

# **ASCE-TCLEE**

***American Society of Civil Engineering***

***Technical Council on Lifeline Earthquake Engineering***

## **LIFELINES PERFORMANCE**

### **KOCAELI, TURKEY, EARTHQUAKE,**

**August 17, 1999**

#### **A Preliminary Reconnaissance Survey**

##### **Introduction**

The ASCE Technical Council on Lifeline Earthquake Engineering (TCLEE) Earthquake Investigation Team, a group of ASCE members, conducted a preliminary reconnaissance survey of the damage to lifelines in the August 17, 1999 earthquake centered near Izmit, Kocaeli, Turkey. The period of the investigation was from September 6 to 11, 1999. The TCLEE team members were Curt Edwards Chair of the TCLEE Earthquake Investigation Committee, Alex Tang Investigation Team Leader and ASCE members Nesrin Basöz, Tom Cooper, John Eidinger, Teresa Elliott, David Lau, Robert Lo, Le Val Lund, Mark Pickett and Mark Yashinski. The TCLEE investigation team was divided into small groups to investigate lifeline performance of water and wastewater, electric power and communications, liquid fuels, transportation, port, airports, hospitals, emergency response and industrial facilities. The TCLEE groups were assisted by graduate civil engineering students at the Bogazici University in Istanbul under the direction of Dr. Semih S. Tezcan, Professor of Civil Engineering. Dr. Derin Ural, Professor of Civil Engineering, Middle East Technical University, Ankara, also provided a graduate student and Graham Martin, ARUP Engineers, Istanbul assisted in the coordination of the preliminary reconnaissance survey.

##### **Earthquake**

The seismically impacted area stretched along the North Anatolian fault zone from Yalova to Düzce. The cities impacted, within Kocaeli and Sakarya regions, in addition to those mentioned were Gebze, Karamürsel, Gölcük, Izmit, Sapanca, Arifiye and Adapazari. Also minor earthquake impacts were experienced from West Istanbul to Gebze. The event had a Moment Magnitude of 7.4, occurred at 3:00 AM (USGS) on August 17, 1999 and the epicenter was located near the city of Izmit. The fault rupture was physically visible through out most of the seismically impacted area from Karamürsel to Akayazi (near Düzce. Preliminary peak ground accelerations ranged from .37 at Düzce, .41g at Adapazari, .32g at Gebze, .22g at Izmit and .26g at Yalova.

##### **Highways**

The main highway in the area is the Trans European Motorway (TEM) which is a toll road connecting Istanbul to Ankara, generally parallel to the fault zone. The design was reported to follow AASHTO standards. The TEM remained functional except for a collapsed overcrossing which had to be removed at the location, near Arifiye, where the fault crossed the freeway and several locations where settlement caused pavement deformation, including at bridge abutments. Temporary detours were made causing traffic congestion. The Sakarya viaduct had damage to its shear keys and elastomeric

bearings and was partially closed to traffic. An interesting result of the usual telephone congestion after a natural disaster, the people when they could not connect to their family and friends on the telephone got in their cars and drove to the people they wished to contact by telephone causing further traffic congestion. An old bridge collapsed near Gölcük on a secondary road.

### **Railroads**

An electric passenger and freight railroad connects Ankara with the Asian side of Istanbul. The system operates on 24,000 volts DC and lost one transformer from the earthquake. Service was provided by back feeding from two other transformer substations. At the fault crossing near Arifiye the tracks were damaged, the usual "S" shape and were repaired and railroad service restored. At another location where tension in the rails caused the track to separate 1.5 meters was also repaired and new rock ballast was placed at number of locations. The rail system was restored in two days; however, traffic was not restored in the vicinity of the TÜPRAS oil refinery due to the fire until the fire was suppressed four days after the earthquake. After the earthquake, the freight system was used to bring pipe and supplies into Adapazari for restoration.

### **Ports**

Most port facilities are privately operated by the industry they served; however, there is one government general cargo and bulk cargo (grain) port at Izmit called the Port of Derince. The bulkhead for the general cargo port was of the concrete caisson type, which failed probably due to lateral spreading. The bulkhead moved away from the wharf up to about 40 cm horizontally and 40 cm vertically causing the collapse of a rail mounted portal crane and severe tilting of a second rail mounted portal crane. A third crane remains in place at a fixed location reportedly supported on piles. Two old steel framed warehouses with tile infill walls that remained standing showed stress due the earthquake. A new wharf, constructed on piles had been completed in May, 1999, had not been fitted with cranes had no problems. The bulk cargo facility was not in operation due to damage to the conveyor belt system and the wharf deck area. The port is being operated at a reduced capacity using mobile cranes. There are no container cranes at this port.

A naval base near Gölcük sustained damage to the dock and liquefaction was visible around the base. One section of the dock was displaced with respect to the other section by 50 cm while another section subsided about 10 cm.

### **Airports**

The airport at Istanbul had no problems. Large emergency generator capacity has been installed, because of the limited reliability of the commercial power. However the elevated fuel tanks and other electrical equipment in the generator area was unanchored. A military airport near Izmit was reported to have severe damage including a control tower near collapse. Temporary helistops for helicopters were used to transport relief help and supplies.

### **Water Systems**

The supply to the earthquake impacted area is from three sources, provided by regional water agencies. The three agencies served about 2.5 million people in the Yalova-Gölcük, Kullar-Izmit-Gebze and Adapazari areas. The Yalova facility serves 13 cities and villages from Yalova to Gölcük, the Kullar facility serves 19 cities from Izmit to

Gebze and the Adapazari facility serves 5 neighboring communities. The first two sources are from reservoirs created by impounding dams on local streams and the third is from Lake Sapanca. At each of these locations were modern water treatment plants, which experienced only minor damage and were easily repaired and returned to service.

Major butt-welded steel transmission lines supplied treated water to reservoirs operated by the 37 cities and villages. There was some damage to these lines especially where they cross the fault zone or areas of severe ground movement. The 80 km transmission line from Yalova to Gölcük was damaged in a number of locations leaving about one million people without water for seven days. However, new damage occurred during aftershocks leaving the system down for another two weeks. Partial restoration of water service did occur during this period. Several elevated concrete tanks were damaged and leaking in this area, but remained in service. There is pipe damage to the distribution system in all areas of significant building damage, but the extent of the damage and repairs can not be made until the building debris is removed. Water demands are reduced because of the relocation of people to tent cities or to other locations outside earthquake impact area. The water supply was poor, because of the broken distribution pipes and some transmission lines, especially in the heavily damaged buildings area and fault rupture area. Water supply to some areas had not been restored a month after the earthquake.

Emergency water supply was provided by portable tanks, tank trucks and barges. Water meters are not being read and customers are being given free water service. There was no reported damage to buried concrete reservoirs, dams and pumping plants other than the loss of electric power. Many of the water agencies reported loss of power to their facilities for two days and none of them, except a new treatment facility in Kullar, had emergency backup power. There are private water supply and treatment facilities located at some of the industrial sites and there were only minor damage reported but no loss of function. The most significant damage was the loss of water supply for the TÜPRAS oil refinery which receives water from Lake Sapanca via a long privately owned transmission line. This loss hindered the refinery personnel suppressing the refinery fire.

### **Wastewater Systems**

Wastewater treatment plants were located near Adapazari and Izmit. One of the three plants in Izmit suffered damage to the mechanical equipment in the clarifier and has been shut down since August 17th. Some of the untreated wastewater reaches either the Black Sea or Izmit Körfezi (bay). A number of the concrete sewer pipes were broken, crushed, collapsed or clogged and the extent of damage and repairs can not be made until building debris is removed. A collector pipe between Gölcük and Izmit fell into the bay along the assumed fault line. Demands on the sewer system are reduced because of the relocation of people to tent cities or to other locations outside earthquake impact area. There was no reported damage to pumping (lift) plants other than loss of power. There are private wastewater treatment facilities-located at many of the industrial sites and there were only minor damage reported but no loss of function.

### **Power Systems**

In Turkey, power is provided by the National Electric Power Authority, TEAS, and the local distribution is by TEDAS. Generation is by hydroelectric and steam generation. There is a nuclear power generation station near Ankara. Power was available within a short time in some areas and others it was not restored in up to 2 weeks. Transmission and distribution lines are supported by concrete and steel lattice power poles and there

is some underground system in the cities. Distribution power lines were damaged due to collapsed buildings were quite extensive. Failure of electric service was quite extensive. Three substations experienced transformer damage and ceramic isolator and bushing damage. The Adapazari substation which is one of the largest in the region reduces voltages from 380 kilovolts (kV) to 154 kV and 154 kV to 66 kV (380/154/66 kV). Cosmetic damage occurred to the control building; however, there was no damage to the controls. Four of the 154/66 kV transformers moved 30 cm and porcelain was broken, others located at 90 degrees orientation had no damage. Adapazari Substation No. 2 was out of service for 12 days due to damage to the aluminum connectors. At the Izmit substation (154/66 kV) damage occurred to bushings, support members and there was an oil spill. The transformer was tilted and out of service for three days. At the Kensta substation (154/34.5 kV) one bushing was replaced and Körfezi and Ford substations (154/34.5 kV) had no damage. A private transformer failure was observed at the Toyota plant. Mutual aid to assist in restoration was used from Ankara and Istanbul.

### **Telecommunication Systems**

Telecommunications in Turkey is provided by Turk Telecom. The usual telephone congestion occurred when the lines became overloaded with calls of family members checking the condition of other family members. The telephone offices (central offices) in the earthquake impacted area suffered damage by toppled batteries, toppled fuel tanks, printed circuit boards cards without clips slipping out of modular switching equipment shelves and backup generator problems. A couple of fiber optic cables were reported severed by fault rupture. A few central office buildings sustained damage to internal and external infill walls and in Adapazari and Gölcük, the telephone equipment could be seen from the street. Ten central offices in the impacted area had loss of power. Three offices had air conditioning unit failure and four had non- structural building damage. Two remote offices collapsed, taking out the equipment. Mobile equipment was deployed to provide service within two days at Gölyaka and Hacısüleymanoglu. Telephone service recovery was within two to five days depending on the extent of the damage and access to the central office. Free use of the telephone service was provided after the earthquake. Cellular telephones helped in emergency response and recovery.

### **Hospital Lifelines**

In general, the lifelines within hospitals that were investigated performed quite well. Hospitals are operated by the government, social insurance, academic faculty, military and private interests. Most of the hospitals had toppled oxygen tanks as they were not anchored and it was reported there was no damage to these tanks and there was no gas leaks. Other unsecured equipment that fell from the tables were monitors for heart patients. Only one hospital reported an air conditioning problem. A private hospital collapse in Düzce. No information was available on the impact of loss of water and electricity service to hospitals.

### **Gas and Liquid Fuel**

There is no extensive natural gas distribution system in this part of Turkey and liquid petroleum gas (LPG) and propane for cooking and heating is distributed by trucks from all over Turkey for use by the customers in small tanks located on their premises. No report was received on the performance of a small gas distribution system in Izmit. Near Izmit the TÜPRAS oil refinery caught fire and the refinery will be out of service

from 6 to 12 months. This had a minor impact on the supply since gasoline and diesel fuel is also available by tank truck from other parts of Turkey. There was limited damage to gasoline service stations and most of them were in full operation.

### **Emergency Response**

A non-government organization called Arama Kurtarm Teskilati (AKUT) provided rescue services immediately after the earthquake. Foreign support arrived within two days of the event. According to one of the officials in Gölcük, the US military and Turkish military were the best suited to facilitate rescue, recovery and provide order in the area. They were very supportive of the medical groups such as the Doctors without Frontier (MSF) and the Social Health Foundation (TOSAV). Resource shortage is one of the bigger issues facing the officials. Treating the victims with dignity is a high priority. They are organizing lifeline services (water, electricity, telephone and wastewater) in selected areas to provide temporary housing so that the people do not have to stay in tents during the winter. Lack of heavy equipment to remove debris hinders clean up and this delay may become a health issue as winter sets in.

### **Summary**

1. Building damage was by far the most significant impact of the earthquake, resulting in loss of lives, injuries, housing and jobs.
2. Ground deformation caused the most damage to lifelines particularly to highways, water and wastewater systems.
3. Water supply and wastewater collection restoration was poor because of the damaged pipelines.
4. Immediate restoration of most backbone transportation, water, power, and telecommunication systems was successful.
5. Pipelines intercepted by faults and ground failure will continue to break.
6. Anchorage of equipment and seismic integrity of structures remains important, especially in power and telecommunications.
7. Redundancy in lifeline system important.
8. Cellular telephones are a viable alternative for communication.
9. Demand on some utility lifeline systems was low due to overwhelming damage to structures and essentially no fires except the one at the TUPRAS oil refinery.
10. Continued need for emergency response and recovery plans, including emergency water supply and waste disposal

Le Val Lund, Original 9-19-99, Revised 10-8-99