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June 20, 1990 Earthquake of Northern Iran: An Overview

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ABSTRACT:

On the day of June 20, 1990 at 21:00 GMT (June 21, 1990, at 00:30 local time) a destructive earthquake of magnitude 7.6 shook northern provinces of Iran. It caused widespread geotechnical and structural damages covering an approximate area of 10,000 sq km resulting in 37,000 life losses, 100,000 injuries, and 100,000 building failures leaving more than 400,000 people homeless.

This paper summarizes the post-earthquake investigations and discusses the general engineering aspects of the June 20, 1990 seismological, geotechnical, and structural aspects of the event. Lessons learned are also discussed.

INTRODUCTION

The Manjil-Roudbar earthquake of June 20, 1990 occurred at 21:00 GMT (00:30 June 21, 1990 local time) in north and northwestern parts of Iran (Figure-1). The body wave magnitude (Mb) of the main shock reported by the Geophysics Institute of Tehran University (GITU) was estimated at 7.3. The surface wave magnitude (Ms) of the quake reported by the United States Geological Survey (USGS) was estimated at 7.6. The epicenter of the earthquake was located at near the city of Roudbar (36:49:00 N and 49:24:51 E) with a focal depth being reported between 10-20 km. (IIEES, 1991)

Sequence of aftershocks were reported immediately after the main shock, the largest being reported in the order of Mb = 6.0. Acceleration, velocity and displacement time-histories of the event (UNDP, 1990) registered at the Gazvin Station is shown in Figure-2. The maximum recorded peak ground acceleration was reported at the village of Ab-Bar at 0.65g and 0.23g in horizontal and vertical directions respectively.

The earthquake occurred in the Alborz Mountain Zone which is one of the main seismotectonics units of Iran. After the period of low seismicity that lasted one century, indications are that the Alborz Zone has again become active. Alborz mountain is part of the Alpide seismic belt. This area has experienced many large earthquakes in the past (Table-1).

The Manjil-Roudbar earthquake occurred in populated provinces of Gilan and Zanjan. The earthquake caused devastating damages to many cities and villages in the affected area. The worst to hit were the cities of Manjil and Roudbar in province of Gilan with a maximum

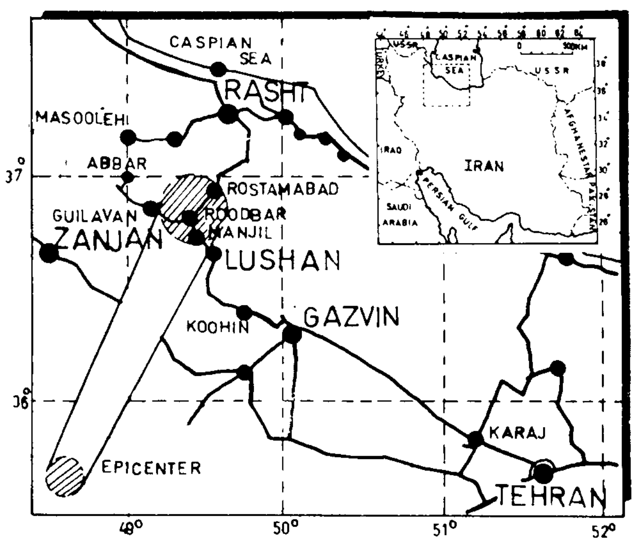
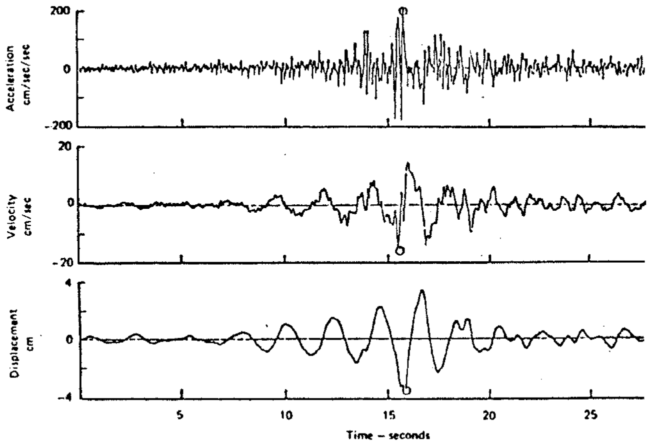


Figure-1 Location Map

Table-1 Historical Earthquakes in the Region (Berberian, 1976)

Year	Lat. N	Lon. E	Mag. Mb
1119	35.70	49.90	6.5
1177	35.70	50.70	7.2
1485	36.70	50.50	7.2
1607	36.40	50.50	7.6
1844	37.40	48.00	6.9
1879	37.80	47.90	6.7
1896	37.80	48.40	6.7
1960	37.00	49.50	6.5
1962	35.70	49.80	7.2
1978	37.00	50.50	6.3
1980	37.80	49.10	6.4



Peak Values: Gazvin Station
Acceleration = 193.3 cm/sec/ses
Velocity = -16.0 cm/sec
Displacement = -3.50 cm

Figure-2 Time-Histories of the Event

intensity estimated at Manjil at X on a Modified Mercelli Scale (MSK). The Isosismal map of the affected region is shown in Figure-3. Earthquake caused widespread geotechnical and structural damages covering an approximate area of 10,000 sq km resulting in 37,000 life losses, 100,000 injuries, and 100,000 building failures leaving 400,000 people homeless.

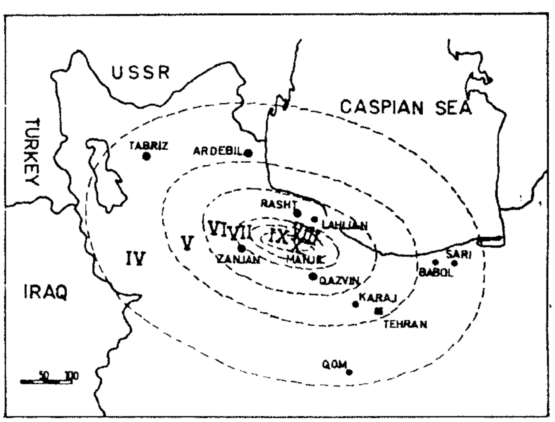


Figure-3 Isosismal Map of Manjil-Roudbar Earthquake

GEOTECHNICAL ASPECTS

A number of geotechnical failures contributed to the destruction in this earthquake such as rock falls (RF), land slides (LS), foundation bearing deficiencies (FB) and liquefaction (LQ). Local site effects (LE) also played a major role in amplifying strong motion and contributed to the structural failures (IIEES, 1990). The extent of widespread geotechnical failures are shown in Figure-4.

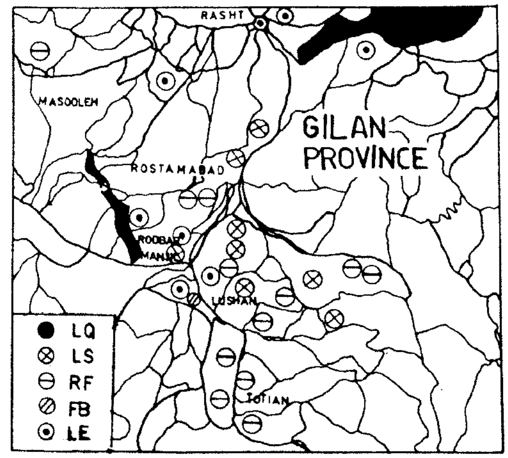


Figure-4 Extent of Geotechnical Failures

Numerous rock falls and land slides occurred in the region around the epicenter, covering an approximate radius of 60 km. They caused many road closures during and after the main shock and also destroyed many villages and towns in the region. The fallen rocks were some as heavy as a thousand tons or more.

Among the widespread land slides throughout the region, the one near the city of Roudbar (epicentral region) caused earth removal of approximately 10 to 20 million cubic meters. A typical rock fall is shown in figure-5.

Figure-5 Picture of a Typical Rock Fall

Soil liquefaction has caused extensive damages in a relatively vast area about 80 km to the north-east from the epicenter. It also occurred in an area near the epicentral region in village of Nasir-Mahaleh.

Liquified soil damaged foundations and disposition irrigation canals. It also broke pipelines, cracked pavements, and filled water wells with boiled sand (Eshghi, 1990). Hundreds of houses were unevenly uplifted, or sunken in the region due to liquefaction as shown in Figure-6.

Figure-6 Effect of Liquefaction

Some evidence of local site effects was observed in the city of Rasht. Local site effects on strong shaking could be blamed for many structural failures such as damages to the mid-rise buildings and the city's elevated water tanks.

STRUCTURAL ASPECTS

The buildings in the affected area can be classified into two distinct types of non-engineered and engineered structures. Rural dwellings and low-rise urban buildings are categorized as non-engineered structures, while mid-rise steel and reinforced concrete structures are designed and built as engineered buildings.

Non-engineered dwellings are built using walls made of in-situ-cast adobe bricks or mixture of stones and mud. Pitched roofs are made of wooden rafters with light coverings while flated roofs are made of wooden beams using heavy earth coverings. Non-engineerd buildings are usually built using masonry concrete hollow blocks or clay bricks with a Jack-arch roofing.

Residential buildings are mostly built as a non-engineered structures while some are built as partially engineered. These are buildings which are not designed in accordance with any seismic code, nevertheless have certain resisting members such as concrete ring-beams. Non-engineered buildings generally performed unsatisfactory resulting in total collapse while partially engineered buildings sustained severe damages but did not totally collapse as shown in Figure-7.

Steel-framed engineered buildings are mostly built using continuous girders and semi-rigid welded beam-to-column connections. Columns are typically battened steel sections and Steel Jack-arch or concrete joist-block flooring systems are predominantly used for flooring. Seismic loads are resisted by lateral bracing system or infilled unreinforced masonry panels in these structures.

Figure-7 Picture of a Damaged Building

A very few number of reinforced concrete framed buildings exist in the affected area. These buildings are designed as simple moment resisting frames. Concrete joist-block flooring system are used to construct the floors in this type of structures.

Most of the mid-rise buildings in the area are constructed using steel framing system. These buildings generally performed poorly. A typical damaged steel structure is shown in Figure-8. Lack of a proper seismic resisting system, unavailability of large steel sections, and poor welded connections can be named as the main reasons for unsatisfactory performance of steel structures during this earthquake.

Figure-8 Damaged Steel Structure

Reinforced concrete-framed structures performed very unsatisfactory. A few number of reinforced concrete framed structures were totally destroyed while others received severe structural damages. Lack of a proper ductile moment resisting frame, using plain reinforcing bars instead of deformed ones, not meeting the development and overlapping requirements, and low concrete quality can be named as the major contributors to the poor performance of these buildings.

In general, poor workmanship, lack of technical supervision during construction and not meeting all ductility requirements provided by seismic codes, contributed to the devastation and destruction.

DAMAGE TO LIFELINES

Lifeline systems suffered seriously in this earthquake. The damages to lifelines were mostly associated with the resulted failures in ground. They interrupted the distribution of essential utilities to the general public and also caused major interferences with the rescue operations during and after the earthquake.

Power plants in the region comprises a fossil-fueled and a hydropower plant. They operate through a network of switchboards and substations. Many structural and non-structural failures throughout the network caused interruptions in the system resulting in power outages for several months.

Water supply system of the region was severely suffered in this earthquake. Two elevated reinforced concrete water tanks were overturned and collapsed after the main shock. The collapsed water tank of the city of Rasht is shown in Figure-9. Similar empty water tanks in the region suffered minor damages but performed adequately. A large buttress dam of 106 m in height, sustained some horizontal and diagonal cracks but kept its stability. Buried pipelines were damaged and natural gas distribution systems were interrupted because of large permanent ground movements and surface faulting.

Rock falls, land slides and other seismically induced ground failures were the primary reasons for the interruptions in the highway system. Steel bridges performed fairly satisfactory while reinforced concrete bridges sustained some damages. Moderate damages were observed in connections of the reinforced concrete bridges, all because of approach fill and abutment settlements. These damages and debris caused interruption in the rescue operations right after but was cleared within the next couple day of the event.

Figure-9 Collapsed Water Tank

Damages to gas and liquid fuel systems has been moderate to extensive. Large ground movements associated with land slides and surface falting caused damages to buried pipe -lines. Power outages in natural gas systems also made difficulties in distribution of these services to public.

CONCLUSIONS

The Manjil-Roudbar earthquake was a major disaster. It was expected because of the seismicity of the region. Widespread geo-technical failures played a major role in destruction. Despite, high potential for liquefaction and slope instabilities related to poor soil conditions, no microzonation studies of such were conducted in the affected region prior to the earthquake.

The primary cause of death, injury and destruction was the total collapse of non-engineered structures. Engineered buildings performed better but not very satisfactory. Poor workmanship, lack of technical supervision during construction and not designing in accordance with seismic codes requirements.

The damages to lifeline systems were directly associated with the resulted failures in ground. Utilities suffered severely due to permanent ground movements and surface falting. Rescue operations were seriously interrupted by debris resulted from large land slides and rock falls.

The information in this paper has been presented from the viewpoint that performance on the actual earthquake conditions is the best test of seismic reliability. More experimental and analytical studies are being currently conducted on the available data and the authors hope to present the results in near future.

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