Erzincan, Turkey Earthquake of March 13, 1992

Introduction - A magnitude 6.8 (NEIC) earthquake occurred along the North Anatolian Fault in Eastern Turkey, on March 13, 1992 at 7:19 pm local time (1719 GMT). The epicenter of this earthquake (39.7N, 39.5E) was very close to the center of Erzincan, a city with a population of approximately 100,000, which is also the site of one of the largest military bases in Eastern Turkey. The official preliminary estimate indicates that the earthquake killed over 800 people, injured over 1,500 and left thousands homeless. Unofficial figures estimate over 2,000 killed. Well over 200 multi-story structures completely collapsed as a result of this earthquake, and hundreds of others were damaged. Located in one of the most highly seismic areas of Turkey, Erzincan has been the site of many damaging earth-quakes in its history. After the city was leveled in 1939, killing over 30,000, it was relocated about a mile north to its present location.

This report is a brief summary of the information gathered to date by the EERI reconnaissance team. A complete report of the findings will be published this summer.

Reconnaissance Team - EERI, with support from the National Science Foundation, dispatched a team of engineers and scientists to investigate the effects of the earthquake. The team members included: James O. Malley, Principal and Structural Engineer, H. J. Degenkolb Associates, Engineers, San Francisco (team leader); Mehmet Celebi, Research Civil Engineer, USGS, Menlo Park; Norman R. Tilford, Geology Dept. Texas A & M University; Atilla M. Ansal, Civil Engineering Dept. Istanbul Technical University; Polat Gulkan, Civil Engineering Dept., Middle East Technical University, Ankara; Col. William Mitchell, Geographer, Maxwell Air Force Base Air Force College; Mustafa Erdik, Dept. of Earthquake Engineering, Bogazici University, Istanbul; and Donald Ballantyne, Civil Engineer, Kennedy/Jenks Consultants, Seattle, representing TCLEE, ASCE's Technical Council on Lifeline Earthquake Engineering.

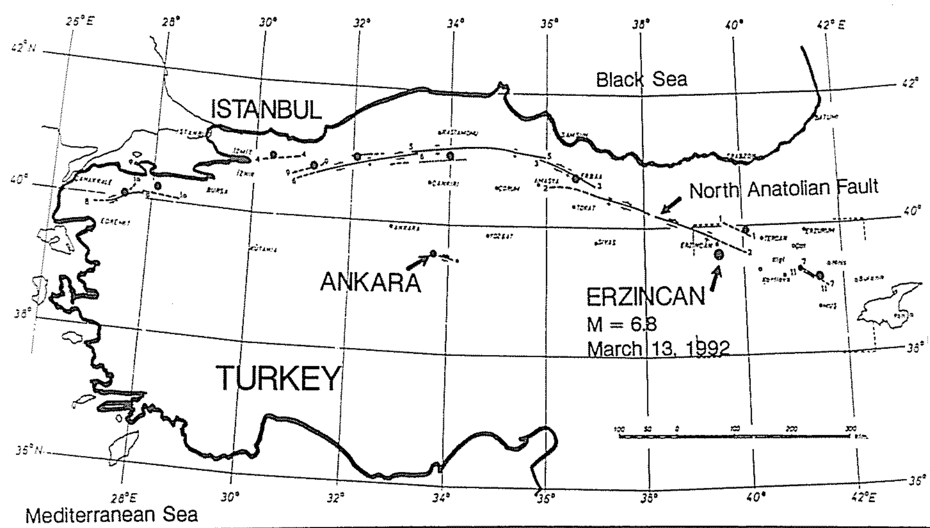

FIGURE 1 - Vicinity map of March 13, 1992 Erzincan, Turkey earthquake

Geosciences/Geotechnical - Erzincan is located in the north central part of the Erzincan Basin, an alluvium filled tectonic depression covering some 400-500 square kilometers. The North Anatolian Fault, which strikes about N60W in this segment, cuts the northern part of the city and foothills of the mountains to the north, along a zone about one km wide. This is one of the most important of the world's active continental transform faults, rivaling the San Andreas in length, and probably surpassing it in tectonic activity. Erzincan has been hit by nearly twenty significant earthquakes during the past 1,000 years, with three in this century alone. It is generally accepted as the northern boundary of the Turkish plate, which is being ejected westward between the Eurasian plate to the north and the Afro-Arabian plate to the south.

This earthquake occurred along a part of the North Anatolian Fault which ruptured in the 1939 quake. A maximum intensity of VIII to weak IX was estimated for alluvium sites in the basin.

Evidence of surface deformation was discontinuous, indicating that the earthquake was deeper than normal for this setting, consistent with the reported focal depth of 26 km. Figure 2 shows a view of one surface rupture with oblique shears which served as conduits for water erupted due to liquefaction of marsh sediments at three meters depth. Right lateral slip of 10-12 cm was matched by about an equal amount of down-to-the-south slip. Note the undamaged building at the top of the photo.

Strong Motion - One strong motion instrument is located in Erzincan. The peak ground accelerations recorded by this instrument were 0.40g, north-south, 0.48g east-west, and 0.25g vertical (see Figure 3). The duration of strong shaking lasted approximately 5 to 6 seconds, including a pulse with a duration approaching 1.5 seconds near the start of the record.

Structural Response - Single-story

construction in the region generally consists of unreinforced masonry bearing wall construction, with walls composed of brick, hollow clay tile, adobe, or rubble stone. The majority of one- and two-story buildings suffered no structural damage in the earthquake, although many showed signs of nonstructural damage. Where severe damage or collapse did occur, the buildings were either of poor construction, or were sited in areas which had been subjected to stronger than typical shaking.

The vast majority of mid-rise (3-7 stories) construction in the region consists of cast-in-place concrete frames with infill walls and partitions of hollow clay tile. The most spectacular damage was suffered by these buildings, with those of four-stories and taller suffering the most severe damage. More than 200 of these structures totally collapsed or lost the first story. The detailing and construction of the concrete frames for these buildings did not meet modern standards for seismic resistance, including those required by the 1975 Turkish Building Code, titled ***Specifications for Structures to be Built in Disaster Areas***, which is still in effect. The concrete was generally of poor quality, with minimal cement content and smooth large aggregate. In many of the failed structural elements large voids were noted at locations of congested reinforcing and at construction joints. Smooth reinforcing steel was predominant. Where ties were present, they were typically 6 mm diameter smooth bars, with 90 degree hooks and short extensions. Column tie spacing was typically 200 to 300 mm, with no ties through the beam-column joints. Column bar splices consisted of short lap splices or J hooks, with all bars being spliced at the same location.

FIGURE 2 - Surface rupture and oblique shears

Typical commercial building construction in the downtown area consists of three- and four-story buildings, with cantilevers over the open first-story storefronts. Concrete frames, open on interior lines and with infill for exterior walls, form the structural system. Typically, frames exist along the column lines in both directions, with the strong axis of the columns oriented in the longitudinal direction. This standard form of construction performed fairly well. The majority of damage noted occurred in the weak, transverse direction. Some corner buildings appeared to have suffered increased damage due to torsional effects. Despite lack of building separations, very little pounding damage was noted due to similar floor elevations and numbers of stories. The majority of structural damage and collapses to commercial buildings occurred in large or special buildings which did not follow the standard building plans.

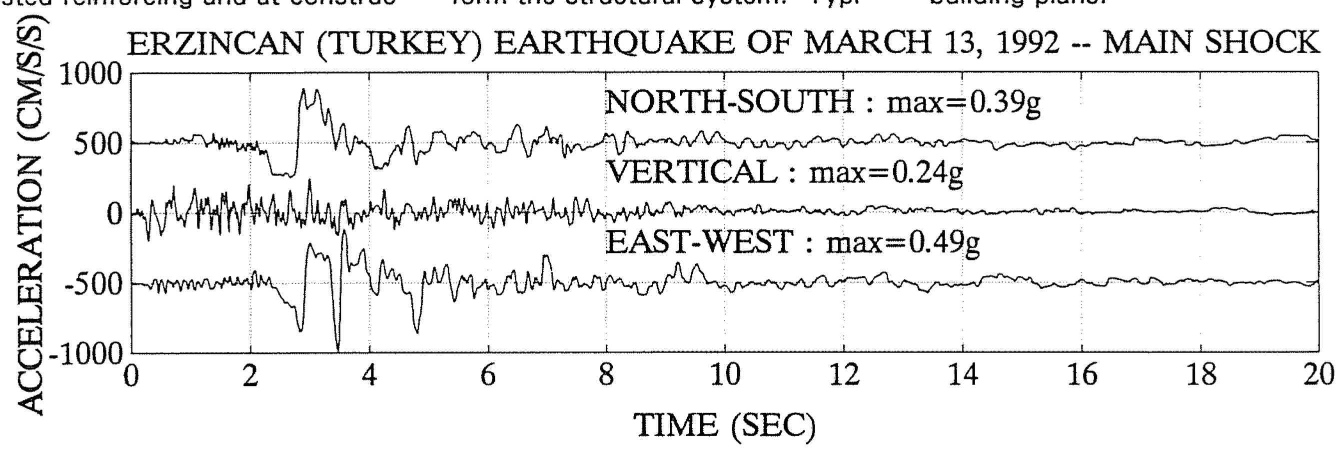

FIGURE 3 - Uncorrected strong motion record from city of Erzincan

Residential mid-rise buildings typically are three, four and five stories, with a double loaded central corridor. The construction consists of concrete frames with hollow tile infill for the exterior walls and interior partitions. In almost all of these buildings, the hollow tile infills suffered damage, ranging from minor cracking to complete failure of the infill. In almost all cases, the gable portions of the end walls fell out due to inadequate anchorage to the roof framing. In many cases, veneer courses fell out after suffering in-plane cracking. A number of these buildings suffered damage to the concrete frames, usually in the form of spalling of the concrete at the lowest level corner column splice locations. In a large housing complex with over 250 such buildings, approximately 12 buildings lost the first story and 6 collapsed completely. Figure 4 shows a paritally collapsed mid-rise residential structure.

Special use, large, mid-rise structures suffered the most severe damage. The three large hotels in the city, each five stories tall, completely collapsed (see Figure 5). The three hospital complexes also suffered major damage. One six-story wing of the military hospital suffered a short column shear failure of the first story (see Figure 6), the complete collapse of an end stair tower wing, and the racking of an entrance canopy, in a response reminiscent of that of the Olive View Hospital in the 1971 San Fernando earthquake. One wing of the seven-story, Z-shaped Social Security Hospital completely collapsed. A six-story dormitory wing of the State Hospital also collapsed. The main functional buildings at this facility suffered damage severe enough to cause them to be evacuated.

Some of the non-typical structures, such as the mosques, performed well, although the minarets of two mosques had cracks at the base of their tower sections.

Industrial Facilities - Since the region is mainly rural, there are very few heavy industrial facilities. The facilities which do exist are typically either steel framed or cast-in-place concrete construction. One concrete feed plant collapsed immediately adjacent to a steel frame feed facility which suffered almost no damage. A six-story, cast-in-place flour plant suffered structural damage to the exterior non-ductile columns, but no damage to the equipment or the attached light metal buildings. At

FIGURE 4 - Partially collapsed mid-rise residential building

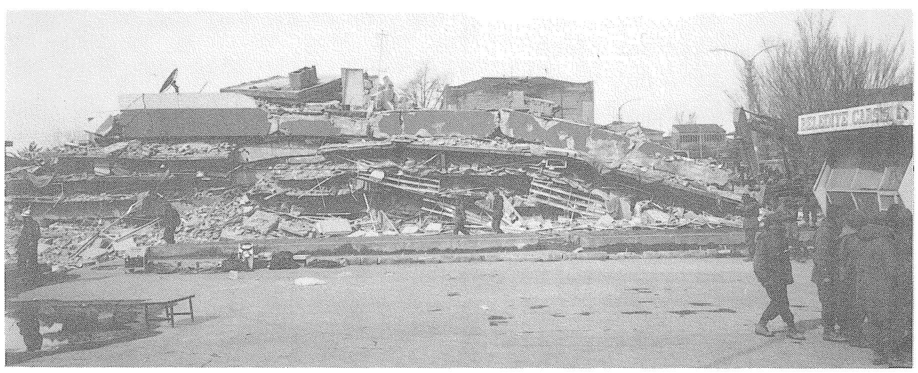

FIGURE 5 - Complete collapse of a five-story, concrete frame hotel building

FIGURE 6 - First story short column shear failure at military hospital

a sugar refinery, a large improperly braced stack collapsed into the main building tearing down a portion of the roof structure (Figure 7). Three large unanchored steel oil storage tanks, the steel framed, brick infill wall buildings, and the two-story masonry buildings at this site were undamaged.

Lifelines - The majority of lifelines in the area were not severely affected by the earthquake. This was largely due to the minimal permanent ground deformation. There were a number of minor rockfalls and an embankment failure on the main road through the valley. The minor settlement of a bridge abutment and an embankment failure near a location of liquefaction slowed traffic along the rail line. Airport runways and taxiways were undamaged and remained functional. Settlement damaged a large diversion dam along the Euphrates River and jammed a number of the gates.

The transmission system which delivers power to the city was undamaged. Electric power supply within the city was quickly restored. The communications system suffered minimal damage, being basically operational once the emergency power generation system became functional.

Only one minor fire occurred as a result of the earthquake. The risk of large fires was low because of the preponderance of concrete and masonry construction, and the absence of any centrally-distributed natural gas system.

The water distribution system was the major lifeline problem. Eighty percent of the city is supplied through a single 800 mm steel transmission line. This line and the lines that distribute water to the rest of the city cross the fault trace. Once power was restored, water was pumped into the cast-iron pipe and a number of breaks were found. Repairs to these breaks were still being made two weeks after the event. There was also damage to portions of the 250 km of distribution pipe in the city. Since most buildings rely on steam for heating, the lack of water left the occupants without heat.

Social Response - At the time of the earthquake, most of the people were in their homes or in restaurants after a day of fasting for Ramadan. While there are federal regulations that provide guidance for emergency response and the city of Erzincan had an emergency response plan in place, a state of confusion prevailed in the hours following the earthquake. One major contributor to this confusion was the fact that two of the three major leaders who were to administer the emergency response plan were personally affected by the death or serious injury of one or more immediate relatives. The third leader was out of the area at the time of the earthquake.

Because of the importance of the Erzincan military base to the regional security, initial efforts concentrated on securing this facility. The military then policed the city and assisted with search and rescue efforts. Initially, search and rescue efforts were hampered by a lack of adequate equipment, electricity, or trained personnel. The two civilian hospitals worked out of tent facilities set up on their grounds. The military hospital was completely evacuated within 24 hours of the event. Approximately 60 percent of the injured were taken by ambulance or helicopter to Erzurum, a city approximately 200 km to the east.

National and international relief began to arrive on the day following the earthquake, and within one week 17,500 tents, 42,000 blankets, a field hospital, field kitchens, generators and medical assistance had been

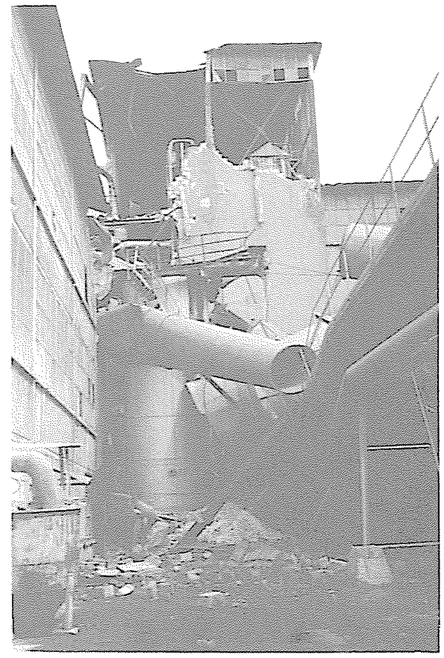

FIGURE 7 - Collapsed stack at a sugar refinery

provided. Search and rescue teams, many including specially trained dogs, came from all over Europe to provide assistance. Within one week, a large amount of heavy construction equipment had arrived and was being used to remove the debris of collapsed buildings. Food was not in shortage except in the first hours after the earthquake. Chlorinated water was distributed by tanker trucks from local wells.

An estimated 50,000 to 60,000 people became homeless as a result of the earthquake. By the end of March construction of 2,000 units of prefabricated housing was started by the Turkish Ministry of Public Works and Reconstruction, primarily to give temporary shelter to people living in tents. Construction of more of these temporary units is being planned, as well as massive construction of mid-rise condominium buildings.

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