EARTHQUAKE PERFORMANCE OF TWO STEEL TANKS ON GEOTEXTILE REINFORCED EARTH

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ABSTRACT: Two cylindrical steel tanks were constructed in Yalova in 1997, an industrial region at the Marmara Sea coast, which is located 80 km south east of Istanbul, Turkey. Since the subsoil consisted of recent sea sediments and the ground water table was high, use of geotextiles has been suggested to improve the bearing capacity of foundation soil. The diameter and the height of the tanks are 42 m and 12 m, respectively. For improving the soil, the ground was excavated to 5.5 m depth and a fill layer at the base of excavation was formed with well-graded gravel compacted by a vibrated compactor. Geotextiles were placed on this layer with 50 cm fill materials. An earthquake with a magnitude of M_w=7.4 took place at East Marmara Region on August 17, 1999, shortly after the cylindrical tanks were put into operation. The epicenter was located near Kocaeli, on the North Anatolian Fault Zone (NAFZ) which had produced many destructive strong ground motions in the past. The earthquake caused a large number of structural damage, fatalities and injuries in the densely built urbans in the region. In this study, an application of the soil improvement by using geotextiles is presented and the earthquake performance of two cylindrical tanks is investigated, which were located at 60 km west of the epicenter and 1-2 km from the NAFZ. Although they were half loaded during the earthquake, no earthquake damage was observed at the tanks, which presents a good example for the earthquake performance of soil improved with geotextiles.

1 INTRODUCTION

A strong earthquake with a magnitude of M_w=7.4 took place at East Marmara Region of Turkey on August 17, 1999. During the earthquake, a large number of buildings collapsed and thousands of people died within the Marmara Region.

The earthquake also caused significant damage in Yalova city which is an old vacation area on the Marmara Sea coast and located 80 km south east of Istanbul. Many buildings collapsed or were heavily damaged in Yalova especially along the coast line of the city, and more than 2500 persons lost their lives. Figure 1 shows the location of Yalova city and the epicenter of the 1999 earthquake on the Turkey map.

A synthetic fibre factory was built many years ago near the seaside of Yalova city, and many chemistry plants having steel or reinforced concrete structural system are located in the field of the factory.

Two steel cylindrical tanks were planned to be constructed in the field of the factory in 1997. Since the subsoil consisted of recent sea sediments, use of geotextiles has been suggested to improve the bearing capacity of foundation soil. Foundations of the tanks were seated on the fill layer formed with sand-gravel mixture and geotextiles. The diameter and the height of the tanks are 42 m and 12 m, respectively. Each tank weighs 17000 tons when completely filled and is able to store a fuel of 16 000 m^3 . The top of the tanks were covered by aluminium ceiling.

In this paper, an example of soil improvement application from the earthquake area by using geotextiles is presented, and the earthquake performance of two cylindrical tanks is investigated. The application of geotextile reinforced earth increased the safety factor against failure and decreased total and differential settlements below the tanks.

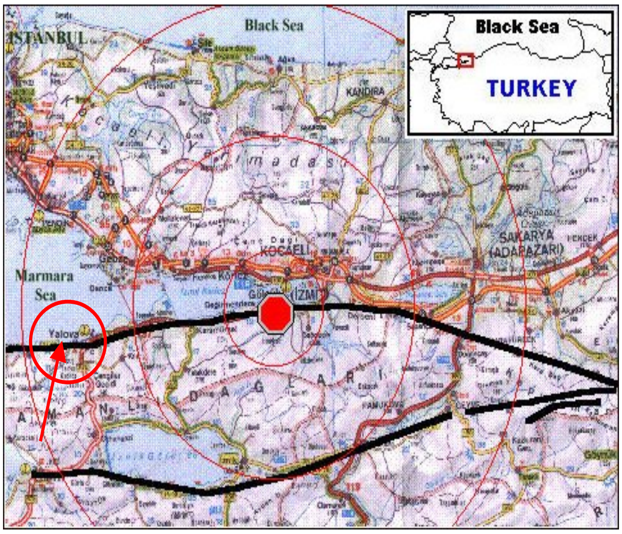

Figure 1 Location of Yalova and the epicenter of the earthquake on the Turkey map

2 GEOTECHNICAL SITE CONDITION

In order to determine the soil condition at the site, several borings to the depth of about 20 m were drilled and laboratory tests were performed. In general, the soil stratification consists of a recent sea sediments composed of alternating layer of silty sandy clay and silty sand, and the thickness of this deposit is about 30 meters (Incecik, 1997).

Soil profile obtained from the borings consists of a fill with thickness of about 2.5 m, underlain by a medium to stiff silty sandy and low plasticity clay with thickness of about 3 m, underlain by a medium to dense silty gravelly sand layer between the depths of 5.5 and 11.5 m. Under this layer, a stiff sandy clay layer is located down to the end of borehole. A typical soil profile, including the SPT-N values based on subsurface borings is given in Figure 2.

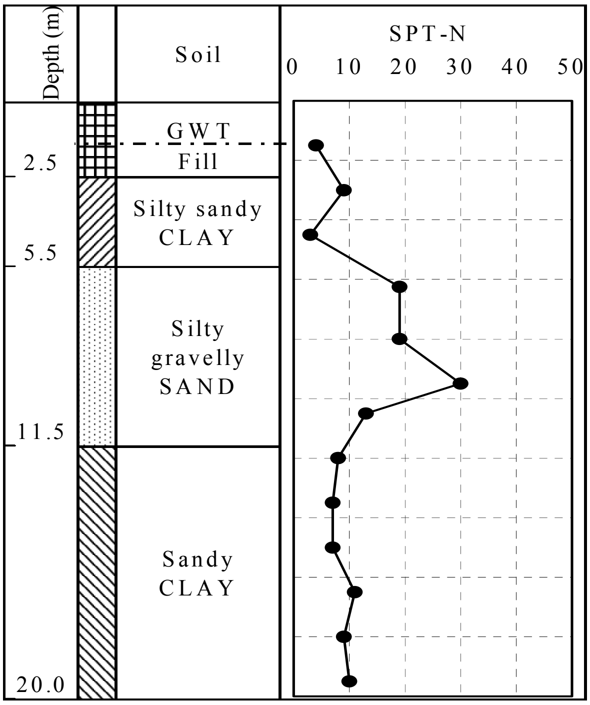

Figure 2 A typical soil profile based on the subsurface borings

The site investigation carried out at the neighbour sites shows that the same soil profile was also encountered down to the depth of 30 m.

The ground surface of the site is almost flat, and its altitude is only few meters from the sea level. The ground water table is 1.5 m below the ground surface.

3 FOUNDATION SYSTEM OF THE TANKS

During the foundation design, it is found out that the shallow foundation placed on the existing subsoil profile at the site does not have enough bearing safety. Therefore, use of geotextile to reinforce earth has been suggested to improve the bearing capacity of foundation soil. For this purpose the ground was excavated to a depth of 5.5 m and woven polypropylene geotextiles were placed on compacted fill material in every 50 cm. Figure 3 shows schematically the cross section of the tank and improved soil at the site.

Geotextiles have potential to improve the bearing capacity of soils. Geotextile and soil form a composite material. Although a complete theory is not available to explain the behaviour of the bearing capacity of this composite material at the present time, use of geotextiles to reinforce the weak soils may be considered to increase the shear strength parameters of the soil (Das, 1997).

For improving the soil at the site, the existing uncontroled fill at the top and the underlying clay layer were excavated to 5.5 m depth and a fill layer with thickness of 5 m at the base of excavation was formed with well-graded gravel compacted by a vibrated compactor of 35 tons (Figure 4).

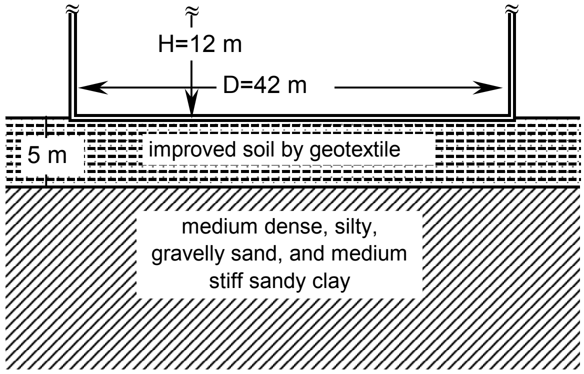

Figure 3 Tank on the geotextile reinforced soil (no scale)

Figure 4 Compaction of the fill material by a vibrated compactor

The degree of compaction was almost 100% in the fill and insitu density tests were carried out to verify the field compaction. Geotextiles were placed on this layer as nine-layer line with 50 cm fill materials (Figure 5 and 6). The nominal tensile strength of the selected geotextile is 25 kN/m (Geolon 25), and its permeability is 0.005 m/sec. The mass unit per unit area and the thickness under a pressure of 2 kN/m^2 are 100 g/m^2 and 0.5 mm, respectively. The tanks were seated on an asphalt cover with a thickness of 6 cm. Figure 7 shows the preperation of the formwork of the ring beam of the steel tanks after the soil compaction.

Figure 5 Placing of the geotextiles on the surface of excavation

Figure 6 Forming of the filling on the geotextiles

Figure 7 Preperation of the formwork of the ring beam of the steel tanks after the soil compaction

The use of geotextile reinforced earth increased the safety factor against failure and decreased total and differential settlements.

Ultimate settlement of 20 cm was calculated at the center of the tank and 10 cm settlement was calculated at the edge of the tank. When the soil improvement was not taken into account, these settlements were found to be 35 cm and 17 cm, respectively.

After the construction of the tanks, the settlement of the soil was periodically observed at the site for one year, and the observed settlements at the edge of the tanks was in the range of 8-12 cm. High percentage of the observed settlements appeared in the first month during the test loading of the tanks. The settlements under the center of the tanks could not be measured.

Thickness of the selected geotextile for improving the soil is relatively thinner than that of geotextile advised in some standards. However, geotextiles were spreaded rather close to each other vertically and backfilling was formed carefully. This geotextile reinforced soil showed satisfactory performance during the earthquake.

4 EFFECTS OF THE EARTHQUAKE

An earthquake with a magnitude of M_w=7.4 took place at East Marmara Region on August 17, 1999, shortly after the cylindrical tanks were put into operation. The epicenter of the earthquake was located near Kocaeli, on the North Anatolian Fault Zone (NAFZ), which had produced many destructive strong ground motions in the past. Yalova was located at about 50 km west of the epicenter.

The focal depth was estimated as about 17 km. The length of the surface rupture was about 125 km and the average displacement along the surface was about 3 m (right lateral strike slip) (Figure 8).

Figure 8 Lateral displacement of the railway between Istanbul and Ankara (Barka,1999)

The recorded peak accelerations were in the range of 26-480 gals in the earthquake area (Figure 9). The earthquake caused a large number of structural damages, fatalities and injuries in the densely built urban areas such as Izmit, Golcuk, Adapazari and Yalova. According to official surveys approximately 17000 persons lost their lives, 24000 persons were injuried and 600000 persons were homeless in the earthquake region (Figure 10).

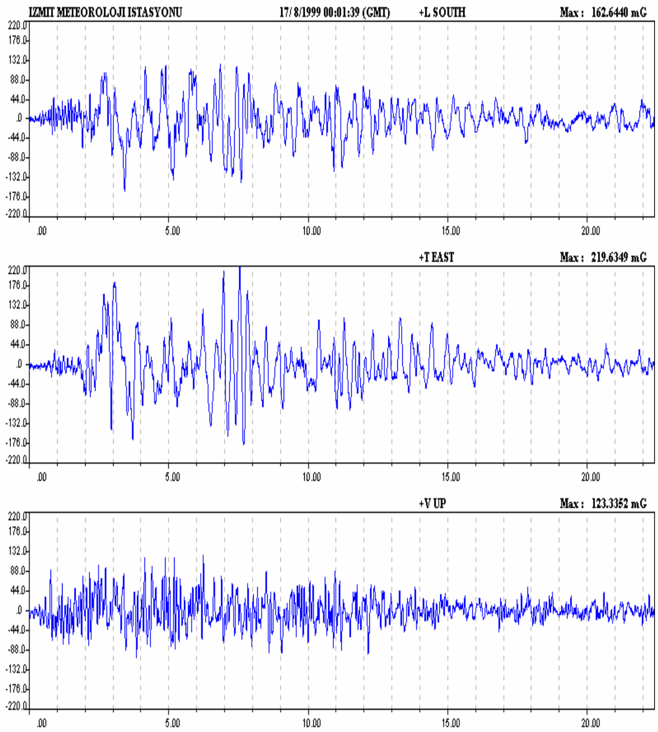

Figure 9 3-D Strong ground motion recorded at İzmit Meteorological Station

This earthquake was the seventh in sequence of westward migration earthquakes along the North Anatolian Fault. The time interval between these earthquakes varied from 3 months to 32 years (Barka et.al. 2000).

The earthquake was consequences of the motion of a wedge of continental crust, known as Anatolian Block, being sequeezed between the Arabian and Eurasian plates. This motion is accommodated by two major strike-slip fault, North and East Anatolian faults. North Anatolian fault is predominantly a single right-lateral strike-slip fault with a differential slip rate of 10-20 mm/year (Erdik&Durukal, 2001).

Figure 10 An example of the structural damage from the earthquake region. (www.sakarya.edu.tr/deprem/res_adp.html)

Loss of coastal lands and subsidence of the ground and liquefaction induced settlements of buildings occured along south coast of Izmit Bay during the earthquake. Several residential buildings settled up to about 20 cm and the settlements increased towards to the coast of Izmit Bay (Yasuda et.al, 1999).

Source characteristics of the earthquake, the local geotechnical site condition and the structural features are the three main factors controlling structural damage during an earthquake (Ansal, et.al.2001). The epicenter of the earthquake was close to Yalova city, there exists a deep alluvial deposit in the soil profile, and most of the building were not designed properly. Large number of reinforced concrete frame structures with 4-8 stories were heavily damaged or collapsed completely.

Poor quality of concrete, poor workmanship, insufficient connection between column and beam, inadequate foundation system, and illegal extra story on the old buildings were considered as the main factors of structural damage (Iyisan,1999).

Although the new constructed tanks were half loaded during the earthquake, earthquake damage was not observed at the tanks which were located at about 50 km west of the epicenter and 1-2 km from the the North Anatolian Fault Zone.

Earthquake caused some rapture on the ground surface near the tanks. After the earthquake, site investigations indicated that additional settlement at the tanks did not occur, and neither cracks nor deformations on the steel body of the tanks were seen. The tanks are being used after the earthquake.

5 CONCLUSIONS

Due to the economical reasons, fuel oil tanks are built at the seacoast or riversides where soil profiles consist of a recent alluvial sediment generally. As well known the steel tanks resist to the large amount of total and differential settlements.

However, it should be taken into account that the bearing capacity of saturated and stiff clays is limited, and failure can occur easily in this kind of soils during an instantaneous loading such as an earthquake.

In this study an example from the earthquake area was presented for the application of the soil improvement by using geotextiles and the earthquake performance of two steel cylindrical tanks was discussed.

A soil improving was carried out at the site in order to increase the safety against failure and decrease the settlements of the two steel tanks built on the young sea sediments in Yalova.

For improving the soil, the ground was excavated to 5.5 m depth and a fill layer at the base was formed with the appropriate granulometric material and 9 layers of woven geotextile having a 25 kN/m of tensile strength were placed on this fill with 50 cm filling materials. The total height of geotextile reinforced earth was 5 m.

After the two cylindrical tanks were put into operation, a destructive earthquake caused a major damage in the region. During the earthquake, a large number of buildings were collapsed and thousands of people died under the debris of collapsed buildings. But although the tanks were half loaded during the earthquake no earthquake damage was observed at the tanks, which presents a good example for the earthquake performance of soil improved with geotextiles.

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