MCEER
MULTIDISCIPLINARY CENTER FOR EARTHQUAKE ENGINEERING RESEARCH
A National Center of Excellence in Advanced Technology Applications

A Summary of Earthquake Reconnaissance Efforts of the Multidisciplinary Center for Earthquake Engineering Research

MCEER RESPONSE

Preliminary Reports from the Kocaeli (Izmit) Earthquake of August 17, 1999

Early in the morning on Tuesday, August 17, 1999, a magnitude 7.4 earthquake struck along the Anatolian fault in the northwestern region of Turkey. Epicentered approximately 11 km southeast of the industrial city of Izmit (Kocaeli), the earthquake lasted 45 seconds and was felt over thousands of square miles in Turkey's most densely populated region. Commercial and residential buildings from Adapazari to Istanbul collapsed resulting in a large-scale loss of life. Within days, MCEER dispatched four researchers to the region — three of them as part of the Earthquake Engineering Research Institute (EERI) reconnaissance team — to examine the earthquake's impacts. Their initial observations and impressions are presented in this issue of *MCEER Response*. A more detailed reconnaissance report is planned for publication later this year.

This publication is also available via MCEER's web site at *http://mceer.buffalo.edu*. The web site also features a 28 page preliminary report of the earthquake by Charles Scawthorn, EQE International, as well as numerous photographs of the area taken by the reconnaissance team. Links to other sites containing information about the earthquake are provided.

Seismological Observations

by Apostolos Papageorgiou
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The earthquake that struck northwestern Turkey on August 17,1999 (origin time 0 h 1 min 38.6 sec GMT) had a moment magnitude Mw 7.4 and caused over 14,000 deaths and destruction of immense proportions. The earthquake was caused by slippage of a segment of the North Anatolian Fault which filled a 100 to 150 km long seismic gap between an event that occurred in 1967 on the east of the gap and two events that occurred in 1963 and 1964 on the west of the gap. The seismic gap was first pointed out by Toksoz, Shakal and Michael (1979) and was later further investigated by Stein, Barka and Dieterich (1997). The latter publication forecasted that an earthquake, such as the one that occurred on August 17,1999, had a 12% probability of occurrence in the above-mentioned seismic gap over the period of 30 years from 1996 to 2026. It is thus evident that the earthquake should not have come as a surprise.

Surface faulting near Golcuk.

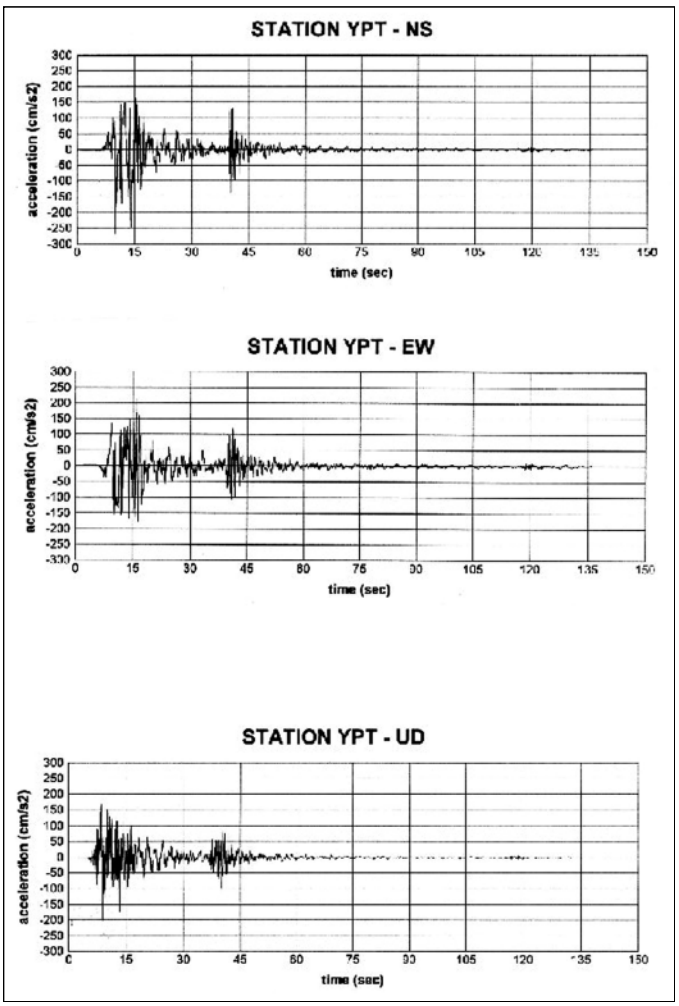
(continued on page 2)

Inside

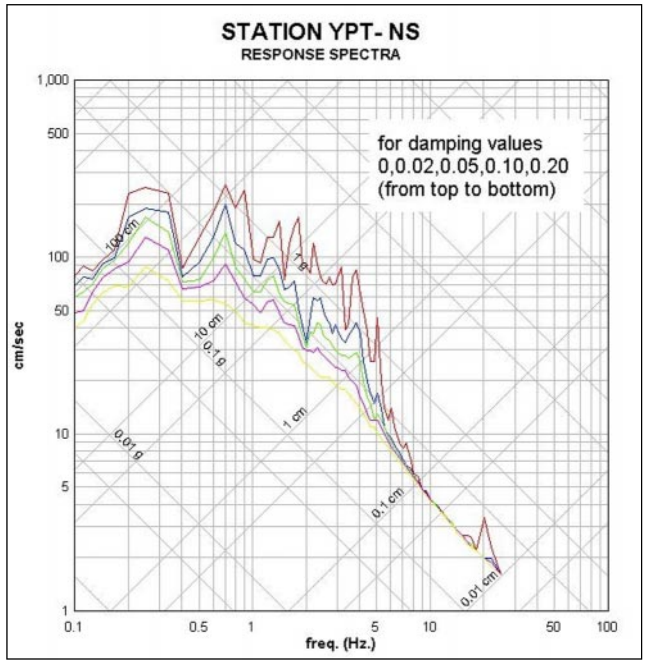
The causative fault zone, the North Anatolian Fault Zone (NAFZ), is a textbook example of a right lateral strike-slip fault that has been extensively studied in the past. It is considered a close analogue of the San

The North Anatolian Fault Zone is a textbook example of a right lateral strike-slip fault

Andreas Fault Zone in that it exhibits similar slip rates and similar total length. Preliminary reports by a team of USGS field investigators (*http://quake.wr.usgs.gov/study/turkey/*) reveal a complex pattern of faulting for the 1999 Izmit earthquake that exceeds 110 km in length. As the USGS team points out in their report,"...understanding how the Izmit earthquake linked together these various fault segments may provide a new understanding of the range of possible earthquakes that can occur near San Francisco and will ultimately help us more accurately estimate hazards in many regions."



Accelerogram recorded at the Yarimca petrochemical complex (YPT) on the north shore of Izmit Bay, approximately 4 km from the fault trace. (Source: http://www.koeri.boun.edu.tr/earthqk/earthquake.htm)



Response Spectra for NS component of YPT accelerogram. (Source: http://www.koeri.boun.edu.tr/earthqk/earthquake.htm)

There are several obvious reasons why the 1999 Izmit earthquake was so destructive — besides the quality of construction of the infrastructure — one of them being that the fault segments that ruptured causing this event crossed the most densely populated region of Turkey. This was compounded by the fact that the infrastructure was no match for the very energetic near-source pulses in the immediate vicinity (within 3 km) of the fault. Furthermore, the right-stepping en-echelon strike-slip segments of the fault in the vicinity of the cities of Golcuk and Izmit gave rise to elongated sedimentary basins, which may have trapped and amplified the incident seismic waves, thus enhancing the destructive power of this event. Finally, the accelerograms recorded in the vicinity of the fault reveal at least two major subevents, probably located about 30 km apart from each other.

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Structural Damage

by Michel Bruneau

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While thousands of people died in the numerous building collapses, the damage to reinforced concrete buildings was not surprising, nor unexpected. Similar types of damage were observed to a lesser extent in many prior earthquakes throughout Turkey. However, because these other earthquakes were in more remote, less populated regions, the message from earlier reconnaissance visits apparently did not resonate to the same degree.

The predominant structural system used for buildings in Turkey consists of reinforced concrete frames with unreinforced masonry infills. This structural form is used for all building heights and occupancy, from single-story commercial to multistory residential and office buildings. Frame-shear wall interactive systems are also used in new buildings. Industrial buildings are either reinforced concrete (cast-in-place or pre-cast) or steel frame structures.

A typical reinforced concrete frame building in Turkey consists of a regular, symmetric floor plan, with square or rectangular columns and connecting beams. The exterior enclosure as well as interior partitioning are of non-bearing unreinforced brick masonry infill walls. These walls contributed significantly to the lateral stiffness of buildings during the earthquake and, in many instances, controlled the lateral drift and resisted seismic forces elastically. This was especially true in low-rise buildings, older buildings where the ratio of wall to floor area was very high, and buildings located on firm soil. Once the brick infills failed, the lateral strength and stiffness had to be provided by the frames alone, which then experienced significant inelasticity in the critical regions. At this stage, the ability of reinforced concrete columns, beams, and beam-column joints to sustain deformation demands depended on how well the seismic design and detailing requirements were followed both in design and in construction.

Figure 1. One example of foundation failure.

The damage to reinforced concrete buildings from this earthquake can be attributed to one or more of the following:

- Foundation failures

Foundation failures were observed for a large number of buildings with large settlements, and in some cases, entire structures overturned.

- Soft stories

A large number of residential and commercial buildings were built with soft stories at the first-floor level. First stories are often used as stores and commercial areas, especially in the central part of cities. These areas are enclosed with glass windows, and sometimes with a single masonry infill at the back. Heavy masonry infills start immediately above the commercial floor. During the earthquake, the presence of a soft story increased deformation demands very significantly, and put the burden of energy dissipation on the first-story columns. Many failures and collapses can be attributed to the increased deformation demands caused by soft stories, coupled with lack of deformability of poorly designed columns. This was particularly evident on a commercial street where nearly all buildings collapsed towards the street.

Figure 2. Many building collapses and failures can be attributed to soft first stories.

- Strong beams and weak columns

Most frame structures have strong beams, remaining elastic, and weak columns suffering compression crushing or shear failure. In many cases, relatively deep beams were used with flexible columns, contributing to the strong-beam weak-column behavior.

- Lack of column confinement and poor detailing practice

Most of the structural damage observed in frame buildings was concentrated at column ends. Unfortunately, confinement reinforcement virtually did not exist in these members, making them unable to maintain the required ductility.

A number of detailing deficiencies were observed in the damaged structures. This included lack of anchorage of beams and column reinforcement, insufficient splice lengths, use of 90° hooks, poor concrete quality, less than full height masonry infill partitions, and frequent combinations of many of the above. These errors were often compounded by geometric irregularities such as eccentric beam-to-column connections that induced severe torsion in short perpendicular stub beams (Figure 3).

Figure 3. Eccentric beam to column connections induced severe torsion in short perpendicular stub beams.

Many buildings directly sitting on the fault were also destroyed by the relative movements of the fault.

It is noteworthy that an industrial complex being constructed 100 feet from the fault had very well confined columns with damage limited to spalling and large residual displacements.

- Steel structures

Steel, being by far the most expensive construction material in Turkey, has been used rather sporadically in construction; only industrial structures rely on steel for their lateral load resistance. Some were damaged by this earthquake. A few collapsed.

Typical causes for collapses include failure of anchor bolts at column bases and structural instability under overturning forces. Other evidence of damage include fracture of brace connections, buckling of braces, and local buckling in concrete filled steel hollow pipes used in wharves.

Figure 4. The anchor bolts ruptured and the unbraced support legs buckled, causing this water tank to tip.

Overview of Highway Damage

by John B. Mander

Associate Professor, Department of Civil, Structural and Environmental Engineering, University at Buffalo

Considering the magnitude of the fault rupture movements and the significant ground shaking, both in terms of accelerations and velocities, the engineered structures on the highway system fared quiet well. Damage to bridges was restricted to an area south-south east of Adapazari. In this area, two main highways run west-east (Istanbul to Ankara), parallel to the fault. The E80, also known as the TEM (Trans European Motorway), is a four-lane divided toll road, and the E100 (the old main highway) is a two lane road. Several overpasses crossing the E80 sustained minor damage in the form of pier tilting (arising from ground movement), cover concrete spalling of the decks at movement joints, and approach fill settlement. Such damage did not impair the use of the roads over the motorway.

One overpass crossing the E80 did collapse. This was not surprising as the fault rupture passed directly beneath the bridge. The fault movement exceeded the available seat width causing the span to fall to the ground. In so doing, it dragged the remaining three spans off their seats as shown in Figure 1. One of the spans collapsed onto a passing bus, killing ten people.

Figure 1. A collapsed overpass crossing the E80 Trans European Motorway near Adapazari. The fault rupture crossed beneath the bridge in the upper left portion of this photograph.

Problems were also encountered with four highway bridges crossing the Sakarya River. Most notable was the bridge carrying the west-bound lanes of the E80 motorway. This ten span bridge is shown in Figure 2. It consists of simply supported prestressed concrete box girders seated on laminated elastomeric bearing pads. A shear key is provided at the end of each box to inhibit transverse movement; the elastomeric bearings are

Figure 2. Looking south at the west-bound E80 bridge over the Sakarya River.

evidently for accommodating longitudinal thermal movements. The large impulsive fault-normal ground shaking coupled with high vertical accelerations caused several spans to fail the shear keys and unseat from their bearings. This is shown in Figure 3. The bridge has been closed to traffic awaiting repairs. The east-bound sister bridge sustained less damage to the shear keys and only partial walk-out of the bearing pads; complete unseating did not occur and the bridge has remained fully operational.

Figure 3. The east (left) and west (right) bound bridges over the Sakarya River. Note shifting of the spans and the unseating of the bearings in the west-bound bridge. The bearings on the east-bound bridge have partially "walked out," but not unseated.

The extent of damage to the engineered fills on the E80 motorway extended some 10 km to the west and east of the Adapazari area. Settlements ranging from 100 mm to 500 mm were observed. This was evident at most single span bridge and culvert locations on that road, resulting in classic bump-onto-the-bridge problems. One example is shown in Figure 4. Repair of this damage was swift. Initial repairs, made in the first few days following the earthquake, consisted of placing asphalt ramps and maintaining a 50 km/h speed restriction. Within 10 days, more long-term repairs were made. Re-profiling and re-paving large stretches of the road surface enabled the speed restrictions to be removed and the motorway returned to its normal 120 km/h operating speed.

Figure 4. A typical view of the bump-onto-the bridge on the E80 motorway. Up to 500 mm embankment settlements were common over a 20 km stretch of road. Notice the guard rail in the photograph as further evidence of the embankment settlement.

Note: John Mander was also part of the Earthquake Engineering Research Institute's (EERI) reconnaissance team. Additional information is posted on EERI's web site at http://www.eeri.org.

Lifeline Damage and Fire Following Earthquake

by Charles Scawthorn

Senior Vice President, EQE International

Lifeline Damage

Lifeline damage was moderate to major, as follows:

- Electric - power failed within minutes of the earthquake, but was generally restored to most areas within several days. Substations did not appear to be damaged, nor transmission lines or towers, except where the lines crossed the fault. Figure 1 shows a tower pulled over due the conductors being put in tension at the fault crossing.

Figure 1. Electric transmission tower pulled to left due to conductors being put in tension due to right lateral fault displacement (fault is to north, or left, of the tower).

- Telephone - service continued with minor disruptions, and cell service was reportedly uninterrupted.
- Gas - there is no domestic underground gas piping in the area. It is unknown as of this writing if there are bulk transmission lines in the area.
- Rail - rail lines were buckled at fault crossings, but repairs were quickly effected, and rail service restored within several days.
- Highways - roads and highways were generally undamaged except for several highway bridges intersected by traces of the fault - where this put the bridge in tension, spans were pulled off their beam seats, and the spans collapsed. The main motorway connecting Istanbul and Ankara passes along the north shore of Izmit Bay and close to Adapazari - in general, it was undamaged.
- Water - The main source of water is the recently constructed Izmit Water Project, built and operated by Thames Water. It is the largest privatized water project in the world as of this writing, and replaces a variety of low quality sources for the various municipalities in the area. The wholesale system begins in the hills south of Yuvacik at a 60 million cu meter

reservoir impounded by a 40 m high clay core earthen dam, constructed in the early 1990's. The dam is uninstrumented, and experienced only very minor settlements, although the reservoir is reported to have experienced a 2 m amplitude seiche. Water is conveyed approximately 4 km from the dam to a water treatment plant, via a steel pipe of 2.2 m diameter.

The water treatment plant is 440 million liter/day capacity (110 mgd), and was undamaged with the exception of fiberglass piping in the clarifiers. Downstream of the plant, water is conveyed to retail customers via a 2.2 m spiral-welded steel pipe, which was reportedly undamaged except at clean-out connections at low points, where flanged fittings appear to have cracked at perhaps a dozen locations. The transmission line was being scheduled for a one day outage on Aug. 26 (i.e., nine days after the earthquake) to repair these leaks.

Approximately 1 km downstream of the plant, the steel transmission line crosses the fault trace. This location was inspected and found to have approximately a 2 m right lateral offset but, while some water flowing to the surface was observed (it was raining at the time, however), the pipe was reportedly undamaged at this location (see Figure 2).

Impacts of the earthquake on water retailers and urban distribution pipe networks are unknown in detail as of this writing, but it was known that retailers were able to store water in their local distribution reservoirs, but were unable to distribute it due to numerous breaks in the distribution system. Potable water needs were being served by tanker trucks supplied from the Izmit water treatment plant and from several naval vessels in the Bay, and by bottled water, Figure 3.

Figure 2 – Photo to left is taken looking north along pipeline alignment. Two men in figure are at the location of the pipe-fault intersection, showing the approx. 2 m fault offset. Photo above is taken looking east along the fault, with the pipeline alignment in foreground. Figure is leaping across fault scarp, to east of pipeline. Note that scarp appears to alter alignment northwards right at pipe (in foreground).

Figure 3. Potable water supply via tanker truck and bottled water.

• Wastewater - no information was available at the time of writing.

Fire Following Earthquake

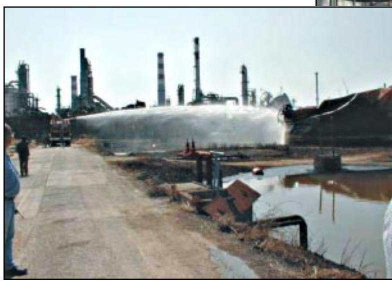
A number of ignitions occurred in building collapses, but these were generally confined to the building of origin, due to the prevalent non-flammable building materials. The most dramatic fire was at the Tupras oil refinery, where it appears that two separate fires initiated during the earthquake, as follows:

• A fire initiated in the Crude Unit, a primary processing plant in the Refinery, as a result of the collapse of a 90 meter tall, 10 meter diameter, reinforced concrete stack, Figure 4. The collapse of this large stack into the middle of the units caused extensive destruction, released fuel and was the primary cause of the fire within the process unit.

• A second fire initiated in the Naptha tank farm, independent of the crude unit fire. It appears that this fire initiated as a result of sparks created by bouncing of the floating roof in one of the tanks, during the earthquake. The sparks ignited the Naptha. Such floating roof tanks are common in petroleum facilities, world wide.

• The crude unit fire was initially brought under control relatively quickly. However, the collapse of the stack also broke the pipeline from the burning Naptha tank, upstream of the block valve. This

Figure 4. In the photo to the right, a collapsed RC stack is shown. Below, firefighters are cooling burning tanks (source: G. Johnson, EQE International)



resulted in an unstoppable supply of fuel and the re-ignition of the fire in the crude unit.

- The tank farm fire enveloped six tanks, with the ensuing heat damaging other tanks as well.
- The fire in the tank farm spread to an adjacent cooling tower, destroying it. A second cooling tower was destroyed by the ground shaking itself.

Social, Political and Emergency Response

by William A. Mitchell

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Over the past quarter of a century, I have studied several earthquakes in Turkey. As an active seismic zone, Turkey frequently experiences devastating shaking. Again and again, buildings collapse, people and animals die, houses and settlements are rebuilt, and the public soon forgets. In the 1970 Gediz, the 1976 Lice, the 1983 Erzurum-Kars, the 1992 Erzincan, the 1995 Dinar, and the 1998 Ceyhan-Adana disasters, the emergency response was fairly consistent and predictable. Survivors on the scene were the first to begin search and rescue, with their bare hands, without lifting equipment, listening devices, sniffing dogs, or lights in the darkness. Local press and visual media were quickly on the scene, followed hours later by foreign search and rescue teams, then even later by NGOs (non-governmental organizations) and governmental organizations. Usually the Prime Minister and/or President quickly arrive on the scene, asking the victims to accept this "act of God," and promising that the settlements and homes will be rebuilt quickly.

The initial response to the 03:02 hours, August 17 earthquake in Turkey was similar to the above response. The prime minister's national crises action center reportedly was activated on day one, followed by provincial and township crises center activation. But here is where this earthquake was different. The event was centered in Turkey's industrial and heavily populated region surrounding the Marmara sea. About 15 million urban people, including some of the wealthiest, best trained, best educated, and professional elitist reside in the roughly 200 km belt stretching from Duzce (Bolu) in the east to Tekirdag in the west. Quickly, television and newspaper reporters descended on the scene and were broadcasting to the nation from town after town that suffered casualties and damages. Thousands of buildings were destroyed, and thousands of people died (15,032 officially, but an estimated 30,000 are unaccounted for). Professional search and rescue efforts were slow to respond, and the public viewed this live without censorship. For about two days, live cameras showed the enormous strain on the survivors and the lack of government or military response. The press was exceptionally critical about the lack of Turkish search and rescue and the slow response of the military to help. Several days after the earthquake, a reportedly 50,000 soldiers (asker) were helping in the disaster area.

This earthquake clearly demonstrated that improperly constructed buildings kill people.

The basic difference from all other earthquake disasters in Turkey is that the populace has mobilized massive public opinion that questioned the government and military institutions in Turkey. For the first time to my knowledge, the Army was consistently criticized for its lack of timely action. Governmental criticism was directed toward its inability to quickly and adequately respond for search and rescue, and for its alleged acceptance of or condoning corrupt contractors and builders. Local, provincial, and national officials were openly criticized as greedy people who took bribes and willingly permitted violations of zoning codes and construction codes.

On the positive side, unlike any past disaster events, there was overwhelming displays of humanitarian gestures from Greece. Greek-Turkish relations appear to have greatly warmed and improved due to the Greek response to the situation. The Greek Prime Minister, along with the mayor of Athens, quickly visited the site and conveyed personal condolences to the Turkish people. Additionally, a Greek search and rescue team, doctors, and volunteers for blood donations, along with an outpouring of Greek towns and clubs sending best wishes and various money and material donations, poured into Turkey .

In summary, this earthquake clearly demonstrated that improperly constructed buildings kill people. It also showed that Turkey is in dire need of an emergency management plan that is effective from top down, and bottom up. It needs to be created from scratch and practiced frequently. Further, the mind set of "fatalism" needs to be openly debated and studied. Finally, bribery and corruption need to be addressed and

Many residential buildings were severely damaged.

corrected. Shutting down a newspaper for a week because it "demoralized the public with its news coverage (The Radikal was very critical of the government response and it did show very disturbing scenes from the victims)" will not correct the problem. This time, Turkey suffered a great loss, but the densely populated city of Istanbul (except for Avciler and about 900 people), with its 9 plus million people, escaped massive destruction and a high number of deaths. Severe earthquakes have been marching down the North Anatolian fault for years, traveling from the east to the west. Each one has gotten closer to Istanbul. The August 17 disaster may be a catalyst that motivates appropriate preparation for the next "big one."

Note: Bill Mitchell was also part of the Earthquake Engineering Research Institute's (EERI) reconnaissance team. Additional information is posted on EERI's web site at http://www.eeri.org.

The First Few Days Following the Earthquake

by Natali Sigaher

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I had just gone to bed – thanks to a late night movie – and I was still awake. At about 3:00 a.m., I felt strong shaking and heard the glass doors of a bookshelf rattling. I had experienced a few moderate earthquakes before, in Istanbul and in the Prince Islands (in Marmara Sea). During those earthquakes, I remained still until the end of the quake; but this time, the shaking was so strong and noisy that after a moment's hesitation, I jumped out of bed. My mother and I pulled my father out of his bed; he had woken up but was too afraid to move. Next, we secured ourselves by standing near the columns of the bedrooms. In the meantime, the electricity went out. After the main shock, just as I was preparing to look around the apartment, another shaking – as strong as the first one – started. I wondered why it lasted so long and afterward, I was frightened that the building might collapse. When it finally ended, my father lit a torch to provide light inside the house. I plugged in the telephone that did not require electricity and called my sister. I was able to reach her after a couple of attempts, as the telephone lines were damaged, too. She said she and her husband had already left their apartment and were in their car. Then I called a Turkish friend in the U.S. at the University at Buffalo. Shortly after I made these calls, the telephone lines went down completely. At about 3:30 a.m., we went to our neighbor's apartment on a lower floor. About 4:30 a.m., we decided to leave our apartment building because the aftershocks were frequent and strong. By that time, my sister and her husband had joined us.

The roads were as crowded as if it was daytime. People were trying to get information from their radios, but most channels were on automatic broadcasting. Finally about 5:00 a.m., it was announced that an earthquake had happened in Istanbul and vicinity and that the magnitude was 6.7. At that time we did not know how destructive the earthquake had been. Later that day we returned home, the electricity was on and off, telephone lines were very busy and there was no water. I tried to follow the news from TV – the epicenter was Izmit, and the earthquake had effected seven cities/suburbs, including Istanbul, Izmit (Kocaeli), Golcuk, Adapazari (Sakarya), Yalova, Bolu, and Eskisehir. About 1/3 of the population of Turkey is concentrated in these areas. There were scenes of collapsed buildings and panicking people. At that time, there was no information about any organized rescue efforts.

The earthquake struck the heart of industry in Turkey. A fire was burning at the largest refinery "Tupras" (near Izmit). This was very dangerous because the refinery had about 30 tanks, and is surrounded by similar facilities (LPG, natural gas). There are also many large factories like Pirelli and Otosan in close proximity to the epicenter.

As I watched the news that day, the extent of the damage started to appear more clearly. It was advised that people whose buildings had been partially damaged should spend the night outside. Although we could not detect any damage, we decided to spend Tuesday night outside, like most people.

On Wednesday, many foreign rescue teams arrived – with trained sniffing dogs. There were also foreign planes to battle the fire in the refinery. It became clear that the damage was tremendous, and the number of dead and injured people seemed to increase every other minute. Most hospitals in the disaster area had been damaged and had difficulty accommodating patients.

On Thursday, rescue efforts had become more organized. The efforts of civilians (AKUT and local people) in the first two days following the earthquake were especially noteworthy. They consisted of volunteers who were involved in both rescuing people and taking donations to the area. By this time, many foreign teams (including those from Greece, Israel, U.S., Russia, France, Germany, Italy and others) had started working day and night along with Turkish military forces and rescue teams.

Unfortunately, the death toll and number of injuries were rising rapidly. Local hospitals were full and most patients were either treated in open areas or transferred to hospitals in nearby cities. In the first few days following the earthquake, the rescue teams did not want to use heavy equipment to remove the rubble because it could hurt trapped survivors, but this made the process too slow to be effective. Meanwhile, the weather was very hot (~35°C), which meant that the dead bodies under the rubble were decomposing quickly. Precautions such as spreading lime over collapses and infectious areas were taken.

The fault rupture is visible next to this damaged manufacturing facility, under construction at the time of the earthquake.

One building is totally collapsed while another is hardly damaged on the Naval Base in Golcuk.

On Friday, we bought blankets, paper towels, toilet paper, water, cookies, etc. and gave them to a donation truck. In the afternoon, I met with Dr. John B. Mander, who was representing MCEER as part of the EERI reconnaissance team. We joined the rest of the EERI team and I accompanied them on the next day's site visit.

At 5:45 a.m. Saturday, we were on our way to Golcuk. Our group consisted of about 24 people – the EERI team and a team from Turkish universities. We visited the factory "Ford-Otosan" at Karamursel, Golcuk. We could see the surface trace of the fault, and how one side of the ground had settled 50 cm to 4 m deep. The welding shop, which was very close to the faultline, was damaged. Next, we went to Golcuk Naval Base. I watched some of the rescue efforts on one of the totally collapsed buildings and talked to a soldier. He said that only half of the bodies of almost 120 people had been recovered so far from that building and there were only a few survivors. He also pointed to another totally collapsed building, which used to be the dormitory, with an estimated 70 people inside. No rescue had been attempted at the dormitory yet. We also saw the open-air hospital inside the naval base. The fault passed through the navy base, and the totally collapsed buildings were very close to it. We then visited the docks, which were also heavily damaged. On the other side of the bay, we could see the fire at Tupras refinery; the heavy smoke weakened as the fire was finally put out.

Next, we visited Degirmendere, where the soil had collapsed along the shore, burying many buildings inside the sea. There was a large amount of donations sent to the disaster area, but unfortunately there was no systematic distribution. I saw a street full of clothing and shoes. We returned to Istanbul at about 9:00 p.m.

This was a major disaster for Turkey and recovery needed extensive time and effort. In the meantime, some points require special attention:

- The North Anatolian Fault, which was the cause of this earthquake, is a very well known and active fault. The history of movement along this faultline in the last 60 years indicates that this recent earthquake was expected. It was not an unlucky event or due to fate that can only be decided by God. Unfortunately, the public is not educated or warned enough about earthquakes – this was not the first nor will it be the last. In the future, the public can pay more attention to the engineering aspects of their homes. Even in the most damaged areas, there were intact buildings adjacent to totally collapsed ones. This is not because the earthquake hit one building stronger than the other, but simply due to bad construction. There should be strict enforcement for all engineered projects to make sure good construction practices are implemented on site. Contractors should be educated to understand that the profit they make by using less/low quality construction materials can easily cost human lives.

Many donations were sent to the affected areas, but there was no organized distribution system.

- The first few days after an earthquake are very important for survivors in the rubble. Their chance of survival without food and water is less than that of a normal person, considering that they have difficulty breathing and most probably have bleeding injuries. Therefore, rescue teams trained only for this purpose should be ready to act immediately. Unfortunately, after this earthquake, there was considerable delay in the organized rescue efforts.

In short, we must learn how to live with earthquakes and take necessary precautions to avoid a tragedy of this magnitude in the future.

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MCEER Information Service

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