YERBİLİMLERİ
GEOSOUND

1st International Symposium on Eastern Mediterranean Geology
13-16 October 1992 Adana-TÜRKİYE

ISSN 1019-1003
SPECIAL ISSUE

SETTLEMENT AND LIQUEFACTION DUE TO THE MARCH 13, 1992 ERZINCAN EARTHQUAKE

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ABSTRACT: *Following the Ms =6.9 Erzincan earthquake of March 13, 1992 with its epicentire in the Erzincan plain, evidence of soil settlement and soil liquefaction due to ground-shaking were observed in alluvial areas close to the epicentre.*

Three sites are described where sand boil deposits, ground cracks, sinking of the ground surface and settlement-related damage to buildings and retaining walls were observed. The material that liquefied during the earthquake is a dark grey silty sand.

1. INTRODUCTION

The epicentre of Erzincan earthquake 13 March 1992 (Ms = 6.9) was located in the Erzincan plain at 39.705° N latidude, 39.549 ° E longitude and 28 km depth according to the Geological Survey of United States (Fig.1). A maximum acceleration of 0.49g was recorded in the East-West component at the Meteorological Observation Station in Erzincan by the Earthquake Research Department of the Ministry of Public Works and Settlement, Ankara.

It is well documented that under earthquake loading some soils, especially loose sands, may densify, and that, where saturated, pore water pressures may develop causing a total loss in shear strength (see Ambraseys, 1985; Dowrick, 1987; Seed, 1987; Vaid et al., 1990; Berrardi et al., 1991 and Tuttle & Seeber, 1991). Following the Erzincan eartquake, evidence of liquefaction and ground settlement were observed at several sites in the Erzincan plain within 40 km of the epicentre (Fig. 1). The liquefied sites were all underlain by flood plain alluvium which mainly comprises sand, silt and clay with lateral transition into other alluvial deposits of the Erzincan plain, such as river bed and braided river alluvium, and alluvial fans controlled by faults (Koçyigit and Tokay, 1985). Sixty-two borcholes and thirty-four drainage wells were drilled between 1960 and 1971 in the plain by The State Hydraulic Works to a maximum depth of 275 m. The nearest borehole to major liquefied site recorded mainly silty and gravelly sand deposits to a depth of 217 m (Tuzcu and Çuhadar, 1981). No indication is given of in situ density. Artesian wells occur throughout the Erzincan plain as well as a hot spring close to the recent epicentre.

2. SITE 1, 35 km SW of ERZİNCAN, 5 km SW of AVCILAR

During a reconnaissance survey just after the Erzincan earthquake, several fractures were observed cutting the highway where constructed on alluvial deposits between Erzincan and Erzurum, approximately 35 km southeast of Erzincan. The highway embankment had slumped severely with associated longitudinal cracking (Fig.2) and this is attributed to liquefaction of the weak foundation alluvial deposits. On the south side of the highway, a number of cracks, 5 to 10 cm wide, more than 10 m in length, and trending N45°W, were observed. Similar cracks were also found locally within an area of 2 km^2.

The most remarkable fractures observed occurred between the railway and the highway. One discrete perfectly elliptical slump approximately 11 m in length and 7 m wide was found in ground inclined at only 6 degrees. The ground had simply rotated on an axis sinking 30 cm at the rear tension scarp and rising 30 cm at the toe (Fig.3). Many of the fractures showed evidence of the upwelling of sand as illustrated in Fig.4. Rings of sand 5-20 cm in diameter and 10-20 cm thick formed as a result of upward flowing water were found adjacent to the the railway track (Fig.5). Following settlement of the ground

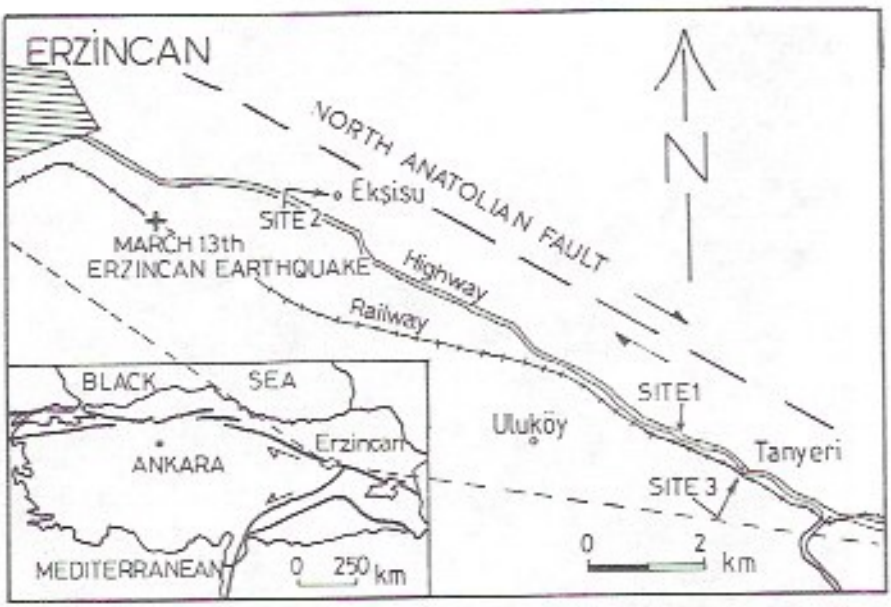
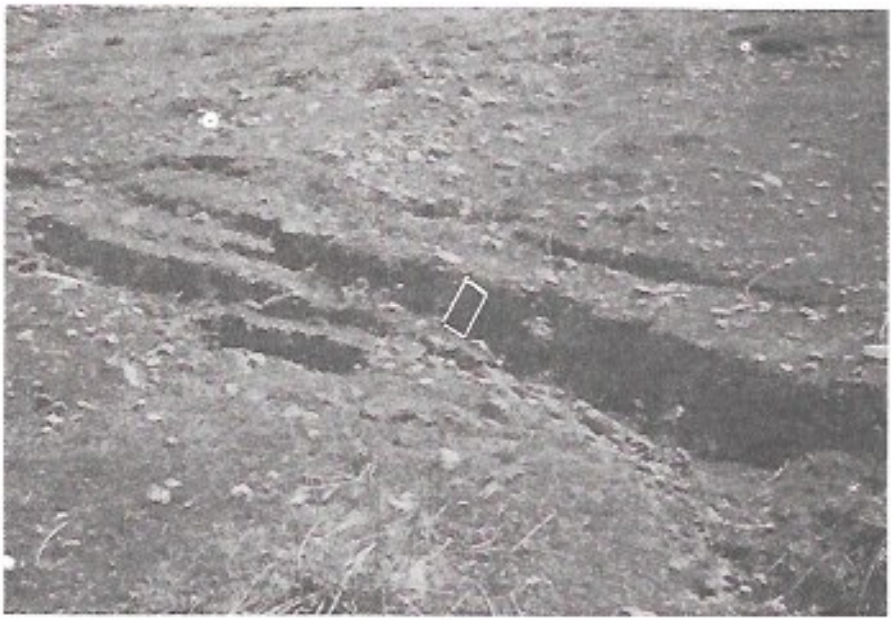
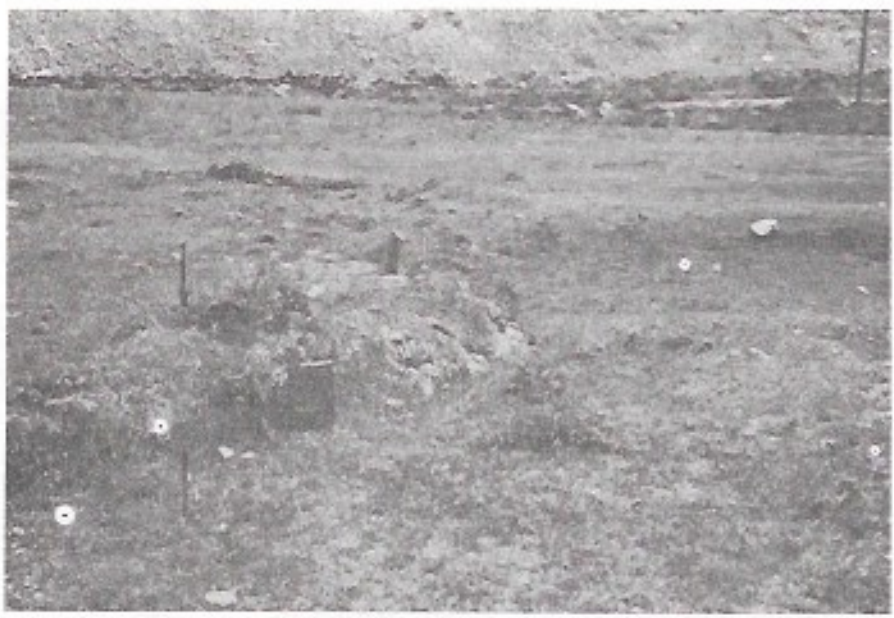


Figure 1. Location map showing 13 March 1992 Erzincan earthquake epicentre, and sites of liquefaction and settlement.

Figure 2. Slumping of highway embankment.



(A)



(B)

Figure 3. Discrete slump due to liquefaction. (A) Ground sinking 30cm at rear tension scarp. (B) Ground rising 30 cm at toe.

a considerable depth of water accumulated at the site. It is reported that the railway embankment had to be raised by 0.5 m locally and evidence was noted at structural damage to a tunnel through the embankment (Fig. 6).

According to the local people there were numerous other examples of liquefaction following the earthquake although many features were soon destroyed by farming. It was reported that in Uluköy village located 15 km southeast of the epicentre, a number of local houses tilted through an angle of 5 to 10 , and out-flow of sand and water was observed along the small irrigation canal running through the village.

3. SITE 2 EKŞİSU

At Ekşisu, 6 km northeast of the epicentre, natural springs are bottled by the local mineral water company for marketing. Ground water levels are close to the surface. Several retaining walls in the vicinity and the car park suffered major damage during the earthquake due to liquefaction of backfill exerting higher lateral pressure on the walls. Tilting and lateral displacements of walls was associated with severe ground cracking.

Movement of retaining structures occurred over a length of 50 m. Retaining walls which are typically of a 1.5 m high gravity boulderwork structure had their lower sections locally tilted outward (Fig.7). Elsewhere lateral translation caused fracturing of the retaining wall with associated tension cracks in the backfill (Fig. 8).

The major cracks across the car park trended N50° W although this direction probably related local failure mechanisms and topography rather than any association with the North Anatolian Fault which runs close by and with a smilar strikes (Figs. 9 and 10).

4. SITE 3 TANYERİ

The third site is located 45 km southeast of Erzincan, next to the highway between Erzincan and Erzurum, at Tanyeri Railway Station. At this location, compaction of alluvial material used as backfill to the basement of a three storey building occurred causing concern to residents. The ground settled by approximately 10 cm around the building which otherwise showed no significant damage (Fig. 11). According to the residents the 2 m basement is dry and no signs of water outflow were observed. It can be concluded that the settlement was simply the result of ground shaking causing densification of loose backfill.

5. CONCLUSION

Evidence of liquefaction and ground settlement were observed at various locations in the Erzincan plain following the earthquake of March 13th 1992. Liquefaction occured in saturated silty sand, due to increase in pore water pressure. Sand vents sometimes surrounded by sand rings provided evidence of water outflow and numerous ground fractures accompanied the sinking of the ground surface. Some remarkable discrete

Figure 4. Evidence of out-flow sand and water.

Figure 5. Sand vents surrounded by sand rings.

Figure 6. Railway bending due to settlement of railway embankment.

Figure 7. Tilting of retaining wall.

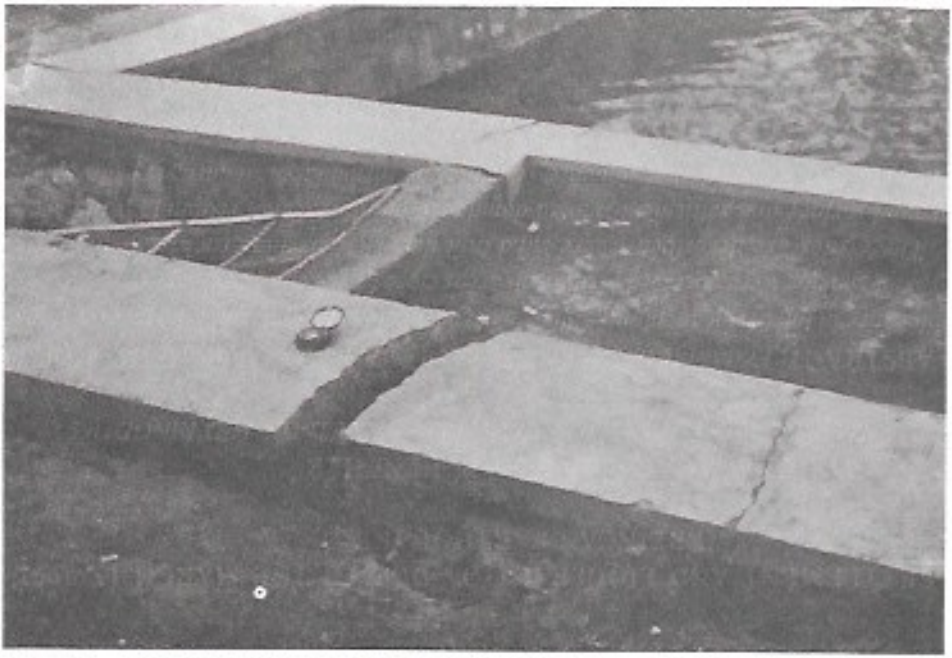


Figure 8. Lateral translation caused fracturing of retaining wall with associated tension crack in backfill.

Figure 9. Large cracks extending across car park.

Figure 10. Subsidiary cracks extending across car park on backfill.

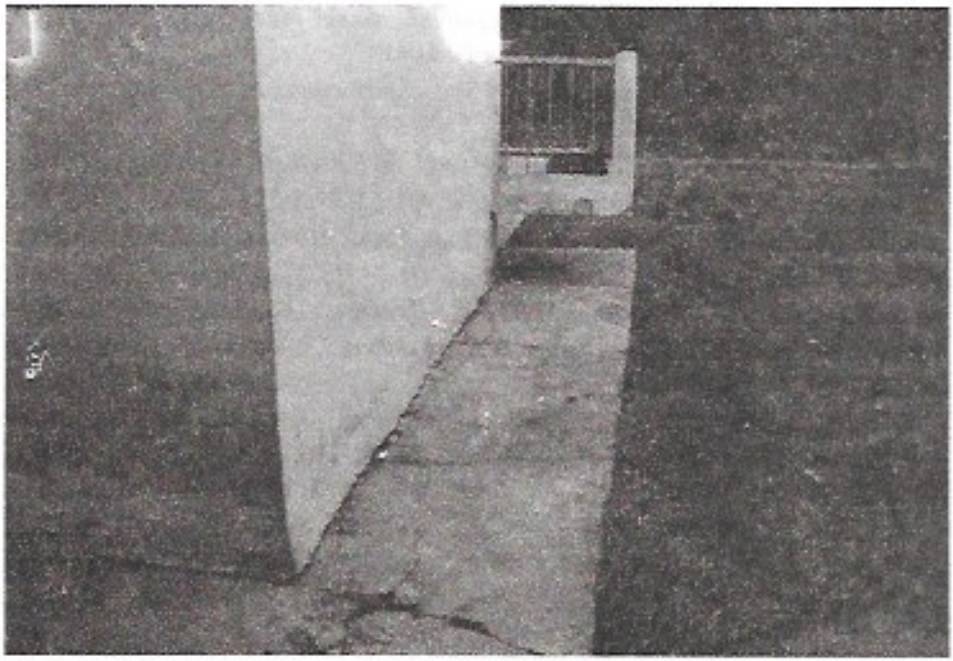


Figure 11. Settlement of fill material.

failure occured in land inclined at only 6 degrees.

It is recommended that the liquefaction potential of sand deposits in the Erzincan plain must be accounted for in the general planning and design of construction projects in the region.

6. ACKNOWLEDGEMENTS

The support of the Natural Environment Research Council, UK for Dr.S.R.Hencher is gratefully acknowledged.

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