特 集 5
研究解説

UDC 614.8 : 551 : 550.34

Lessons Learned from the Damage of the Erzincan Earthquake, Turkey, March 13, 1992

トルコ・エルジンジャン地震(1992.3.13)の被害に学ぶ

Kimiro MEGURO* and Yoshiaki NAKANO**
目 黒 公 郎・中 埜 良 昭

An earthquake of magnitude 6.9 occurred in the eastern part of Turkey on March 13, 1992. Erzincan City which is located near the epicenter sustained damage. The authors visited the area three weeks after the event and investigated the damage as members of a reconnaissance team. Based on their field surveys, this report briefly describes the damages to buildings, human casualties, and response activities.

1. Introduction

On March 13, 1992 at 19:18:40 (local time), an earthquake of Ms 6.9 (USGS) occurred in Erzincan located in the eastern part of Turkey. Although the magnitude of the earthquake was not so big, 677 people were killed and many buildings collapsed or were substantially damaged.

The Architectural Institute of Japan and Japan Society of Civil Engineers dispatched a combined reconnaissance team including the authors to investigate the damages jointly with researchers from Bogazici University, Turkey. Though the damage such as landslide, snowslide and disruptions of electricity and water supply occurred, the major damage was the collapse of buildings which caused most of the death casualties. This report briefly summarizes the damage to buildings, human casualties and response activities following the earthquake.

2. Overview of Erzincan

Turkey has 71 provinces as shown in Fig.1. Erzincan is located in the eastern part of the Anatolia Plateau, 690 km east of Ankara, the capital city, and 1,103 km east of Istanbul. The province of Erzincan has eight cities and towns (Fig.2). In Turkey, the capital city usually has the same name as the province. Erzincan City is the capital of Erzincan Province.

Erzincan City is located in the Erzincan Basin made by the Firat River, one of the branch rivers of Euphrates River. This basin lies along the Firat River from the northwest to the southeast. From deep boring experiment, it was found that alluvial layers exist to a depth of more than 300m. The exact depth of the alluvial layers is not known. The altitude of the basin is about 1,200 m and the basin is surrounded by mountains 3,000-3,500 m high. Erzincan is very cold and has heavy snow in winter, with temperature falling down to below -10 degrees.

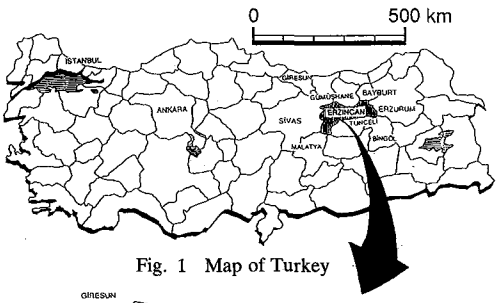

Fig. 1 Map of Turkey

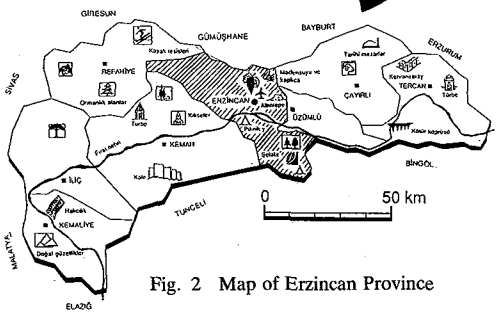

Fig. 2 Map of Erzincan Province

Erzincan Province has a total land area of 11, 903 km2 and a population of about 300,000 which has not changed during the last 15 years. However, the population of Erzincan City has been increasing because of the migration of people from surrounding areas. About 60% of the population of Erzincan Province are living in the basin. Erzincan City and its surrounding areas have a population of about 150,000, and including that of Uzulum which is

* International Center for Disaster-Mitigation Engineering, INCEDE
** Department of Applied Physics and Applied Mechanics

about 30,000, a total of 180,000 residents live in the basin. Figure 3 shows the changes in the population of Erzincan City.

In 1939, Erzincan City was totally destroyed by a M7.9 earthquake, after which people moved and the present Erzincan City was established in the northern part of the basin. From the harsh experiences of the 1939 earthquake, the number of stories has been limited. Buildings along main streets are limited to three stories and in the other areas, two stories. However, the increase in population from migration and the need to build houses to spur the economy necessitated an increase in the limit of the number of stories. Today, six-story buildings are allowed along main streets and four-story buildings in the other areas. Recently, the suburbs of the city have been developed primarily with medium-rise buildings which

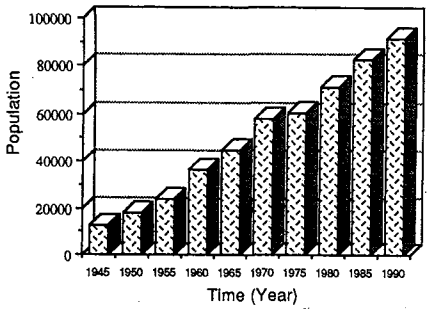

Fig. 3 Changes in population of Erzincan City

Table 1 Buildings in Erzincan

	Date of Construction				
	Pre-1974	1975-79	1980-84	Unknown	Total
Frame Const.	5,708	773	1,162	32	7,675
RC or Steel	1,563	745	1,156	15	3,479
Wood	4,145	28	6	17	4,196
Other	-	-	-	-	-
Unknown	-	-	-	-	-
Masonry Const.	4,002	3,176	779	44	8,001
Concrete Block	73	33	55	5	166
Brick	3,333	3,073	719	32	7,157
Stone	18	3	-	-	21
Adobe	565	64	2	2	633
Other	1	-	-	-	1
Unknown	12	3	3	5	23

Table 2 Breakdown of buildings according to number of stories and type of buildings

Number of Stories	Vertical Load Carrying System		
	Framed Const.	Masonry Const.	Total
1	5,441	6,119	11,560
2	1,085	1,704	2,789
3	726	171	879
4	150	6	156
5	253	-	253
6	18	-	18
7	-	-	-
8	-	-	-
9	1	-	1
10+	-	-	-
Unknown	1	1	2

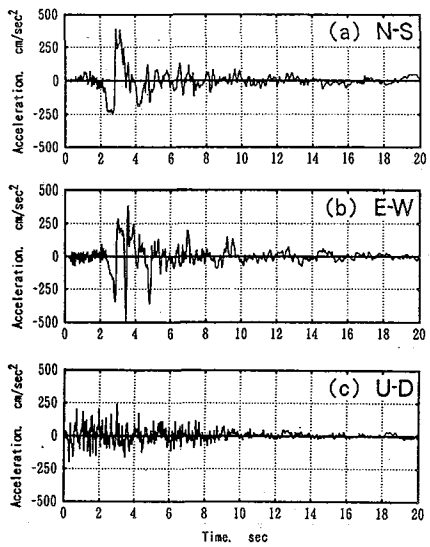

Fig. 4 Strong motion record

can accommodate several families. These new buildings concentrate in the northern part of the city because government planners think it is safer than the southern part judging from historical earthquake occurrences. However, these buildings suffered severe damages during the 1992 event. From our investigation, we noted that there are a lot of free spaces where one- or two-story buildings can be built. People told us these medium-rise buildings look better and can be built at lower cost. Table 1 shows the number of buildings according to their types and the years of construction. Table 2 shows the number of each type of buildings with different stories in 1984.

3. Strong Motion Record

One strong motion instrument (Kinemetrics SMA-1) in the Meteorological Service Building located approximately 3 km away from the epicenter recorded the motion (Fig. 4). The peak accelerations are approximately 0.5g in east-west, 0.4g in north-south, and 0.25g in up-down direction. Strong shaking with a comparatively long predominant period can be observed within the initial 5 to 6 seconds.

4. Damage to Building Structures

4.1 General Description of the Damage in Erzincan City

As stated previously, after the devastating earthquake in 1939, the city of Erzincan was relocated to its current place. Just after the 1939 earthquake, buildings with more than three stories were not allowed to be constructed in

the new Erzincan city. Taller buildings, however, have been gradually allowed and currently up to six-story buildings are constructed. In 1983, an earthquake of magnitude 5.6 occurred. Although this earthquake did not cause any fatalities, several buildings including Hotel Urartu and Municipal Annex Building which will be described later sustained heavier damages than were expected in this level of earthquake. Almost all buildings damaged in 1983 were, however, simply replastered and put into service without any adequate repairing nor strengthening. These buildings totally collapsed in the 1992 earthquake.

Almost all buildings in the city of Erzincan were cast-in-place concrete frame structures with hollow brick infills and RC shear walls were not usually provided except for those with more than four stories. Spectacular building damages were observed in the central districts such as Inonu, Kizilay, and Karaagac, the east districts such as Fatih, Yunus Emre, and Aksemsettin, and the northwest district such as Yavuz Selim. Field surveys were carried out in the east and northwest districts to investigate the correlation between the damage levels and the number of stories. Figure 5 clearly shows that the buildings with three or more stories sustained heavier damage than those with less than three stories indicating that the destructive damage would not have occurred if the number of stories had been limited to two stories as had been specified after the 1939 earthquake.

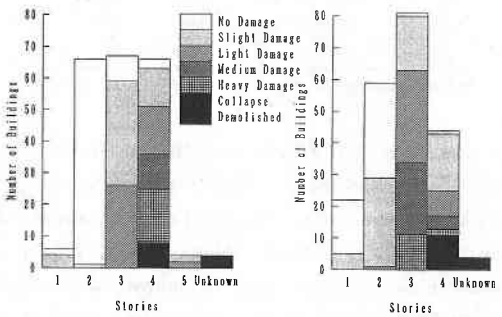

Fig. 5 Damage statistics (after Ref. 1)

4.2 Damage Observations

Hotel Urartu, a four-story RC building completed in 1974 and located in Kizilay District, totally collapsed as shown in Photo 1. This hotel suffered structural damage during the 1983 earthquake, but it was put into use again without any adequate retrofit. The hotel was more than 50% full at the time of the earthquake[2] and 8 guests were killed. The Municipal Annex Building located next to Hotel Urartu also collapsed totally as shown in the left

Photo 1 Totally collapsed Hotel Urartu (right) and Municipal Annex Building (left) [Kizilay District]

Photo 2 Totally collapsed residential building [Kizilay District]

Photo 3 Residential building collapsed in upper stories [Kizilay District]

Photo 4 Close-up view of column with pullout failure due to inadequate anchorage of column reinforcement to beam

Photo 5 Collapsed State Hospital

Photo 6 Communication Building collapsed in the second story [Karaagac District]

Photo 7 Totally collapsed apartment building [Yavuz Selim District]

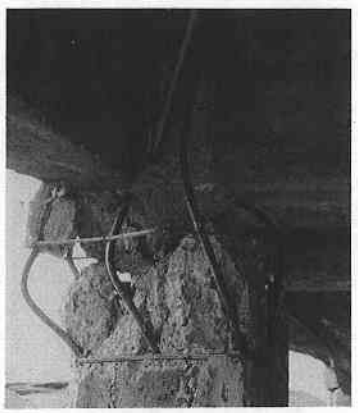

Photo 8 Buckling of longitudinal bars due to absence of lateral reinforecement in beam-column joint

Photo 9 Soft story failure

Photo 10 Honeycombs exposing embedded reinforcement

Table 3 Schmidt hammer test of concrete in central Yavuz Selim District

	Damage Level*			
Story	H	H	M	S
3	80	95	80	80
2	80	95	< 80	80
1	100	120	80	80
B1	150	185	100	120
Ave.	103	124	85	90

*H:heavy damage, M:medium damage, S:slight damage

hand side of Photo 1. This building also suffered damage in 1983, and as was the case with Hotel Urartu, was put into service with no adequate retrofit. Photos 2 through 4 show damages to residential buildings observed in Kizilay District. In most cases, as shown in Photo 4, the damaged buildings showed poor detailing of reinforcement such as (1) inadequate anchorage of reinforcement to connected members and/or (2) wide spacing of shear reinforcement with a small diameter, having 90-degree hooks at both ends which cannot provide sufficient confinement when subjected to a strong seismic excitation.

Photo 5 shows the five-story State Hospital in Karaagac District. The hospital consists of two buildings with an expansion joint between them. The east wing suffered heavy damage but survived the earthquake probably because the masonry infilled staircase contributed to the

Photo 11 Neighboring six-story apartment buildings

strength and stiffness of the building. Photo 6 shows the four-story Communication Building located near the State Hospital. The second story of the building failed, making it look like a three-story building.

Three-story apartment buildings with basement, located in the central area of Yavuz Selim District, totally collapsed as shown in Photo 7. In this area, more than forty buildings, each consisting of two identical but mutually independent structural units, were under construction on the ground excavated to 2 m below the surface. Since the spaces surrounding the basements were not refilled in most buildings, these buildings were essentially four-story at the time of the earthquake. Major damages were observed in the exposed basement. Extensive cracks in columns, poor confinement resulting from the absence of lateral reinforcement in beam-column joints (Photo 8), and concrete crushing in columns were common in the buildings which suffered substantial damage. In some buildings, the soft story mechanism in the basement due to flexural failure in columns was observed as shown in Photo 9. In general, the quality of concrete was poor, and honeycombs exposing reinforcement were seen in many buildings as shown in Photo 10. It is interesting to note that the damages to these buildings ranged from slight to total collapse although they had identical structural plans. To investigate the correlation between the concrete strength and damage level, Schmidt hammer tests were made for several buildings in the central Yavuz Selim District. Table 3 summarizes the test results. Although the quality of concrete was generally poor, no obvious correlation was found. On close examination, however, it was found that the buildings with less than slight damages had concrete block infills in the frames of basement, which seemed to have contributed to the strength and stiffness of the buildings.

Photo 11 shows two neighboring six-story apartment buildings with identical structural plans having RC core wall in the center, located in Bahcelievler District. Major damages were seen to have taken place in the first story. In the central core wall, shear cracks and failures were observed in the transverse (EW) direction as shown in

Photo 12 Shear failure in the central core wall

Photo 13 Collapsed Social Security Hospital [Inonu District]

Photo 14 Collapsed Military Hospital

Photo 12. Flexural failures were noted in many columns especially in the EW direction and slight damages in the NS direction. Shear failures were found in short-span beam, extending cracks into the slab. In general, damages were more extensive in the EW direction of the building than in the NS direction.

The Social Security Hospital with four stories (partially five stories) in Inonu District, completed in 1968, totally collapsed in the south wing as shown in Photo 13. This hospital had a Z-shape in plan, with the two wings connected to the main building by staircases. An expansion joint was provided between the collapsed wing and the staircase, but torsional responses around the rigid staircase might have affected the performance of the building, resulting in total collapse. The failure of the building caused 59 fatalities including doctors, nurses, and patients.

Photo 14 shows spectacular damage to another hospital. The west-most wing of the five-story Military Hospital totally collapsed and its middle-west wing failed in the second story.

5. Human Casualties and Response Activities

In Erzincan City, 526 people were killed by this earthquake. In the whole Erzincan basin, a total of 677 people died. This number could have been larger. The earthquake occurred on a Friday night during the Ramadan month (fasting season of Muslims). Thus, most of the people were either in their houses or in the mosques. Most of the collapsed buildings in this earthquake were office or public buildings. If the earthquake had occurred in different circumstances, the death toll would have been higher.

Many buildings for public use including hospitals were heavily damaged. The collapse of hospitals posed a big problem because of its central role in rescue operations.

Therefore, the Public Health Ministry, Medicines Sans Frontiers and Red Crescent (Kizilay, in Turkey) had to serve important roles in the rescue operations.

5.1 Damage of Hospitals

Erzincan City has three large public hospitals, two private hospitals, and seven clinics. In the suburbs, there are 41 small hospitals. Most of these hospitals were severely damaged. There were no hospitals that could be fully utilized after the earthquake. The following are the figures of human casualties in the three major hospitals:

- Erzincan State Hospital (275 beds) established in 1939
  The dormitory for nurses collapsed, killing 23 nurses and seriously injuring 8. Sixty people were rescued.
- Social Security Hospital (120 beds) established in 1968
  Fifty-nine people, including doctors, nurses, and patients, were killed and three others were seriously injured.
- Military Hospital (200 beds) established in 1974
  At the time of the earthquake, there were 64 patients. Fortunately, all were rescued and no one was killed.

5.2 Red Crescent (Kizilay) Camps

The Kizilay camp was set up in a soccer stadium in the central part of the city Photo 15, where first aid treatment and other basic needs were provided. Emergency goods from other branches of Kizilays Erzurum, Elazig, and Adana arrived in the city within five to six hours after the earthquake. Within ten hours after the quake, its head office in Ankara sent emergency goods to the city. At ten in the morning of March 14 or 15 hours after the earthquake, the camp was set up.

By May 13, or two months after the earthquake, 25,586 tents, 16,081 from Kizilay, 9,505 from abroad; 120,858 blankets, 64,125 from Kizilay, 156,733 from abroad; 7,298 units of blood; 30,711 bales of clothes; 1,022 tons of foods and 11,760 boxes of various supplies were delivered to the people of Erzincan City and its surrounding areas. By April 7, at the time of our investigation, 8,468 patients had received treatment. In the first 15 days, the number of people who received treatment in the camp was 6,633. Among them, 1,865 people were injured directly by the earthquake. Victims of burns numbered 781, and those of trauma and other various infections, 481 and 600, respectively. There are two reasons for the large number of burnt people. Firstly, when the earthquake occurred, it was very cold in Erzincan and most homes were using heaters. Secondly, since it was the fasting (Ramadan) month, people were preparing tea or dinner immediately after sunset when the earthquake struck. Most of them including many children were scalded by boiling water. About 4,800 people suffered from respiratory infections, mainly caused by the dust from collapsing buildings and the cold climate. People were forced to stay outside with inadequate clothing after their houses collapsed.

The Kizilay camp was staffed by five managers, five drivers, ten cooks, seven helpers, and two night guards. The medical team consisted of a chief doctor, an assistant chief doctor, a chief nurse, an assistant chief nurse, five nurses from Kizilay, eleven temporary nurses from the Public Health Ministry, and four temporary doctors. During the first days, however, there were around

Photo 15 Kizilay camp in the soccer stadium

Photo 16 Operating room

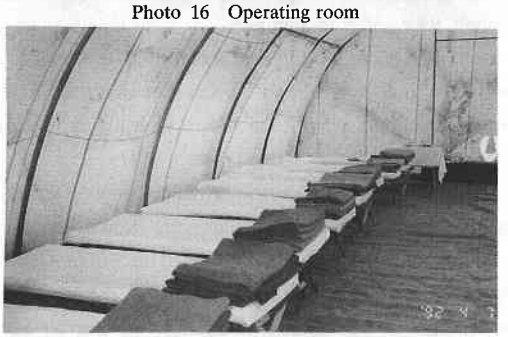

Photo 17 Beds for patients

Photo 18 Mobile kitchens

eighteen to twenty doctors in the camp. The facilities of the camp included an operating room, a delivery room, and 200 beds as shown in Photos 16 and 17.

Food was cooked in the mobile kitchens of Kizilay shown in Photo 18. Eight mobile kitchens supplied around 18,000 meals a day.

According to the leaders of the camp, the most

Photo 19 Interior of the warehouse

important emergency measures were to find temporary shelter, food, and medical treatment in the first 24 hours. They have an effective system to deal with disasters. In Turkey, Kizilay has 36 blood centers, a nursery school, and 660 branches where they also give lectures on first aid and rescue. Their strongest point was that they had severe actual experiences in dealing with a great number of injured persons. The Kizilay had enough experience in treating refugees (e.g., Kurds, Suryanis escaping from Northern Iraq and Turks and Turkmen escaping from Bulgaria). This experience helped them to deal effectively with the victims of the earthquake. The leaders said that they simply followed the standard operating procedures, and that the same had been done for other disasters in the past. The only difference was that the injured people could be taken cared of at existing hospitals in the past disasters. Since hospitals were badly destroyed by the earthquake, a temporary hospital had to be set up in the field.

The supplies provided by the Kizilay came from Turkey and other foreign countries. To investigate the level of international relief aid, we visited one of the two temporary warehouses located about 12 km from the camp. The warehouse was protected by soldiers with automatic rifles. Photo 19 shows the inside of the warehouse. Acceptance and delivery of the relief materials were under the control of Kizilay officials, who said that the food from their own country was basically enough for the people's needs, but that they needed the tents and blankets donated by foreign countries.

6. People's Lives in the Damaged Area

To study the people's way of life after the earthquake, questionnaire surveys were conducted. The questionnaire had only fifteen simple questions.

There were 66 respondents, of which 64 were men and 2 were women. The big gap in the number of men and women respondents was due to the difficulty of getting

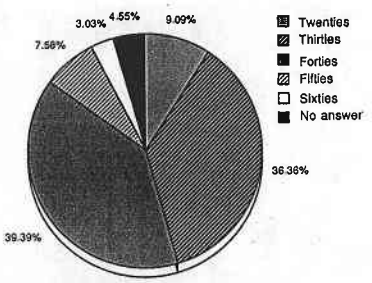

Fig. 6 Age distribution of respondents

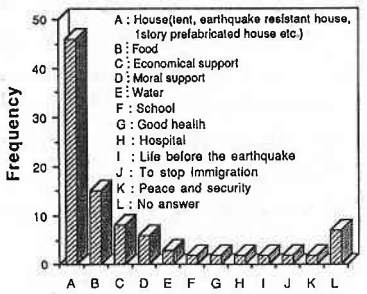

Fig. 7 Distribution of people's needs based on the survey

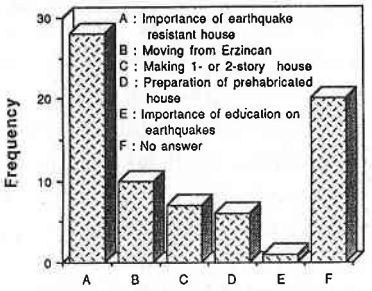

Fig. 8 Distribution of lessons learned from the earthquake

Muslim women's cooperation. Figure 6 shows the age distribution of the respondents. Both women were 40 years old.

Thirty-four respondents (51.5%) said that they had experienced earthquakes before. Thirty of them had experienced the 1983 Erzincan earthquake (M5.6). Seventeen people (25.8%) said that they thought before this earthquake that there would be a big earthquake. Only two persons said that they received training and information on earthquake preparedness from the government. Figure 7 shows the answers of the respondents to the question "What is most needed now?". As of three weeks after the earthquake, the most important problem was housing. Figure 8 shows the answers to "What lessons did you learn from this earthquake and what are you planning to do now ?". Many people got the importance of earthquake resistant houses and wanted to move from Erzincan.

7. Concluding Remarks

Based on the field surveys in the damaged areas, the following can be pointed out to avoid damages from future earthquakes:

Poor details of reinforcement which had caused major damage in past earthquakes were again observed in heavily damaged buildings. It seems that lessons from past damage have not been well understood by structural engineers. Shear walls should be used to improve seismic performance. Totally collapsed buildings did not have shear walls. Several buildings which had shear walls sustained minor damages or survived the earthquake even though they suffered damages.

Collapse of the buildings for public use, such as hospitals and hotels, caused many casualties. These structures should be constructed in such a way to make them more earthquake resistant.

During the earthquake, the provincial centers suffered major damage and many officials were injured or killed, or their family had severe damage. Thus, organizations dealing with emergency services could not carry out their functions. To mitigate the damage of earthquakes, preparation (of the systems, organizations, emergency goods, etc.) for future earthquakes both in the capital and in the provinces is necessary.

(Manuscript received, December 28, 1992)

References

1 AIJ-JSCE Joint Reconnaissance Team, "Quick Report on the 1992 Erzincan Earthquake," AIJ-JSCE, June 1992.
2 Polat Gulkan, "A Preliminary Field Reconnaissance Report on the Erzincan Earthquake of 13 March, 1992," prepared in conjunction with the Learning from Earthquakes Project of the EERI.
3 State Institute of Statistics, 1984 Census of Buildings, Ankara, 1984.