 3 types.

Type 1 is rural houses, built with adobe bricks and alluvial stones, having wooden roofs. Due to the heaviness of the walls and lacking of any connection between them, this kind of houses has no resistance even against the low intensity earthquakes. Type 2 is masonry houses, one to three stories high, made with unreinforced and unbraced brick walls. These walls transfer the vertical load of beams to the foundation. There is no frame or bracing systems in this type. Figure 5 shows two adjacent buildings of this type. Also in this figure structural pounding effect is evident. Type 3 is high buildings from three to eight stories high, made with reinforced concrete or steel frames. In figures 6 and 7 two examples of this type have been shown. Generally the stability of braced steel frame buildings (Fig. 7), comparing with reinforced concrete structures, was good, although some welded connections of braces have been destroyed (Fig. 8). The action of infilled frames in reduction of the intensity of damages were evident. Weakness or lack of any special bracing system or shear wall, free and soft ground story (Fig.6&9) and poor constructions quality were the main reasons of the collapse in this type.

In central part of the shaken area, Manjil and Rudbar cities, most of the houses were type 1 or 2. Concerning that in this region high frequency waves were dominant and powerful ( $a_0$ , ground acceleration, was calculated about 0.71g in epicentral area -IIIES 1991), it is obvious why more than 90% of the houses were destroyed.

Most of the 3rd type buildings were located in Rasht city, where the ground acceleration was about 0.30g (IIIES 1991). Due to the high intensity of low frequency waves in this city most of the undamaged buildings with more than three stories suffered some cracks.

### 4 LIFELINE SYSTEMS & SPECIAL STRUCTURES

In this disaster, transportation systems like roads, bridges and tunnels; water supply systems such as water towers, pipelines and agricultural canals; electrical power distribution and communication systems suffered many damages. Horizontal and vertical displacements (more than 10 cm.) are shown in one of the bridges in shaken area in figure 10. Figure 11 shows completely damaged water tower in Rasht. The main reason for collapse of this tower was unsuitable connection between prestressed tank and R.C. shaft. Generally, geotechnical features of the earthquake such as rockfalls, landslides and liquefaction were the main reasons for damages done to lifeline systems.

The region affected by earthquake is a well developed agricultural and industrial area. There were more than 68 industrial factories and workshops, like two cement factory, thermal power plant, shoe factory and spinning and weaving factory, which were severely damaged or collapsed in some part. Also Sefidrud storage dam, buttress dam with 106 m. height (Fig. 12), Tarik and Sangar diversion dams are three important hydraulic structures that suffered light damages. Sefidrud dam was located almost in epicenter. Figure 13 shows leakage of the water from the longitudinal cracks, which concentrated around horizontal construction joints. There were some damages in parapet of crest and instabilities in the abutments, however, the general stability of the dam was good. Fortunately, repairing operations of the dam were completed after less than one year.

### 5 CONCLUSIONS

In this paper civil engineering features of damage due to Manjil-Rudbar earthquake have been studied. During this earthquake widespread damages were due to the strong ground motions, geotechnical and local site effects and structural weaknesses.

Most of the conclusions taken from this earthquake are, unfortunately, the unheeded lessons from previous destructive earthquakes in the world. In this earthquake the damages done to structures were mainly due to the inadequacy in design methods and construction techniques.

Earthquake resistance design methods, complete geotechnical explorations and construction quality controls are the important parameters that should be mentioned in the reconstruction of damaged areas.



Figure 2. One of the rockfalls along the main road.

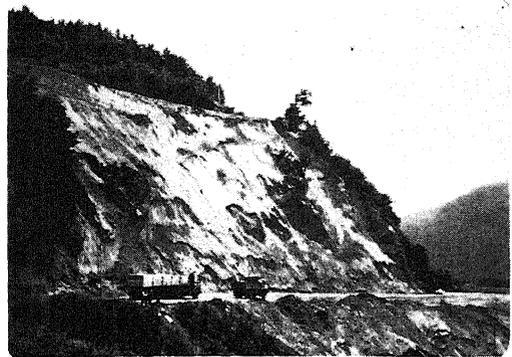


Figure 3. Failure in clay slopes.



Figure 4. Filled water well with liquefied silty sand.

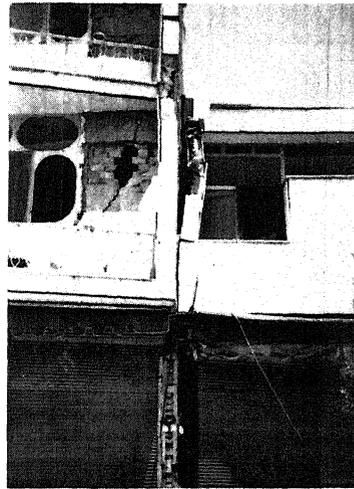


Figure 5. Structural pounding in masonry houses.



Figure 6. Destroyed 7 story residential apartment in Rasht.



Figure 7. 8 story steel frame building in Rasht.

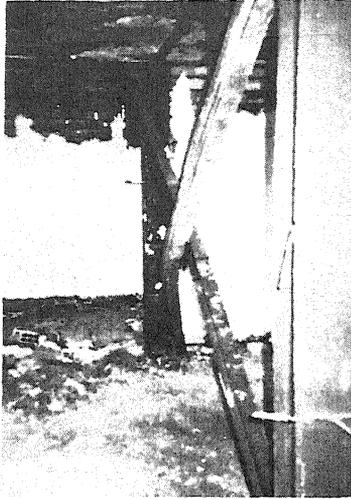


Figure 8. Collapse in welded connections.

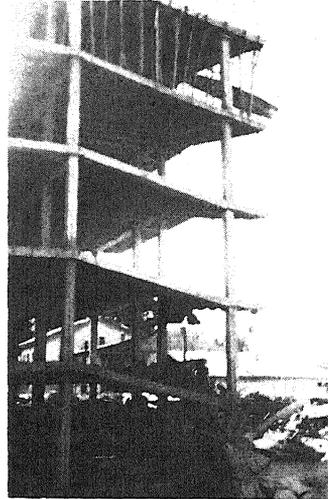


Figure 9.  
Destroyed 5 story  
reinforced concrete  
building in Rasht.

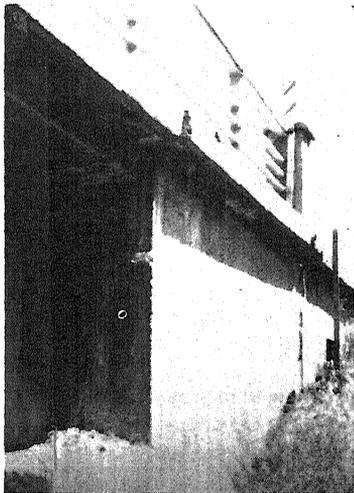


Figure 10. Horizontal and vertical displacements in a  
concrete bridge.

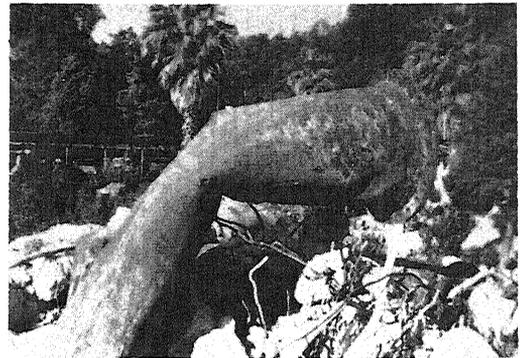


Figure 11. Destroyed water tower in Rasht.

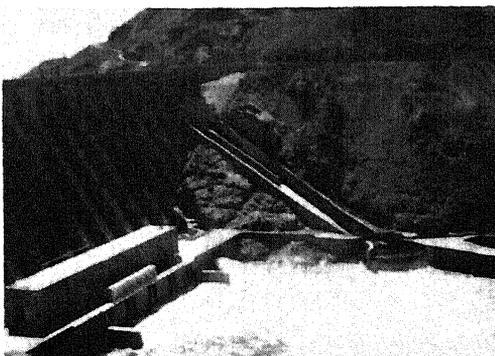


Figure 12. Sefidrud storage dam located in the epicentral  
area.



Figure 13. Leakage of the water from the horizontal  
cracks of the sefidrud dam.

#### REFERENCES

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