NATIONAL CENTER FOR EARTHQUAKE
ENGINEERING RESEARCH

State University of New York at Buffalo

RECONNAISSANCE REPORT ON THE NORTHERN IRAN EARTHQUAKE OF JUNE 21, 1990

by

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Technical Report NCEER-90-0017

October 4, 1990

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NOTICE

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INTRODUCTION

On Thursday, June 21, 1990 at 12:30 a.m. local time (9:00 p.m. Wednesday, June 20 Greenwich Standard Time), a destructive earthquake occurred in the Gilan Province in northern Iran. The magnitude of this earthquake was estimated at 7.3 by the University of Tehran Seismology Center and at 7.7 by the National Earthquake Information Center in Denver, Colorado. The epicenter was reported to be approximately 200 km northwest of Tehran between the towns of Manjil and Rudbar. The earthquake caused strong shaking in a large part of Iran, including Tehran and Tabriz some 200 and 400 km away, respectively. It caused widespread damage in areas within a 100 km radius of the epicenter, including the City of Rasht (some 60 km away) and hundreds of towns and villages in Gilan and Zanjan Provinces.

It has been estimated that this earthquake caused life loss on the order of 35,000 to 50,000 people. Most of the casualties resulted from collapse and major damage to approximately 100,000 buildings. The number of homeless persons has been estimated at 400,000.

This earthquake affected a relatively populated, urbanized region of Iran with many important engineered structures. Detailed review of some of these structures is anticipated which will substantially add to the body of existing knowledge on earthquake behavior of structures.

This report summarizes observations of the author during a brief reconnaissance survey of the area one month after the earthquake, as well as information reported by other sources on this earthquake. It serves to provide preliminary information to set the stage for more detailed future investigations.

SECTION 2
SEISMOLOGICAL AND GEOTECHNICAL ASPECTS

The June 21, 1990 earthquake occurred in a region with recognized high seismicity. Manjil is located on the Alborz Mountains, which is part of the Alpine Himalayan seismic belt. The area has experienced many large earthquakes in the past. Based on the information reported by N.N. Ambrasseys (1), the region within 200 km of the epicenter has experienced 14 earthquakes of magnitude 6.0 to 7.7 within the last twelve centuries. The area is zoned as the highest seismicity in the Iranian Code for seismic resistance of buildings (2).

The epicenter of the earthquake, based on damage distribution, has been estimated to be about 5 km north of City of Manjil near Sefidrud Dam. Figure 2-1 shows the epicentral region and major cities affected by the quake.

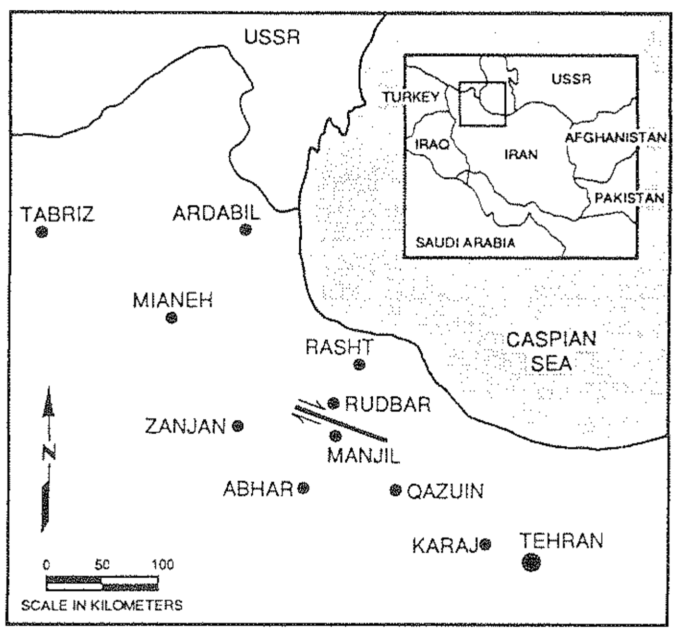

Figure 2-1. Map of Northern Iran

A preliminary estimate of the Modified Mercalli Intensity distribution has been reported by A.A. Moinfar and A. Naderzadeh (3). These intensity estimates are: Manjil X; Rudbar IX; Zanjan and Rasht VI; Tehran V and Tubriz IV.

2.1 Peak Ground Accelerations

Ground accelerations have been reported (3) from some 15 accelerograms at the time of preparation of this report. Selected peak horizontal ground accelerations and approximate distance to the fault are as follows:

City	Approx. Distance to Fault (km)	Peak Horiz. Acceleration (%g)
Ab-bar	10	65
Ghazvin	50	19
Abhar	70	13
Zanjan	50	10
Karaj	170	4
Tehran	200	2

2.2 Faulting

Preliminary surveys tend to indicate a right lateral surface fault rupture with a length of 80 km. The horizontal and vertical displacement of the faults are approximately 20 and 50 cm, respectively (3). The fault is at a distance of less than 1 km north of the Sefidrud Dam.

2.3 Landslide and Rockfall

Numerous landslides and rockfalls have been reported. Rockfalls due to the main shock and, subsequently, due to the aftershocks, resulted in closure of roads. This situation

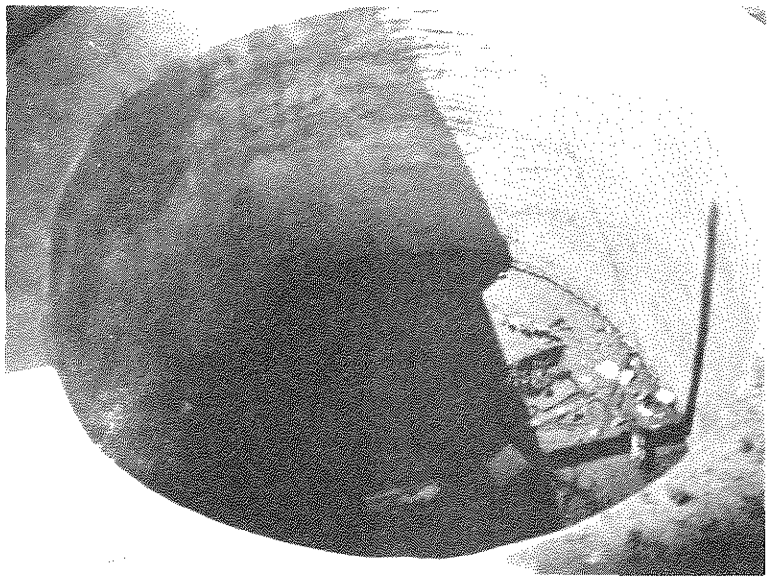

Figure 2-2 Sand filled water well caused by liquefaction

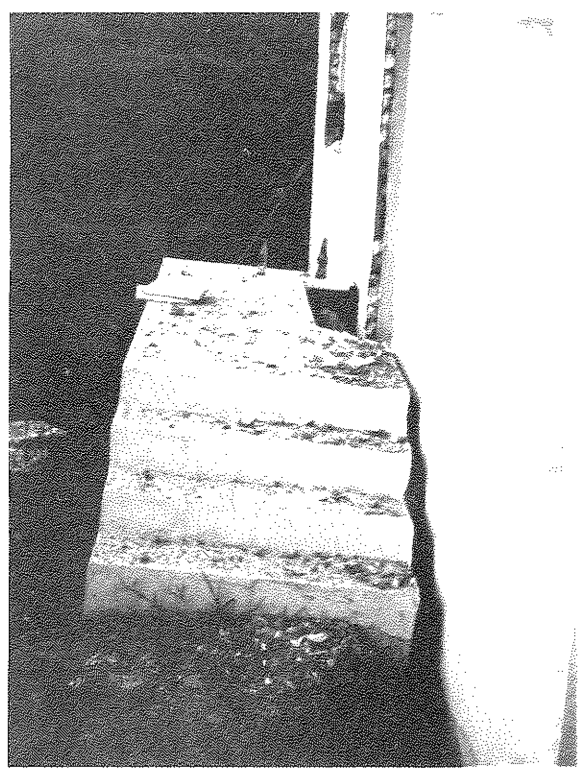

Figure 2-3 Liquefaction related settlement of the house relative to the stair

Figure 2-4 Wall crack caused by liquefaction settlement.

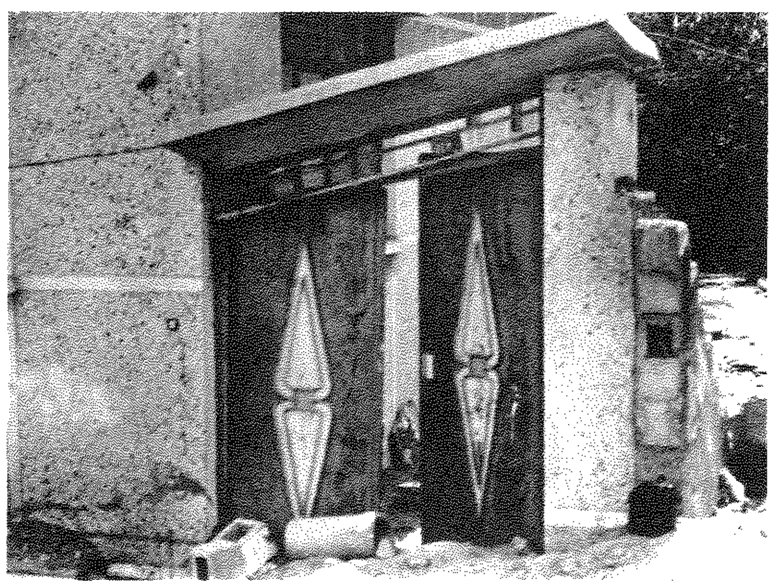

Figure 2-5 Large differential settlement due to liquefaction

delayed relief operations. A massive rockfall adjacent to the Sefidrud Dam resulted in collapse of the guard house and the death of its guard.

2.3 Liquefaction

Liquefaction and resulting ground settlement were observed in several towns, most notably in Astaneh Ashrafieh, Loshan and Noosher. Many shallow water wells were filled with sand (Fig. 2-2) and several cases of sand boils were observed. Figs. 2-3 through 2-5 show structural damage due to large differential settlement which resulted from soil liquefaction.

SECTION 3
STRUCTURAL PERFORMANCE

Many engineered and non-engineered structures were severely shaken by the June 21, 1990 northern Iran earthquake. A brief survey of performance of each structure will follow.

3.1 Adobe and Unreinforced Masonry Bearing Wall Buildings

As in past earthquakes in Iran and elsewhere, buildings constructed with adobe and unreinforced masonry bearing walls experienced substantial damage and/or total collapse. The damage was particularly widespread in regions close to the epicenter and was responsible for the great majority of life loss associated with this earthquake.

In Manjil and Rudbar, located near the epicenter, the degree of damage to unreinforced masonry buildings is such that only a few buildings remain standing. Most buildings that have not collapsed are beyond repair and require demolition. The damage generally appeared to be equally severe for brick or block walls supporting either lightweight roof systems, concrete slabs, or brick infilled steel (jack arch) roof systems. Fig. 3-1 through 3-3 show the degree of destruction in the Manjil area. Fig. 3-4 shows the collapse of the parapet and roof of the City Hall building in Rasht. Buildings with many unreinforced masonry walls acting as shear resisting elements were also damaged beyond repair (Fig. 3-5).

Many unreinforced masonry bearing wall structures used reinforced concrete bond beams (concrete beams poured on top of walls). Potential for total collapse of these buildings appears to have reduced (Fig. 3-6).

A exception to the damage pattern is the Rostamabad post office (Fig. 3-7) which appears to be unreinforced masonry, but remained undamaged. Further review of this building should reveal the reasons for its good performance.

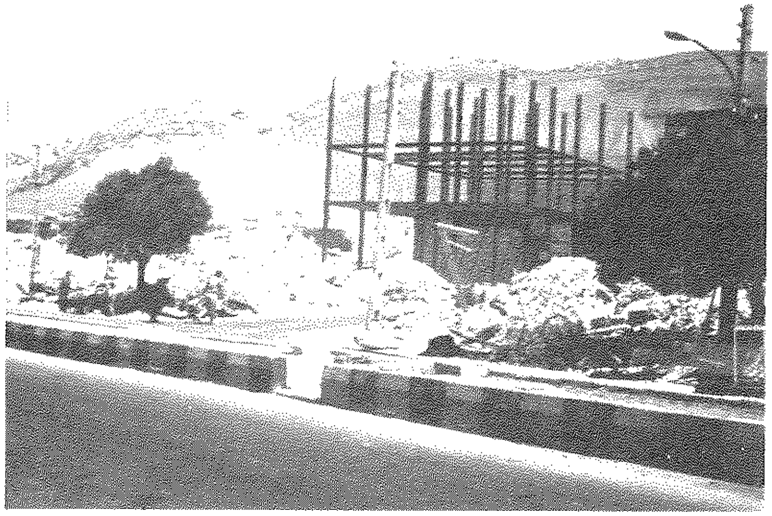

Figure 3-1 Destruction of buildings in the epicentral region

Figure 3-2 Widespread collapse of unreinforced masonry buildings.

Figure 3-3 Roof collapse in an unreinforced masonry bearing wall structure. The roof is brick infilled steel beam (jack arch) system which is very common in Iran.

Figure 3-4 Parapet and partial roof collapse of Rasht City Hall.

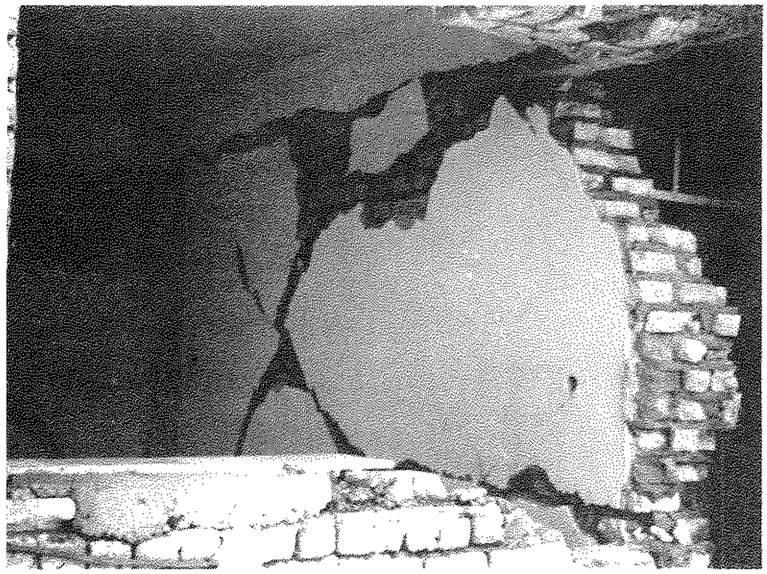

Figure 3-5 Major damage to buildings with extensive amount of unreinforced shear walls

Figure 3-6 Building of Figure 3-5. Presence of reinforced concrete bond beam prevented roof collapse

3.2 Unreinforced Brick Masonry Infill Walls

Thin unreinforced hollow or solid brick masonry infill is used almost exclusively in buildings in Iran. These thin walls have repeatedly proved to have poor performance in severe earthquakes. Their performance during this earthquake proved not to be an exception. Widespread damage to buildings with thin unreinforced masonry infill occurred in Rasht, located some 60 km from the epicenter. Numerous relatively modern buildings with expensive architectural finishes were evacuated by their residents due to extensive cracking or collapse of these "non-structural" elements (Fig. 3-8).

The thin unreinforced masonry infill in a three-story steel structure in Manjil (Fig. 3-9) appears to have performed better due to the presence of light steel sections which had been installed in plane of the wall. This resulted in reduction of wall span for out-of-plane bending.

Thick solid unreinforced masonry walls were sometimes used as shear resisting elements in mid-rise buildings. These walls typically are placed at two opposite ends of buildings and have no openings. In several buildings of this category in Rasht, these walls appeared to have reduced building drift, preventing total collapse.

3.3 Steel Structures

The design of steel structures in Iran differs substantially from that of the United States due to the unavailability of larger steel sections. Columns are typically double I-beams with batten plates or continous cover plates. Main girders typically consist of two I-beams located along the two sides of each column and supported underneath by bearing angles. In some cases, an angle is installed at the top of the beam to provide a minimal moment resisting connection.

Figure 3-7 Post office building in the area of high ground motion appears to be undamaged

Figure 3-8 Typical damage to hollow clay unreinforced masonry infill walls

In the direction perpendicular to the main girder, beams designed for gravity only support the infill brick floor system (jack arch). Alternatively, a reinforced concrete joist system spans between the main girders. In either case, there is no moment connection for lateral loads perpendicular to the main girders. Lateral loads in this direction are often resisted by cross bracing or solid unreinforced masonry walls are used as shear walls. Sometimes the structure is constructed with no apparent lateral load resisting system.

Extensive damage was experienced in many of these steel buildings which have 4 to 8 stories. Several cases of total collapse occurred in the City of Rasht, where a majority of these structures were constructed. The degree of damage to mid-rise steel buildings in Rasht could also be related to the hypothesized long period of the ground motion in this city. The damage to all steel structures surveyed by the author may be traced to major deficiencies in the design and construction of the structures. Fig. 3-10 shows a 4-story damaged steel structure which lacks bracing on one side. The bracing, where provided, is shown in Fig. 3-11. These braces failed at the connections and, according to the building technician, have been repaired to their original configuration. This points to very poor design of brace as well as welding at connections. Poor welding was also observed in the gravity load system of this building.

Fig. 3-12 shows permanent sway of an 8-story steel structure which was under construction at the time of earthquake. Fig. 3-13 shows the second floor framing of the same building, indicating a lack of moment frames in the direction in which permanent sway occurred.

3.4 Reinforced Concrete Buildings

Typical reinforced concrete construction in Iran uses poured-in-place concrete floor joists. Hollow clay or concrete blocks fill the space between joists and provide forming for the topping slab. Reinforced concrete girders typically have the same depth as floor joists.

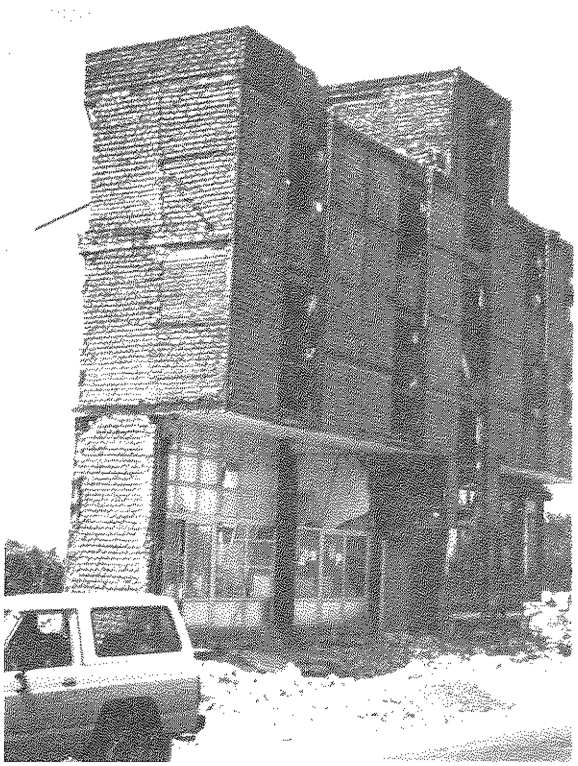

Figure 3-9 Masonry infill constructed with light steel reinforcement

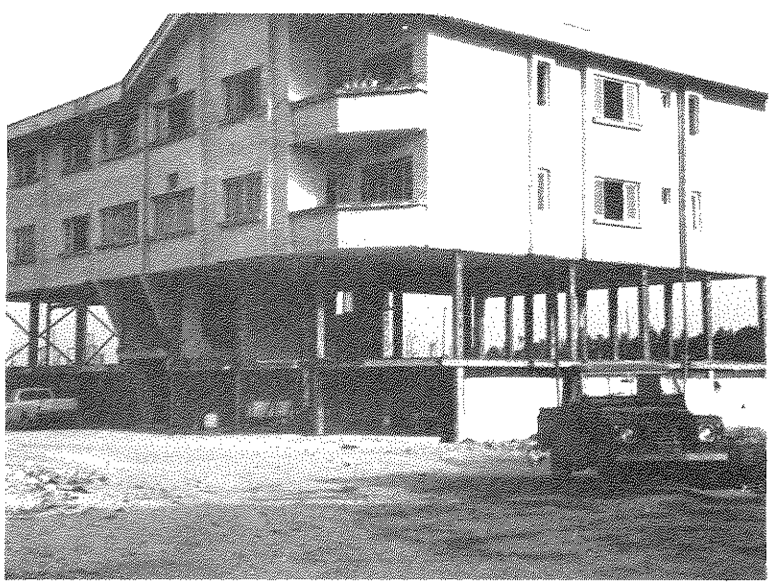

Figure 3-10 Damaged steel structure with inadequate bracing

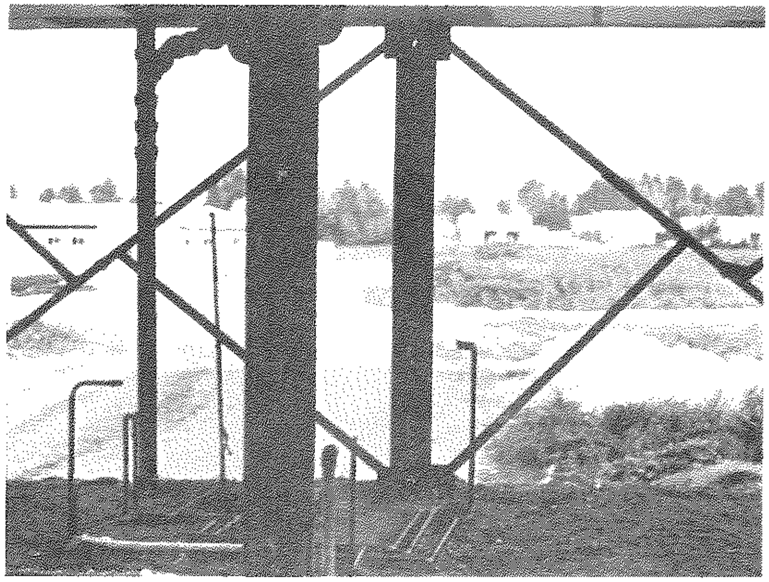

Figure 3-11 Steel bracing of building in figure 3-10.

Figure 3-12 Permanent sway of an 8-story steel structure under construction

This system provides a flat surface under the floor structure (Fig. 3-14) to receive gypsum trowled-on ceiling.

Although some structures have reinforced concrete shear walls to resist seismic forces, many buildings with this type of construction rely on the moment frame action of the gravity frame for lateral loads. However, ductile detailing in the form of beam stirrups, column hoops, joint reinforcement and development lengths as required by the U.S. codes are typically not used. As expected, performance of these buildings proved to be very poor.

Fig. 3-15 shows two adjacent 5-story concrete frame buildings that were under construction at the time of the earthquake. The structure on the right collapsed completely, impacting and buckling the corner column of the structure to the left.

Fig. 3-16 shows another mid-rise concrete building totally collapsed. The reinforcement of this building, as shown in the picture, is plain (undeformed) bars.

Note that both collapsed buildings are in the City of Rasht, some 60 km from the epicenter. Although ground motion records are not yet reported for this City, accelerations on the order of 20 percent gravity is estimated. It should also be noted that both buildings were under construction, and did not yet carry the total gravity load to which they were designed.

3.5 Industrial Buildings

A great majority of industrial buildings in the earthquake striken area are of light steel construction (Soule or Butler type). Although extensive damage and collapse of infill was experienced, the structure itself performed well. Even when the steel rod-bracing was ruptured, the structure often remained undamaged. Fig. 3-17 shows such a structure in Ganjeh, some 30 km from the epicenter.

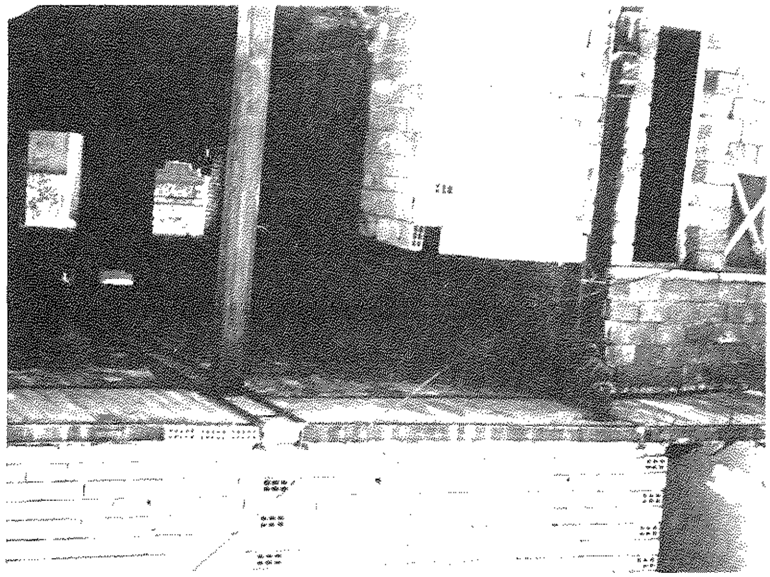

Figure 3-13   Structural steel framing in building of Figure 3-12

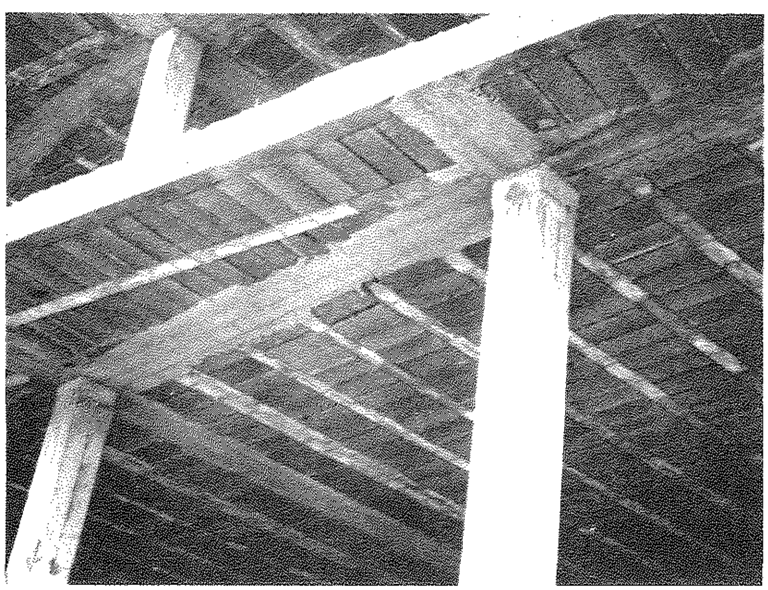

Figure 3-14   Typical concrete frame construction in Iran

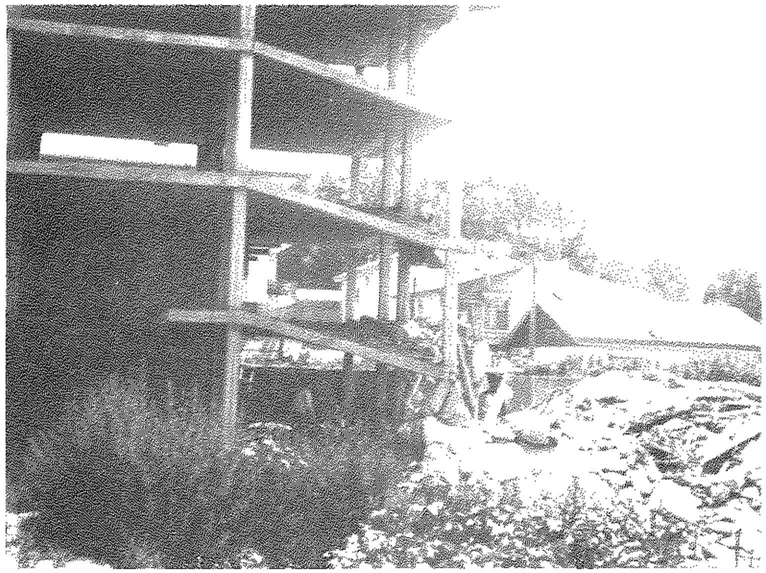

Figure 3-15 Collapse of a mid-rise concrete building and damage to the adjacent building.

Figure 3-16 Collapsed concrete building in Rasht.

3.6 Miscellaneous Structures

Elevated Tanks: A 1500 m^3, 46 meter high water tank, constructed 20 years ago and serving the City of Rasht, completely collapsed. This structure was reported to be about two-thirds full of water. The structure had a reinforced concrete shaft and a prestressed concrete tank. Fortunately, the structure collapsed away from the adjacent structure (Fig. 3-19 and 3-20).

Two similar elevated tanks (Fig. 3-18) in the same area, which were under construction and were thus empty, experienced horizontal cracks at the shaft near the base.

A steel elevated water tank in Manjil experienced rupture of its bracing members but remained upright.

Bridges: There are many steel and concrete bridges in the area. No major damage to bridges was reported. One major bridge (Fig. 3-21) within 20 km of the epicenter showed lateral displacement at the ground level of approximately 10 inches (Fig. 3-22). There was no readily observable damage to the columns or girders of this bridge.

Dams: Sefidrud Dam is probably the most important structure in the epicentral region. It is located less than one km from the fault. The dam is of the buttress type (Fig. 3-23), with a height of 106 meters and length of 425 meters. The upstream and downstream slope is 0.4 and 0.6, respectively, resulting in a base width of 100 meters. It has been reported that the dam was designed for a static lateral force coefficient of 0.25. The reservoir was almost full at the time of earthquake. This dam experienced horizontal and diagonal cracks at the top of some buttresses, but remained stable.

Sangar Dam, a diversion structure located some 50 km north of the epicenter was structurally undamaged. However, several radial gates of the dam failed at their connections and reportedly were thrown several hundred feet downstream. This damage was reported to have been caused by dislodging of the counterweight cables.

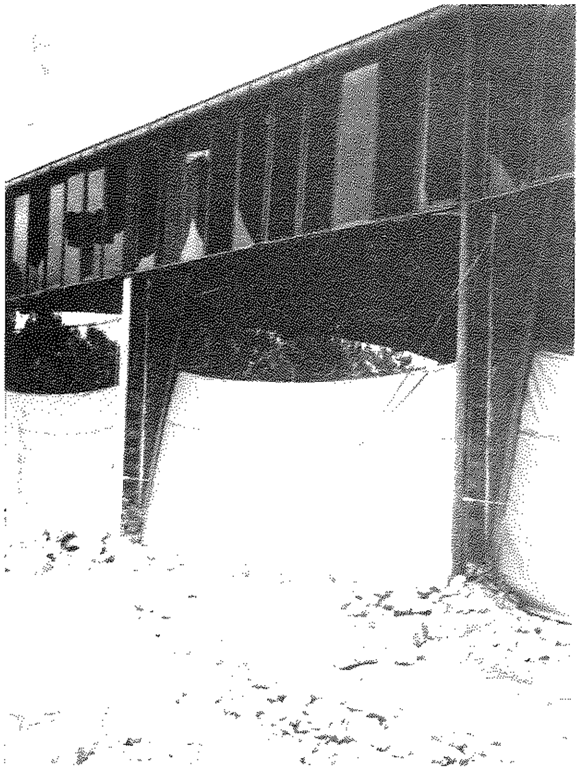

Figure 3-17 Light steel industrial building without structural damage after rupture of rod bracing.

Figure 3-18 Concrete elevated water tank without water exhibited tension cracks at the base of its shaft.

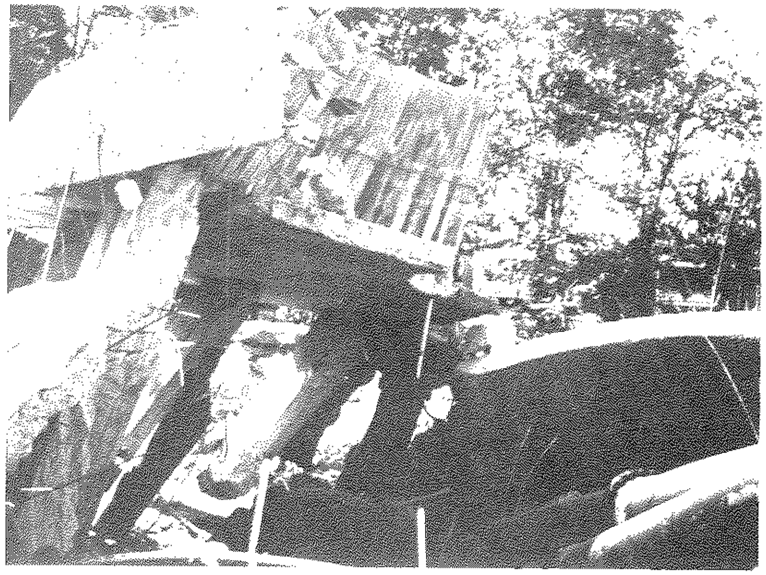

Figure 3-19 Concrete elevated water tank, 2/3 full, collapsed

Figure 3-20 Elevated water tank of Figure 3-19 collapsed away from the adjacent building

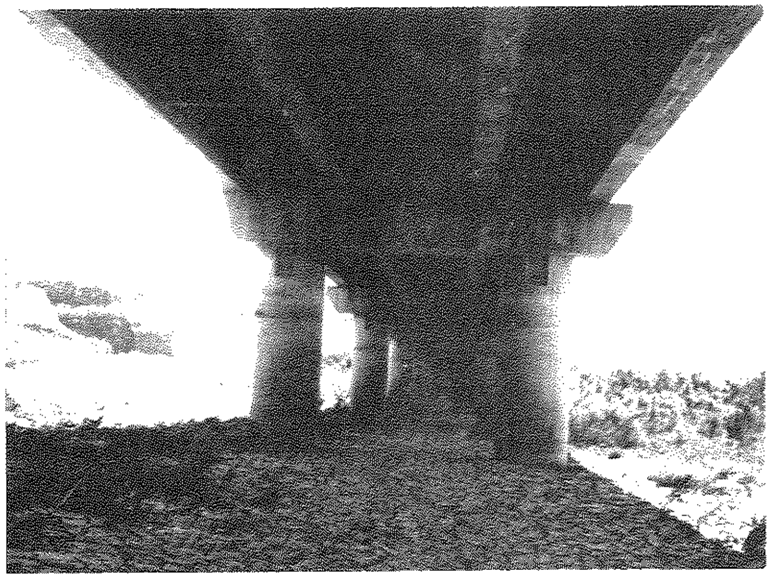

Figure 3-21 Concrete bridge with large lateral pier displacement appears to be undamaged

Figure 3-22 Pier displacement of bridge shown in Figure 3-21.

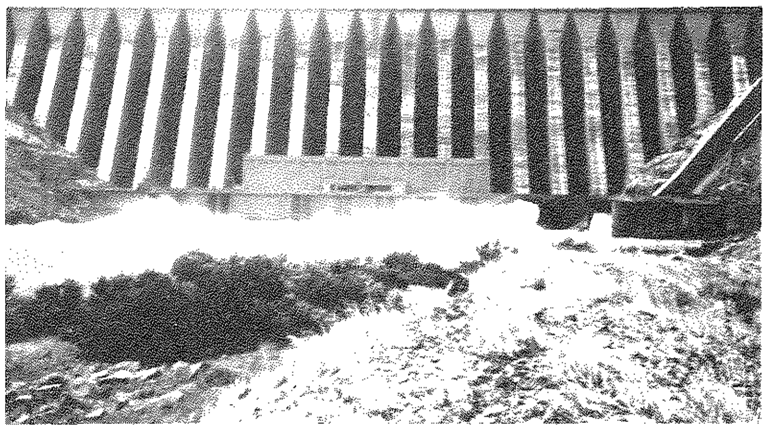

Figure 3-23 Sefidrud dam within 1 km of the fault.

SECTION 4
SUMMARY AND CONCLUSIONS

Although the performance of buildings in this earthquake seems to be consistent with lessons learned in the past, it provides a substantial amount of new data for further study and research. Findings of this reconnaissance survey are summarized as follows:

1. Poor performance of buildings was due to the use of brittle construction materials, inadequate design and detailing or deficiency in workmanship. In many cases, all these factors were present together in a single structure.

2. Unreinforced masonry buildings once again proved to be the most hazardous form of building construction. Presence of reinforced concrete bond beam at the top of unreinforced masonry walls appeared to reduce the probability of total collapse of the structure.

3. Far field, long-period ground motion appeared to be a factor in poor response of mid-rise buildings in the City of Rasht.

4. Nonductile concrete frame buildings showed poor performance as in past earthquakes. Detailed review of these buildings can provide valuable information for calibrating existing methodology for evaluation of the collapse resistance of this type of building construction.

5. Bridges performed relatively well. Review of these bridges can be instructive for assessment of existing steel and concrete bridges in the U.S. and elsewhere.

6. Elevated concrete water tanks had unacceptable performance. Much can be learned from detailed review of this type of "inverted pendulum" structure.

7. The 106 m high Sefidrud Dam, located within 1 km of the epicenter and subjected to very intense ground motion (0.60g), appeared to sustain little damage. This structure can also be an excellent data point for evaluating concrete gravity dams.

SECTION 5

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