

5. GEOTECHNICAL HAZARDS

Affected areas lie on the plateau of 900 to 1,500 m elevation have a continental climate, with cold winters and hot summers. The plateau is for the most part barren, and therefore surface soils are mostly dried up. Most mountain ranges and long valleys run in NW-SE direction indicating their geological structures. Hills are mainly composed of Miocene siltstones with their southern area covered with Quaternary fan deposits, and the geological features seem to explain geotechnical hazards in this area.

5.1 ROCKSLIDE

Several gorges cut deep in a terrace of silt rock, and Changureh village that has been flattened in this earthquake spreads along a rim of the terrace. On the other side of the gorge, a thin mountain ridge dips gently towards north. A rockslide took place on its west slope (**Figure 5.1**). The stratified silt rock mass with a cap rock covering its top dips about 25-28 degrees S40°W as shown in **Figure 5.1**, and the slide seemingly took place along layer boundaries.



Figure 5.1 Rockslide in the foreground and Stratified structure of the rock

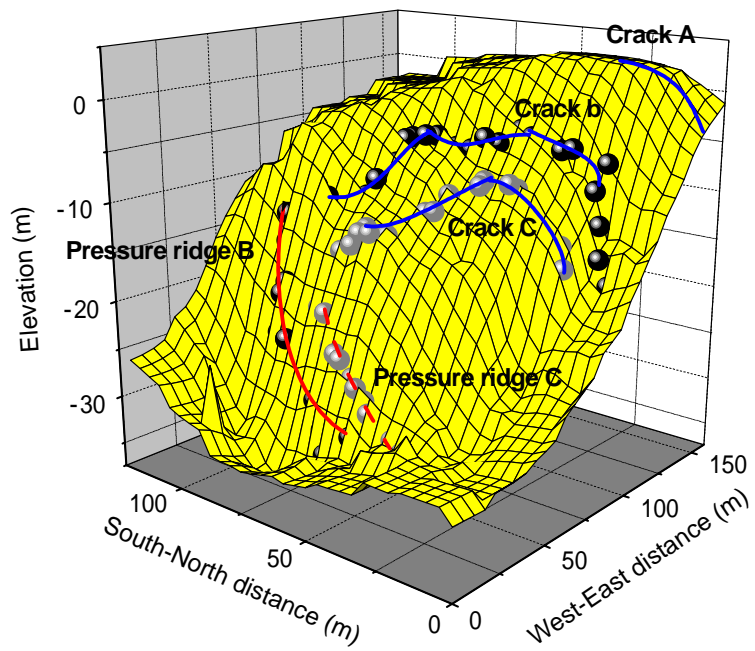
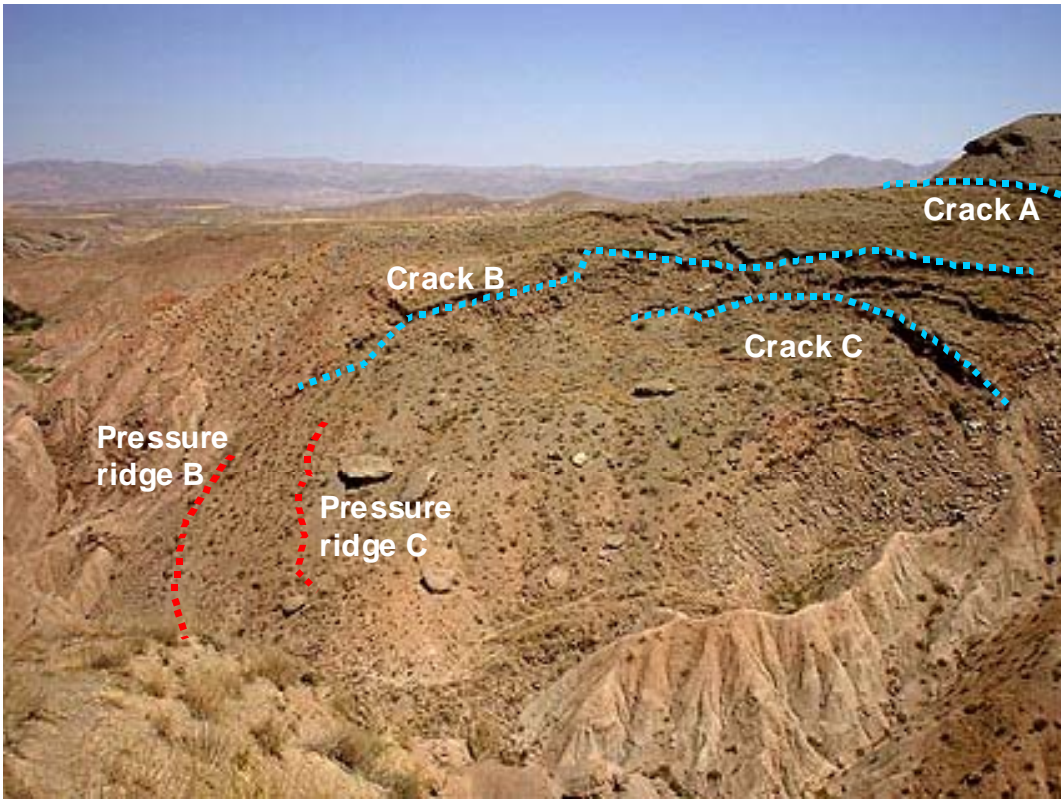


Figure 5.2 Slipped rockmass

The slid rock mass of about 150m long, 100m wide and 30m high is barely caught on the slope, and its configuration was measured by using a laser theodolite (**Figure 5.2**). The upper part of the rock mass was cracked along the perimeter of the slipped mass, and major cracks were mapped on **Figure 5.2**. The opening of cracks became wider as we came closer to the top, and the maximum opening and depth of 3.5-4 m and 5m were reached at **Point A** on Crack A (See **Figure 5.3** showing the plan of Crack A). It is noted in **Figure 5.3** that there was little difference between elevations of both sides of this crack; this fact suggests that the failure surface geometry could be planar.

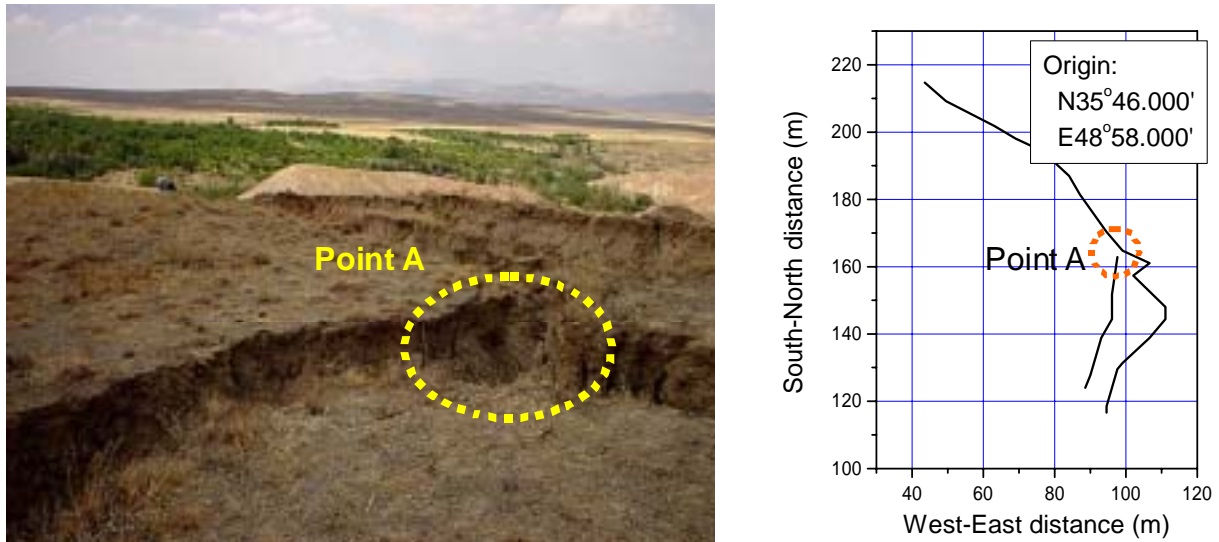


Figure 5.3 Crack A and its plan

5.2 LIQUEFACTION

Hesar, about 5km north of Abdarreh, lies in the middle of a valley of about 15km wide extending in NW-SE direction. A liquefaction took place in a flat area of a little grassy land about 2 km northwest of Hesar (**Figure 5.4**). **Figure 5.5** shows the traces of liquefied sand. The bunch of cracks appearing across the area seems to be winding along a small river trace, which is dried up in hot weather. Soils along the crack at **Point A** are covered 5-10 cm thick with fine sand (about 0.5 mm in diameter, **Figure 5.4**), while gravels were found at **Point B** (**Figure 5.6a**). The flat mass of gravel stopped there was cut upright (**Figure 5.6b**) to discuss its possible sedimentation process. The bottom part was full of middle size grains of about 3-5 mm diameter, which was then covered thick with finer sand. And lastly, a number of bigger grains (5-15 mm) were found all over the sand mass. This fact suggests that the liquefied matter was forcibly spouted twice.

A trench was excavated at **Point C**, where the surface soil was covered thick with fine sand (0.5 mm in diameter). Several cracks were found almost upright on a stiff clay wall of the trench through which liquefied sands forced their ways up (**Figure 5.7**). There were several cracks appearing upright on the clay wall of the trench, through which liquefied sands forced their ways up. The clay layer was 2m thick lying over the completely wet sand layer.



Figure 5.4 Liquefied sand at Point A

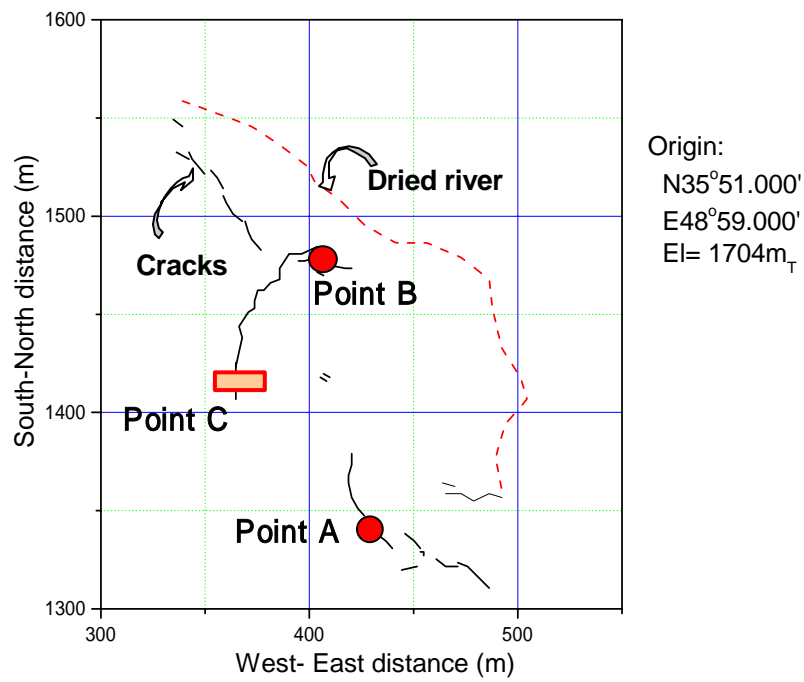
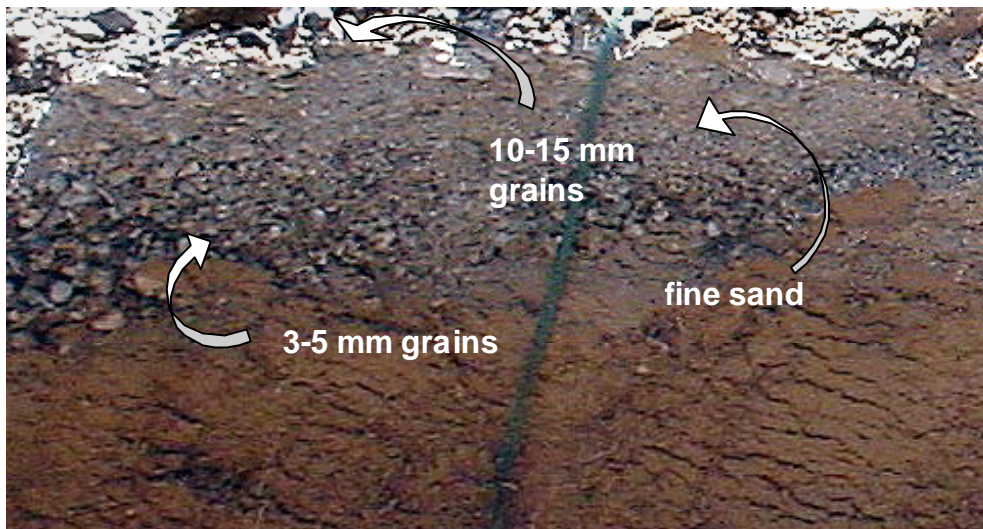


Figure 5.5 Crack mat at the liquefied area, Hesar



(a) Liquefied gravels



(b) Cross-section of flat mass of liquefied matters

Figure 5. 6 Gravels liquefied at **Point B**

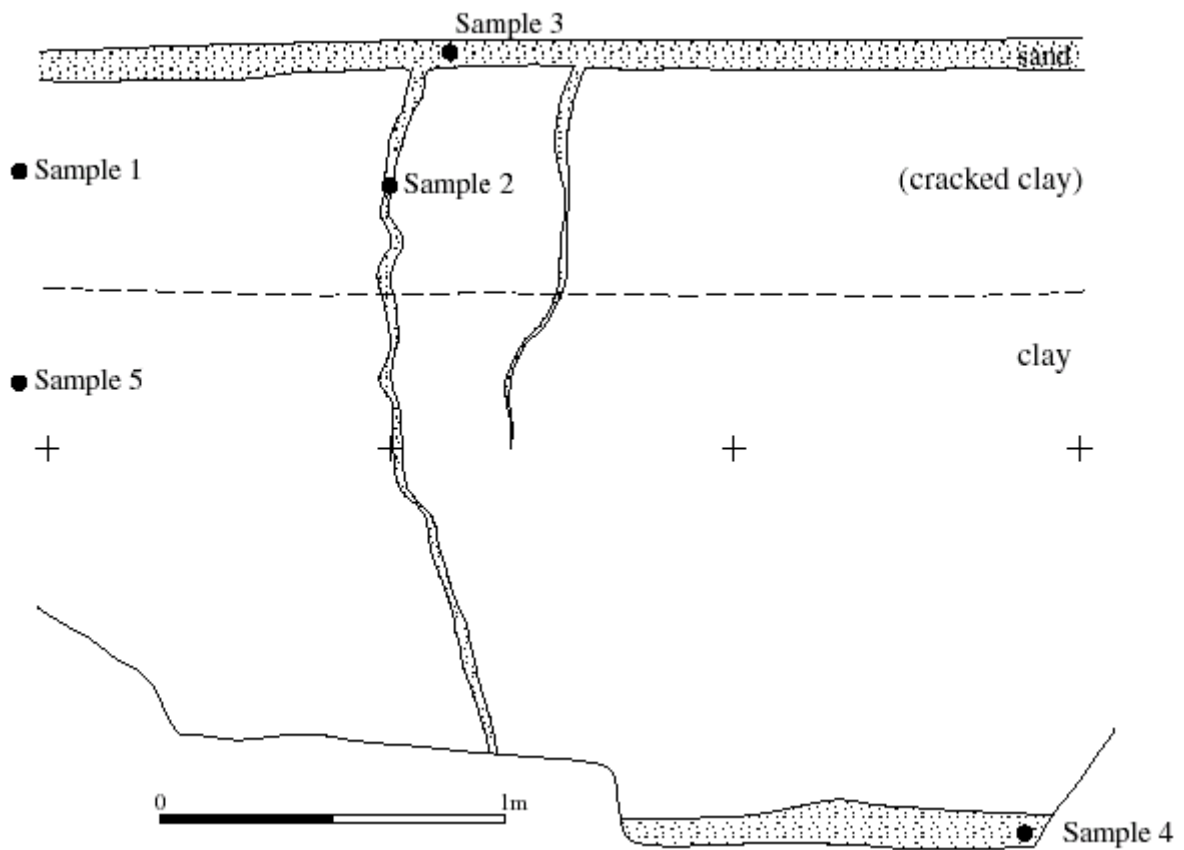
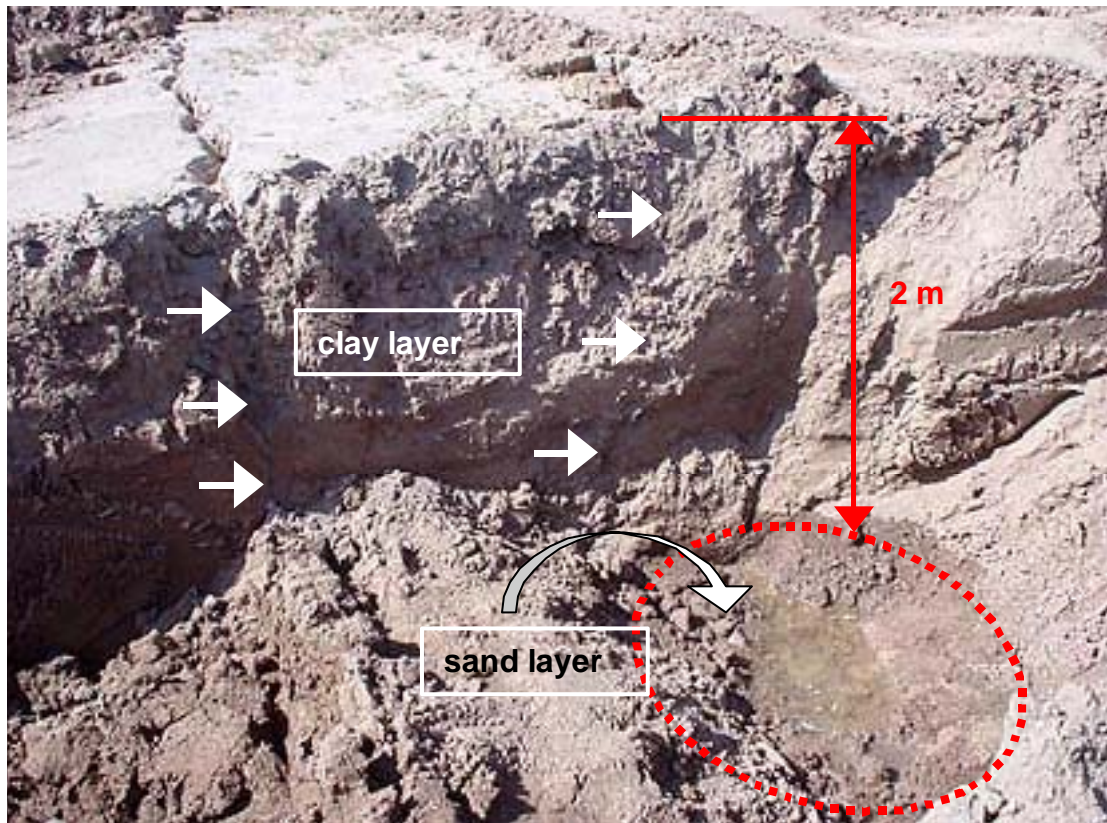


Figure 5.7 Liquefied sand channels through clay layer

5-4 DAMAGE TO EARTH DAM AND NEARBY GROUND

A small size earth dam, located at northwest of Abdarreah village experienced the strong ground motion caused by Changureh earthquake (**Figure 5.8**). The height of dam is approximately 10 meter. The body of this dam consists of clayey soil with no core section constructed inside. The upstream side is covered by rock fill material. Approximate cross section and layout of the dam is shown in **Figure 5. 8**.

Figure 5.9 shows the general view of this dam. As it can be seen in this photograph the dam reservoir was not full at the time of earthquake. For this reason the body of dam was not water saturated. In contrast the ground at upstream and downstream sides seems to be wet and probably saturated due to the certain level of water in the reservoir. This condition can well explain the damage pattern of the mentioned dam and adjacent ground.



Figure 5. 8 General view of the small earth dam located northwest of Abdarreah village

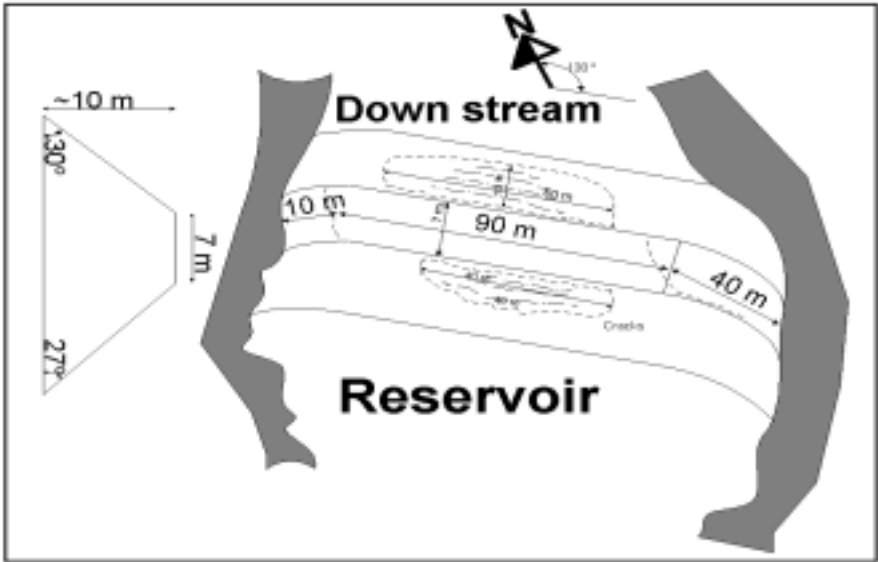


Figure 5. 9 Layout of the earth dam and the crack distribution on its body

The instabilities appeared in the form of some longitudinal cracks indicating failures of upstream and downstream slopes of the dam. Some minor cracks which cross the body at both end of the dam were also appeared. Figure 5.-5-1 shows the distribution of these cracks. **Figures 5.10, 11, 12, 13 and 14** also show the cracks at both sides of dam and at its two ends.

By measuring and summation of the width of all longitudinal cracks the total permanent displacement of both upstream and downstream slopes were estimated to be 56 cm and 87 cm respectively. These amounts represents the deformation of the displaced ground, whereas the amount of horizontal permanent displacements were 10 cm and 30 cm for upstream and down stream slopes as shown in photographs 4-5-2 and 4-5-3. As it is shown in Figure 5.-5-1 the size of dislocated zone at downstream side is almost 60 m in length and 10 m in its width. To estimate the maximum acceleration at the position of the dam a simple analysis based on Seed-Makdisi method is conducted. By measurement of internal friction angle of almost 30° and cohesion of ~25 KPa, using remolded soil samples obtained from the body of dam and selecting an average shear wave velocity of 400 m/sec, the maximum acceleration is approximated to be 0.16g at the ground level and 0.58g at the crest of dam which looks to be reasonable.

Two other types of failures are observed at two different points in the riverbank of both upstream and downstream sides. The large deformation caused by earthquake at the left bank of river in the downstream part is shown in **Figure 5.15**. A kind of slumping is occurred probably due to softening of the soil caused by reduction of effective stress. The evidence for lateral movement is the clear displacement of trees, which were located at the feet of the bank as is shown in **Figure 5.16**.



Figure 5.10. Instabilities at upstream slope



Figure 5.11. Instabilities at down stream slope



Figure 5.12. Instabilities at upstream slope from a closer view



Figure 5.13. Cracks crossing the body of dam near its right abutment



Figure 5.14. Cracks crossing the body of dam at its left abutment



Figure 5.15. Slumping of the left bank of river at upstream side



Figure 5.16. The movement of trees indicating lateral displacement of ground



Figure 5.17. Lateral movement of left bank at upstream side

Another failure, somehow similar to that explained above, is occurred at the left river bank in upstream side. **Figure 5.17** illustrates its configuration. As it can be seen in this photograph the soil was wet and probably saturated. The cause for the lateral deformation could be the softening of soil due to reduction of effective stress.

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 (5.3/ Abbas GHALANDARZADEH, Department of Civil Engineering, Tehran University)