August 17, 1999 Kocaeli and November 12, 1999 Düzce (Turkey) Earthquakes

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ABSTRACT

On August 17, 1999 a magnitude MW 7.4 earthquake struck the Kocaeli and Sakarya provinces in northwestern Turkey, a densely populated region in the industrial heartland of Turkey. The earthquake nucleated at a depth of about 15km at about 10km east of the town of Gölcük. It is associated with a 120km rupture involving four distinct fault segments on the northernmost strand of the western extension of the 1300 km-long North Anatolian fault system. Predominantly right-lateral strike slip offsets were in the range of 3 to 4 m over a significant length of the fault. Since 1939, there have been 11 M>=6.7 earthquakes along this fault system, generally progressing from east to west. The earthquake region has been identified as a seismic gap with stress concentrations indicative of a large impending earthquake. The August 17 earthquake is considered to be the largest event to have devastated a modern, industrialized area since the 1923 Tokyo earthquake. Another segment at the eastern end of the fault break has ruptured on November 12 producing the MW=7.2 Duzce earthquake.

Kocaeli earthquake has generated six motions within 20 km of the fault, adding significantly to the near-field database of ground motions for Mw >= 7.0 strike-slip earthquakes. Of these, the largest peak ground acceleration was about 0.4g at Sakarya. All of the attenuation relationships over predict accelerations at distances less than about 20 km. At distances greater than 20 km, the acceleration data from the Kocaeli earthquake are generally bound by the plus and minus two standard deviation predictions. Forward directivity may be observed both to the east and west of the fault. Sakarya and Yarimca records display strong velocity pulses and a static displacement of 2.0 m and 1.5 m, respectively, in the E-W component. The Ambarli site in Istanbul recorded unusually large accelerations (above the plus two standard deviation prediction for each attenuation relationship) possibly due to strong focusing and site effects.

Along the southwestern shore of the Gulf of Izmit large scale ground subsidence has occurred due to combination of vertical tectonic motion associated with pull-apart structures and landsliding. Many buildings located near the surface fault were torn apart by the fault rupture and collapsed, although there were similar buildings near the fault with no apparent damage. In Adapazari, located over young riverbed sediments with soft and liquefiable silts and sands, hundreds of buildings sank or tilted due to shear failure of the foundation media and liquefaction. Surface manifestations of liquefaction in Adapazari and Sapanca included sand boils and lateral spreading. Avcilar, to the west of Istanbul, exhibited relatively high rates of building damage indicating the influence particular geological conditions, also evidenced by strong motion records with higher peak accelerations than in surrounding areas.

Buildings were damaged across seven provinces for a distance of 250 km from Istanbul to Bolu displacing about 600,000 people. About 21,000 buildings were heavily damaged or collapsed with about 3,000 pancake-type collapses. Death toll is close to 18,000 with about 50,000 hospitalized injuries. Although the main reason for such a high casualty is extensive building damage, the difficulties encountered in initiating an effective emergency response after the Kocaeli earthquake is recognized as a contributory factor. In Koceli earthquake the majority of the building collapses occurred in towns located on the southern shorelines of the Sea of Marmara and in Adapazari. Damage is concentrated in Duzce an Kaynasli in the Duzce earthquake. A western suburb of Istanbul, Avcilar, suffered about 1000 fatalities despite its distance of about 100km from source zone. Most of the collapsed and damaged buildings were of 4 to 8 story high reinforced concrete frame type with hollow clay brick infill walls. The majority of partial collapses involved the first two floors. Although it is apparent that the newer buildings suffered relatively more collapses indicating a deterioration of code compliance in recent years, the observation is more of a reflection of the change in building typologies.

The highway system performed well considering the scale of the fault rupture and the significant near fault ground motion. In Koceli earthquake damage was restricted to isolated bridge collapses at fault crossing locations in the region southeast of Adapazari. The Arifiye overpass totally collapsed due to excessive tectonic displacements. The Duzce earthquake caused damage in Bolu crossing involving an geometric misalignment in an important viaduct and progressive collapse of a tunnel. Telephone communication was temporarily lost due to damage to the main optic cable at a fault crossing. Regarding the water system, no damage was reported to dams or reservoirs. However, pipes were damaged especially in fault rupture and liquefaction areas. In addition to damage to distribution lines, damages at power substations included failure of transformers supports and breakage of insulators causing power blackout in northwestern Turkey. Most of the ports and jetties of industrial facilities in Izmit Bay sustained damage including the extensive damage at Golcuk navy base and the Derince port.

The epicentral area can be considered as the home of Turkey’s heavy industry, including petrochemical plants, car manufacturers, tire factories, steel fabrication plants, cement plants and paper mills. Damage to industry was more extensive than those in other earthquakes with similar ground motion levels. The damage encompassed cooling tower collapses, damaged cranes; collapse of steel, reinforced concrete framed and prefabricated structures, damage to jetties, and extensive equipment failures. Many major facilities are known to face extensive business interruptions.

Building losses are reported to amount to about US$5 billions. Damage to lifelines is estimated to be in the order of US$1 billion. Industrial facilities and small business losses are respectively about US$2 and US$1 billion. If we assume that the indirect socio-economic losses will be about as much as the direct physical losses the total loss figure will be in the vicinity of 16 Billion US$ (about 7% of GDP of Turkey). Most of the industrial losses will be covered by the insurance. The penetration of insurance in residential property is estimated to be about 10%. Most of the residential losses will be

borne by the government since under the current disaster law the state serves as the free insurer of households.

The Kocaeli earthquake has provided extensive lessons for the earthquake physics and engineering especially on the near fault ground motion, permanent ground deformation, importance of code enforcement, risk management, land use regulations and performance of the industrial facilities. However, it should be noted that most of these lessons were predictable and there were no major surprises.