

## Lessons learned from the 20 June 1990 Manjil, Iran earthquake

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**ABSTRACT:** The main topics covered are seismology, the intensity and distribution of strong ground motion, faulting and geotechnical aspects. Lessons learned from the reconstruction of the earthquake stricken area are also presented.

### 1 INTRODUCTION

A devastating earthquake of magnitude  $M_w$  7.3 struck northern Iran on 20 June 1990. The event occurred as a multiple shock. The result was a tremendous loss of life and destruction to property. According to The Plan and Budget Organization Reports the number of deaths were 14,000 and the number of injured was 8,000.

Total number of damaged residential units were reported as 214,000 of which 102,000, 19,500 and 92,000 were damaged over 60%, 30% to 60% and under 30%, respectively. 679 health facilities, 1,572 schools, 9,044 retail centers, 3,346 production centers, 472 governmental buildings and 1,590 cultural centers were heavily damaged. The towns of Manjil, Rudbar and Lowshan experienced extensive losses, and many other towns and settlements suffered low to moderate losses.

Contrary to the experience of other earthquakes that have occurred in Iran, this earthquake hit a populated area. Several cities and towns with modern structures are located in the affected area.

Long period motion was experienced 75 km distant from the city of Rasht. Large scale of liquefaction occurred in the city of Astaneh, about 75 km from the epicenter. There were big changes in underground water levels with increase or decreases in the amount of water in several springs.

### 2 BACKGROUND SEISMICITY OF THE REGIONS

The Manjil area is located in the Alborz mountain range which is part of the Alpine-Himalayan seismic belt. This area has been recognized for a long time as a very active zone seismically and is a high seismic zone in the Iranian code for Seismic Resistant Design of Buildings (1988).

The historical seismicity of the region shows that

a similar earthquake in the same area, killed 12,000 people, but the Manjil area has not experienced any destructive earthquake in the 20th century. The only moderate earthquake to have occurred in the area this century is the 17 June 1948 earthquake with  $M$  5.5 which caused slight damage to Manjil. Table 1 shows some of the historical earthquakes of the region ( $M > 5.5$ ) within a radius of 200 km from the epicentral area. Over 40 earthquakes with  $M > 5$  have occurred within a radius of 200 km from the epicentral area during the 20th century.

### 3 EPICENTER AND HYPOCENTER

The 20 June 1990 earthquake occurred as multiple shocks followed by many aftershocks. Two earthquakes were felt in Tehran within 5 minutes. The macroseismic epicenter of the earthquake was estimated to be in the vicinity of the town of Manjil and around Sefidrud dam ( $36.75^\circ\text{N}$ ,  $49.40^\circ\text{E}$ ). Instrumental epicenter was reported by the Institute of Geophysics of Tehran University at  $36.817^\circ\text{N}$  and  $49.414^\circ\text{E}$ .

The epicenters of about 250 aftershocks which took place in the first three days after the earthquake have been calculated by the same Institute, and most of them have been found to be located near Pakdeh and Harzevil. According to the studies carried out by the Institute, and based on the study of aftershocks, the hypocenter was determined to be at a depth of 19 km.

### 4 INTENSITY

The 20 June 1990 earthquake was felt over an area of  $600,000 \text{ km}^2$  with an intensity III (MSK). In Tehran, the earthquake (200 km from the epicenter) caused panic and cracks developed in several tall buildings. The intensity in Tehran was about V

(MSK) and in Tabriz (a major city 300 km from the epicenter) it was about IV. The intensity in other major cities like Oazvin, Zanzan and Rasht was VI. The highest intensity was in Manjil and Harzevil which are very close to the fault. The intensity in Manjil is estimated to have been X (MSK). The intensity in Rudbar (8 km north of Manjil) was about IX. An area of about 1,500 km<sup>2</sup> was shaken with an intensity greater than IX (MSK).

## 5 GROUND MOTION RECORDINGS

The earthquake ground motions were recorded at 20 accelerographs ranging in distance from about 10 km of the fault to 220 km. An additional two were on the tenth and twentieth floors of a tall building in Tehran.

The closest accelerograph, which recorded 0.54 g vertical and 0.52 g horizontal, was located in Abbar about 35 km from the epicenter and 10 km from the Abbar segment fault as inferred from the aftershock distribution.

Table 2 shows peak ground acceleration (pga) values from the Strong Motion Accelerograph Network operated by Building and Housing Research Centre (BHRC) of Iran. Figure 2 shows the geographical location of the triggered strong motion accelerographs installed within a radius of 220 km from the epicenter. At greater distance, Ghazvin recorded 0.18 g horizontal.

The first building recordings in Iran were obtained during this earthquake. Further studies on these records are in progress.

Although this earthquake produced valuable recorded data, additional instruments would have been very useful. For example, the importance of site amplification was demonstrated by the surface ground motion measurement and pattern of damage throughout the region. More instruments at different locations would provide a clearer understanding of this phenomena. Moreover, there was a lack of downhole measurements which might have provided data upon which to gain analytical insight into amplification and lead toward better engineering practice. Also, due to malfunctioning of the instrument, no strong motion record was obtained in the city of Rasht (about 60 km north of the epicenter) where several medium rise buildings and water towers collapsed or suffered heavy damages. The long period effect could have well been demonstrated by some records in this city.

There is a continuing need to expand the strong motion accelerograph program of BHRC according to priorities of the engineering community.

## 6 SOME GEOTECHNICAL ASPECTS

### 6.1 Ground motion amplification

One of the major geotechnical features was ground

motion amplification. Sites located on rock or stiff soil have the lowest accelerations, sites located on alluvium have intermediate accelerations and sites located on soft alluvium have the highest accelerations. For example, peak horizontal ground acceleration recorded on coarse grained and hard alluvium in Chizar (215 km distance from the epicenter) was 0.014 g, whereas, near the same area, a softer site (fine grained alluvium containing mud) in Kahrizak (220 km distance) was 0.046 g which is over 3 times higher. Another example is the record obtained on a soft alluvium containing clay and sand in Tonekabon (130 km distance) which was 0.13 g, whereas a harder site (alluvium containing gravel, sand and clay) in Eshtehard (135 km distance) was 0.075 which is almost 2 times higher. A majority of the structural damage in Rasht occurred on deep clay sites. The soft soil effect seems to be amplitude dependent but instrumental data from very intense shaking are not available.

### 6.2 Liquefaction

A relatively wide geographical distribution of liquefaction was a major feature. Extensive damage was caused in Astaneh and Rudbaneh by liquefaction. There was no strong motion recording on these soft soils. However, 0.20 g is a reasonable estimate considering that a soft soil site at the nearby Lahijan recorded a horizontal pga of 0.17 g.

Liquefaction extended well inland several kilometers from the Caspian Sea along the present and abandoned channels of Sefidrud river, resulting in lateral spreading which damaged hundreds of meters of levees along these channels.

Liquefaction and lateral spreading in the Astaneh area caused different types of damages such as collapse and differential settlement of some houses, damage to buried pipes, damage to some roads, resulting in broken and uneven pavement surface. Other liquefaction induced ground damage included sand boiling from room floors and rice farms, boiling of sand and water from water wells which resulted in sand fill in wells, uprooting of trees and changing the irrigation canal lining roots.

### 6.3 Ground displacements and deformations

Ground deformations and displacements were developed at several places due to the earthquake. For instance, there was: east-west discontinuous faulting for a distance of over 80 km, huge landslides, large rockfalls, changes in water tables, discontinuation of some springs and creation of several new springs, etc.

## 7 FAULTING

Apart from several huge landslides and many large

rock falls which took place in a vast area of the region, a discontinuous fault with a total length of 80 km, was associated with the earthquake. The arrangement of the segments of the fault indicates an "en-echelon" form and showed a horst type deformation in a vast area.

There are six areas which comprise the earthquake fault ruptures. These are located in the vicinity of Selfidrud dam (Manjil region), Abbar, Baklor, western Rudbar (Kabateh area), eastern Rudbar (Borebon area) and Pakdeh (Figure 3).

The segment of the faulting which occurred in the Manjil area is in the vicinity of the most important tectonic feature of the region "the Harzevil fault zone" and is nearby the Sefidrud concrete dam. The geodetical surveys which were done in the region after the earthquake, revealed that some parts of the region have been uplifted about 60 cm.

Ground ruptures arranged in the "en-echelon" form bordered an uplifted left laterally displaced mountainous region between the "Harzevil reactivated fault zone" and the alignments of the northern fault segments, thus a left-hand transpression mechanism could be concluded.

## 8 THE HOUSING RECONSTRUCTION PLAN FOR GILAN AND ZANJAN AREAS

A major program of reconstruction was required to revive living conditions in the population centers, providing the grounds for the employment and jobs, construction of permanent houses, maintaining community services within the framework of regional and/or national potentiality, which must be taken into consideration as major grounds. The following essential questions were considered in adopting the reconstruction policies:

1. Reconstruction or renovation?
2. Financial policies? Identification of financial sources and how to secure and allocate such sources?
3. The manner of selection, supply and distribution of construction materials? Taking into account the local construction materials and the method to be used for improving their production quality, the manner of supplying materials to be provided from outside of the region?
4. How to select the proper technology?
5. How to prepare and approve the drawings and technical specifications of the residential units?
6. How to select the construction method as well as operating management of the reconstruction? Proper understanding of the role of people? The role of assisting groups? The role of Government?
7. How to provide the manpower required for the reconstruction?
8. How to supply the machinery required for the reconstruction?
9. How to provide the facilities for the transportation of materials and removal of the existing debris?
10. The method to be used for locating the

villages? Displacement or reconstruction at the spot?

11. Proper structure of village and residential complexes?

12. How to gain access to a pattern of people's participation?

13. How to identify those families who have incurred more severe damages in the earthquake, but have no facility at their disposal either to repair their houses or support their families?

In drafting a reconstruction programme, answers should be provided for all the foregoing matters.

Conflicting views expressed by various people, and published in the newspapers in the early days of disaster, contributed to the confusion. The Housing Foundation of Iran, relying on its experience and forecasting the problems to be encountered, mobilized all its forces and proceeded with drafting a work program. The program consisted of three parts:

1. Reconstruction policies.
2. Organization and execution of reconstruction plans and policies.
3. The operating budget required for the reconstruction.

The major proposed policies were:

1. The landlords shall be responsible for the construction management of the damaged residential units in respect of supplies, design and executive operations. The role of Government (who executes the reconstruction) is to participate with the landlord in such matters he is not able to carry out, as well as to direct and supervise the executive

Table 1. List of historical earthquakes of  $M > 5.5$  that have occurred in a radius of 200 km from the epicentral region<sup>2</sup>.

Date			Time	Epicentre		Magnitude
Year	Month	Day		North	East	
855				35.6°	51.5°	7.1
958	2	23		36.0°	51.1°	7.7
1119	12	10	18	37.7°	49.9°	6.5
1177	5			35.7°	50.7°	7.2
1485	7	15	18	36.7°	50.5°	7.2
1608	4	20	12	36.4°	50.5°	7.6
1678	2	3	6	37.2°	50.0°	6.5
1808	12	16	18	36.4°	50.3°	5.9
1844	5	13	19	37.4°	48.0°	6.9
1876	10	20	15	35.8°	49.8°	5.7
1879	3	22	4	37.8°	47.9°	6.7
1880	7	4		36.5°	47.5°	5.6
1896	1	4	16	37.8°	48.4°	6.7

2) Reference: A history of Persian earthquakes by N. N. Ambraseys.

Table 2. Peak ground accelerations recorded by strong motion accelerographs.

Item	Station	Location		Direction		$\Delta^1$ (Km)	Max. Corrected Acc. cm/sec <sup>2</sup>			Soil Type
		N	E	L	T		L	V	T	
1	Abbar	36.92	48.97	N 36 W	N 54 W	35	516.2	537.0	492.4	Alluvium resting upon gypsiferous conglomerates
2	Abbar	38.14	49.22	N 57 E	N 33 W	65	128.1	66.9	193.8	Alluvium including gravel and pebble
3	Ghazvin	36.27	50.01	N 66 E	N 24 W	70	183.7	90.0	131.9	Alluvium including sand gravel, silt and clay
4	Lahijan	37.21	50.33	N 26 E	S 64 E	75	106.3	74.0	172.4	Alluvium with clay, mud and gravel
5	Zanjan	36.66	48.57	N 70 W	N 20 E	80	124.8	50.6	58.7	>100m alluvium including gravel and sand
6	Rudsar	37.13	50.28	N 40 E	N 50 W	90	92.8	69.5	83.2	Soft alluvium, including clay and sand
7	Tonekabon	36.81	50.87	N 132E	N 42 E	130	130.26	33.45	85.98	Soft alluvium including clay and sand
8	Eshtehard	35.72	50.36	N 2 E	S 88 E	135	71.3	41.8	75.0	Alluvium including gravel, sand, and clay
9	Miyaneh	37.42	47.71	N 36 E	S 54 E	165	28.0	----	30.9	Rocky (marl and siltstone)
10	Karaj	35.81	51.00	S 74 E	S 16 W	175	34.9	12.6	12.30	Relatively thick and hard alluvium
11	Gachsar	36.11	51.31	N 24 E	S 66 E	185	63.1	36.5	98.7	Rocky
12	Ardebil	38.26	48.28	S 30 W	N 60 W	195	29.9	15.0	28.3	Alluvium including coarse gravel, sand, and clay
13	Robatkarim	35.47	51.08	S 36 W	N 54 W	195	12.6	18.8	17.4	Tehran type alluvium
14	Roud Shoor	35.44	50.90	N 14 E	S 76 E	200	39.4	31.5	43.4	Alluvium
15	BHRC <sup>2</sup>	35.74	51.36	S 02 E	S 88 W	215	36.8	15.4	24.4	Alluvium including gravel, sand and clay
16	Chizar <sup>3</sup>	35.79	51.44	S 16 W	N 74 W	215	14.3	19.5	12.1	Coarse-grained and hard alluvium
17	Sharif Univ. <sup>4</sup>	35.70	51.34	N 08 E	S 82 E	215	10.6	26.3	12.6	Alluvium including clay, gravel and sand
18	Kahrizak	35.51	51.36	N 26 E	S 64 E	220	46.0	28.2	34.7	Fine-grained alluvium including mud

1- Epicentral Distance    2- Building and Housing Research Center - Tehran    3- Tehran    4- Tehran

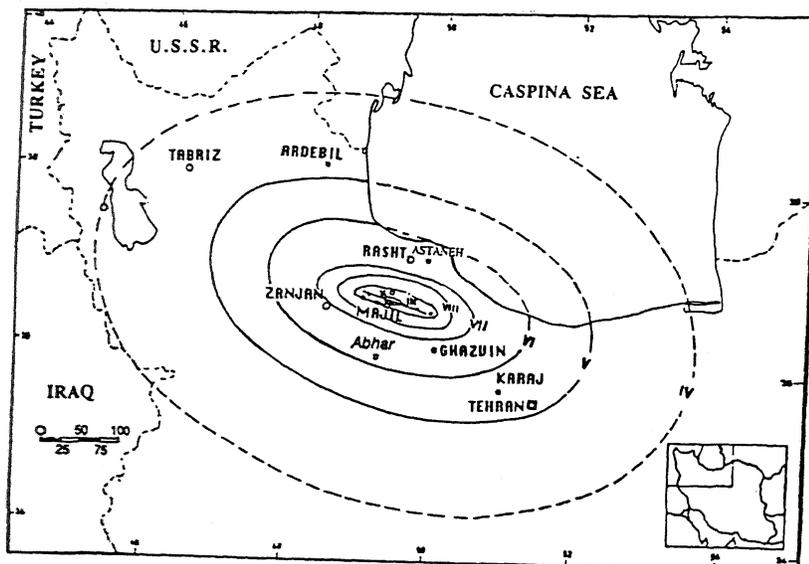


Figure 1. Preliminary isoseismal map of the 20 June 1990 Manjil, Iran earthquake.

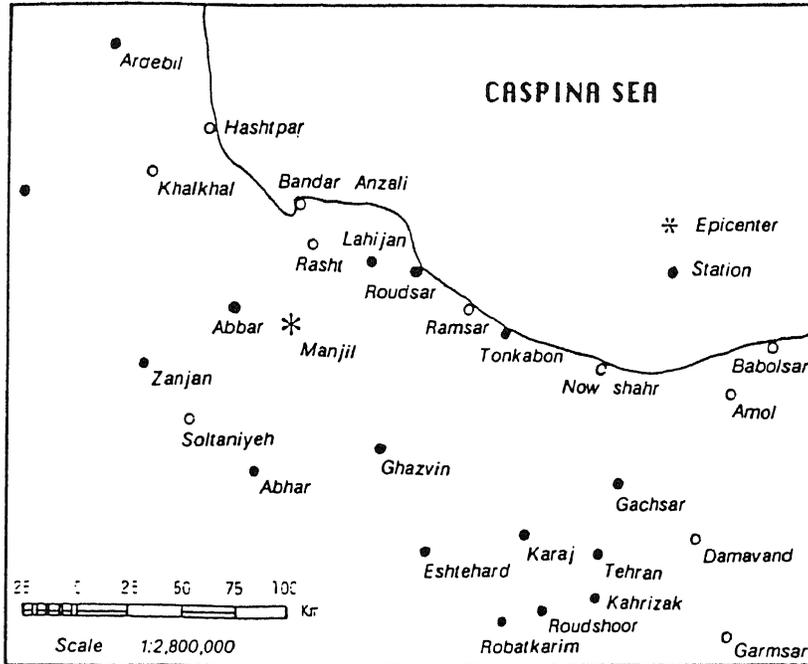


Figure 2. Geographical location of triggered strong motion accelerographs installed within a radius of 220 km from the epicenter.

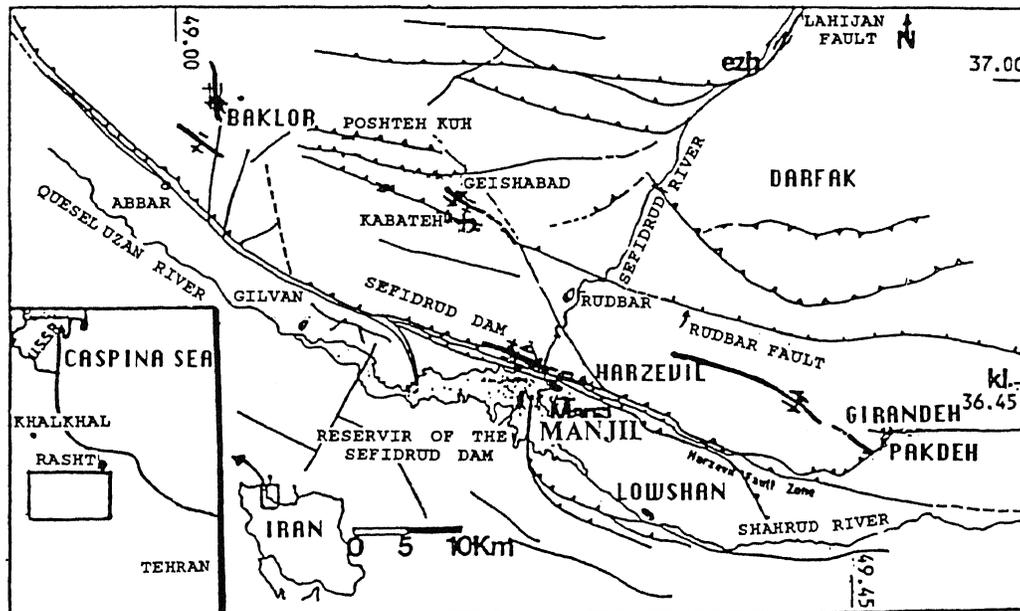


Figure 3. Earthquake fault of the 20 June Manjil, Iran earthquake.

program in such a manner that the reconstruction works are implemented in the shortest period of time, with the most suitable quality, the least problems and social tensions.

2. To establish, at the earliest time, headquarters and workshops in the region to execute reconstruction programs with a focus on strengthening the regional offices of the organization in charge of reconstruction activities and to refrain from assigning works to the concerned organizations.

3. To organize the assisting groups by the executive reconstruction organization and employ the same on the basis of the reconstruction policies approved by the Government.

4. To minimize the Government investments in the housing sectors and such other sectors where the early and safe return of the capital is possible.

5. To support the financial position of the disaster victims by providing them with interest free loans and banking participation at a low rate.

6. Government investment in infrastructure and public services.

7. To render gratuitously technical services related to the disaster victims, such as clearing and preparation of the site, production, and transportation supply of construction materials, technical supervision, etc.

8. Upgrading of the residential units and the environment as compared with the conditions prior to the disaster in the form financial possibilities of the Government and people's knowledge.

9. To adopt such methods of construction techniques which are, in the first place, in accordance with self-sufficiency principle throughout the region and, in the second place, in compliance with the national self-sufficiency.

10. The organization in charge of the execution of reconstruction works should, during the reconstruction operations, provide the grounds for strengthening qualitative upgrading of housing construction by drafting the criteria, recommending the design and executive matters, providing patterns as well as controlling and directing the disaster victims. The architectural drawings will be provided or selected by the disaster victims.

11. The required manpower should be maintained from the region by providing the necessary training and, if necessary, manpower should be dispatched to the place of disaster from the neighboring areas.

12. The forecast of the procedures, and provision of the appropriate training to enhance the level of technical know-how for construction purposes in the region should be carried out by the construction executive.

13. To provide and increase the quality of materials production and reduce the need for construction materials from outside of the region.

14. Supply of construction materials by the reconstruction executive for the sake of supporting the disaster victims and controlling the market price or, in other words, to reduce, as far as possible, the

need of the disaster victims to refer to the market.

15. To conduct, as far as possible, regional and local studies and provide structure plans to be executed possibly in all levels such as provision of plans amending the streets and passages in certain villages, rural guide plans for large villages, urban guide plans, and if such plans do not exist, to draft the regional plans within the limits of the disaster stricken area and the territories thereof.

16. To refrain from dislocating the villages and residential complexes unless there are justified technical reasons to do so.

17. To activate local and regional decision making processes and methods of people's participation through establishment of Reconstruction Headquarters within the region and the place of disaster involving local authorities and organize rural Reconstruction and Development Committees involving elder and reliable persons of the rural people.

#### 9 LESSONS LEARNED FROM HOUSING RECONSTRUCTION PHASE OF THE EARTHQUAKE-STRICKEN AREAS

In the phase of reconstruction of dwellings, the Housing Foundation had and will have the direct responsibility for the urban and rural housing reconstruction. The matters raised in this section deal with the experiences learned in the course of implementation of its plan.

The plan was not fully implemented because the required sources had not been allocated during the execution of the plan. The Foundation, however, to discharge the responsibility for the reconstruction operations, managed to station its Headquarters in the city of Rasht and seventeen Assisting Headquarters throughout the earthquake stricken areas. Such Headquarters managed to equip fifty (50) Reconstruction Sites and identified 217,000 damaged houses and, as far as it was possible, provided the earthquake victims with the services foreseen in the plan.

Much was learned from the experience with this disaster. Part of the experiences explain the strong points of the work and parts thereof explain the shortcomings and weak points:

1. The advantage of an approved plan, procedures, instructions, executive formats and unified procedure.

2. The advantage of assigning the reconstruction responsibility to an executive body that is ready to accept the responsibility.

3. Activating local and regional foundations and the fixed assignment of the managers in the course of reconstruction operations.

4. Absorption of people's participation, establishment of rural development and reconstruction committees.

5. Classification of villages, refraining from displacement of villages, drafting and implementing structure plans.

6. State's mobilization plan of technical capability in reconstruction and the need for the establishment of a planning center to manage disasters.
7. The significance of providing technical guidelines and the role of presenting patterns.
8. The urgency of technical and vocational expansion, employment of local forces on reconstruction and non-dispatch of forces.
9. The necessity of using local materials and reducing the import of materials to the region.
10. The importance of selecting a proper financial system for reconstruction operations.
11. The importance of building renovation and repairs.
12. Improper application of supervisor engineers control act in the construction of houses in small cities.
13. The urgency of drafting a system of information circulation and keeping records.
14. The need for drafting and enacting the laws and administrative regulations for the management of disasters.
15. The necessity for refraining from expressing hasty views by the authorities.
16. The necessity of conforming reconstruction sites (work shops) with the settlement peculiarities of the disaster victim.

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