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INVESTIGATION OF THE EFFECTS OF DETONATIONS NEAR THE BATTALGAZİ CAMPUS OF İNÖNÜ UNIVERSITY, MALATYA, TURKEY ON SOIL SHALLOW-DEPTH

ABSTRACT

This study was carried out in the İnönü University Battalgazi Campus and aimed to investigate the effects of detonations in the area used by the Turkish Armed Forces as a shooting range on Campus Site shallow-depth, by using the Multielectrode Vertical Electrical Resistivity (MVER) method. Combat aircrafts from the Turkish Armed Forces 7th Main Jet Base Command weekly carry out two shooting tests in the region. In the selected region, two MVER applications, prior to detonation and three months after detonation, were carried out in the same location and direction and measurements were compared to each other. The results showed that the shooting tests affected the shallow-depth.

Keywords: Geophysic, Resistivity, Shallow Soil Depth, Multichannel Vertical Electirical Resistivity, Malatya

1. INTRODUCTION

In recent years, geophysical applications have been frequently used in civil engineering, geological engineering and environmental engineering studies. In various engineering applications from basic construction studies to dam and road building, geophysical methods are preferred, in addition to other methods. Hazards in the civil engineering discipline essentially stem from undetected near-surface structures including cavities and/or inhomogeneity of geological materials (Araffa S.A.S. et al., 2014). Geophysical methods prevail, if there is a determinant and significant contrast between the physical properties of different lithological units. The physics of electrical current reveals that there are good contrasts in electrical resistivity between different lithological units and between water-bearing and dry formations (Israil M., et al. 2003). This study was carried out in the Battalgazi Campus of Inönü University located at the north of Battalgazi-Malatya, Turkey (Figure 1). The land was previously used as a shooting range by the Turkish Armed Forces for combat aircrafts and now, a part of the land is left to İnönü University. The region at the east of the study area is still used by the Turkish Armed Forces and combat aircrafts from the 7th Main Jet Base Command carry out weekly shooting tests in the region. In the lands left to İnönü University, Faculty of Agriculture and certain vocational colleges carry out educational activities. For this reason, soil investigation studies of the region are important. In the studied area, very few geophysical and geotechnical studies have been conducted before. Detailed geotechnical and geophysical studies were

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carried out during the course of our studies. In this study, only a fraction of them have been included.

2. RESEARCH SIGNIFICANCE

This study, entitled "Investigation of the Effects of Detonations Near the İnönü University, Turkey on Shallow Soil Depth" was carried out in Battalgazi (Malatya, Turkey) Campus Site. The area located adjacent to the area is used as a shooting range by the Turkish Air Forces. The aim of the study was to investigate the effects of shootings made at least twice a week in the area on the soil. Accordingly, Multielectrode Vertical Electrical Resistivity (MVER) experiments were conducted before the detonations in the same direction and three months after the detonations. The results showed that the shootings intensively affected the soil.

3. GEOLOGY OF THE STUDY AREA

The study area is composed of young Quaternary alluvial-fluvial deposits (Figure 2). These deposits generally comprise processed-unprocessed gravel, sand, silt and clay-interlayered mud. According to geophysical-seismic data, the unit in the region has a thickness of 70m and 0.5-m red-brown oxidized agricultural soil cover the top layer. In Malatya and its vicinity, there are East Anatolian Fault, Çöşnük Fault, Malatya Fault, Suçatı Fault, Mudarasın Fault and Southeast Anatolian Thrust Fault. Among these faults, Malatya Fault is the only passive fault. Among the active faults, the fault that can possibly generate large-scale earthquakes in Malatya is the East Anatolian Fault located at 25-km south of Malatya. The Çöşnük Fault, which is 15km away from the study area, is also among the important active faults. The Çöşnük Fault, which constitutes the southern borders of Malatya, is a Plio-Quaternary left-lateral strike-slip oblique fault (Koral H. et al., 2007).

4. EXPERIMENTAL METHOD

The Shooting Range used by the Turkish Airforce 7th Main Jet Base Command is located at the east of the campus site. Combat aircrafts from the Turkish Armed Forces 7th Main Jet Base Command weekly carry out two shooting tests in the region. Information on the crafts carrying out shooting tests and shooting applications is not revealed in the study for military confidentiality reasons. In the study, effects of detonations carried out in the shooting range on soil were investigated with the MVER method. Electric resistivity method is an effective method to determine the conductive or resistive geological structures of underground (Uyanık O. et al., 2014). It is based on measuring the electrical potentials between one electrode pair while transmitting a direct current between another electrode pair (Jongmans, D. Et al., 2007). For the geophysical study purpose, 48 electrodes were used and distance between the electrodes were adjusted to 5m and an AB/2 value of 96m was used. The measurements were carried out using the Schlumberger configuration and the results were evaluated with RES2D-RES3D program (E. Piegari et al., 2009). In the MVER32 measurement profile, measurements were parallel to the road (Figure 3). Furthermore, to investigate the soil, 16 wells were drilled and in all of these wells, disturbed samples were taken from every 3m. Sieve analysis (ASTM D 42), Atterberg limit (ASTM D 4318) and specific weight (ASTM D 854) tests were carried out for these samples.

Figure 1. Site location map of the study area
(http://www.google.com/intl/earth/index.html)

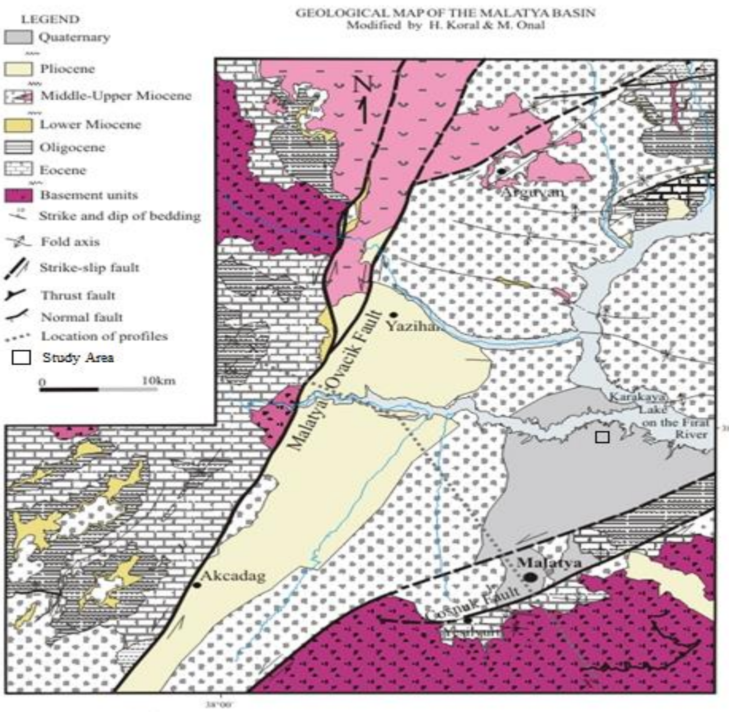


Figure 2. Simplified geological map of the study area
(Gözübol A.M. et al., 1986; Önal M., 1986; Koral H. Et al., 2007;
Ayyıldız T. Et al. 2009)

Soil classification was performed in accordance with the data and the Unified Soil Classification System (USCS). To determine the annual change in ground water levels, five of the soil drill wells were used as observation (OW) wells (Figure 3). For every month in one year, ground water levels (GW) were measured and recorded (Table 1). In the study, data obtained from the tests performed on samples collected from observation wells was used. Ground water level in the study area varied between 2.29m and 6.42m. Table 1 reveals that the lowest ground water level was observed in March. In the region, which is mostly an agricultural region and in which seasonal precipitation is low, with the initiation of the irrigation season due to increasing temperatures, ground water levels increased after April. From the three 50 m-deep wells drilled for irrigation purposes in the campus site, an average of 50 l/s water is obtained. This indicates that the study area is groundwater-rich.

Table 1 Monthly GW measurements in the study area

Month	GW (m)					Month	GW(m)				
	OW1	OW2	OW3	OW4	OW5		OW1	OW2	OW3	OW4	OW5
July	5.85	2.95	3.20	4.48	5.32	January	6.30	5.17	5.24	4.78	5.88
August	5.88	2.96	3.20	4.51	5.32	February	6.35	5.35	5.42	4.81	5.88
September	5.91	2.98	3.23	4.53	5.30	March	6.42	5.57	5.78	5.00	6.18
October	5.77	2.82	2.29	4.31	4.67	April	6.41	4.58	5.76	4.85	6.27
November	6.00	4.06	3.98	4.60	5.13	May	6.14	4.75	4.10	4.78	6.19
December	6.28	5.10	5.15	4.77	5.70	June	5.96	4.04	3.84	4.72	5.75

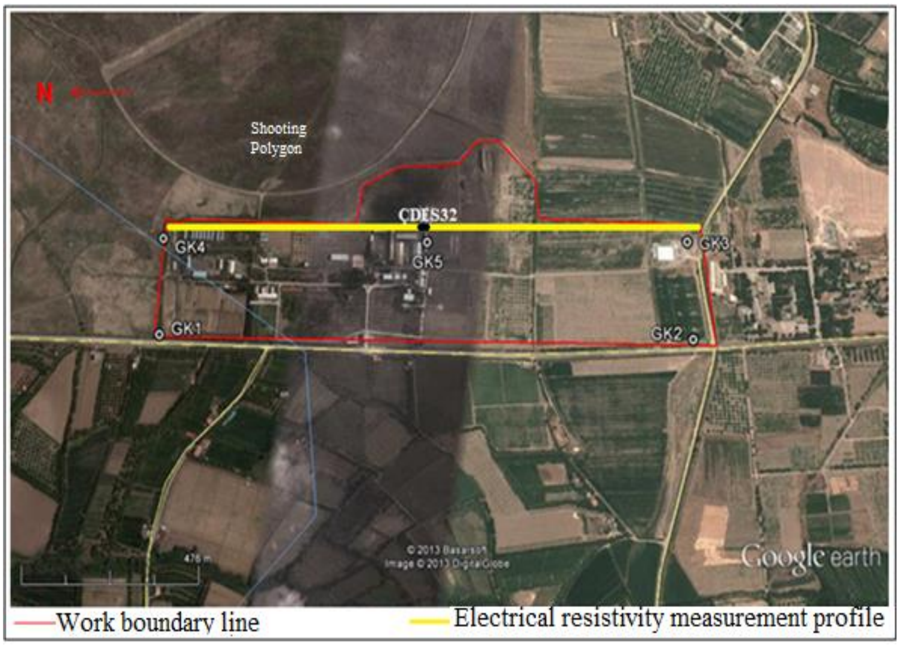
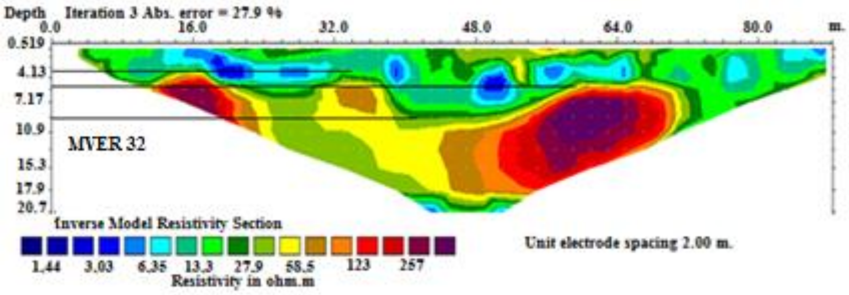


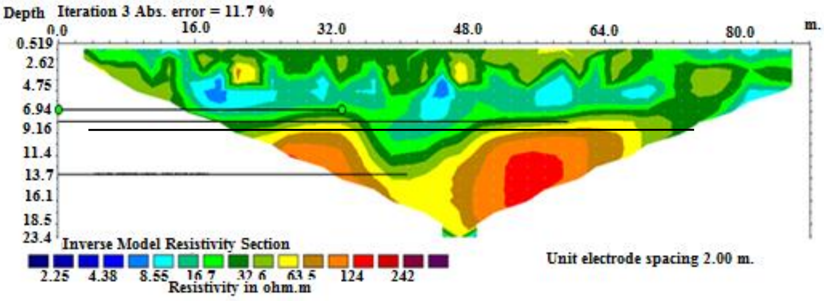
Figure 3. Observation wells used to measure the ground water levels in the study area

5. RESULTS

Within the study area, measurements were carried out at the NS direction with the multielectrode vertical electrical resistivity method (MVER 32). To observe the effect of the detonations in the military shooting range, the first measurement was carried out in September 2013 and after three months, the second measurement was carried out at the same direction. The results are given in Figure 4a and Figure 4b.



a. Pre-detonation (September, 2013)



b. Post-detonation (December, 2013)

Figure 4. Results of the multielectrode vertical electrical resistivity measurements at the NS direction
a) Before detonation; b) After detonation

The change from light to dark indicates that the relevant unit thickens from light to dark. The comparison of the pre-detonation and post-detonation figures in Figure 4 clearly reveals that, at the 16.0 and 80.0 points, the silt unit above the sand-intercalated gravel unit was pushed towards the surface. In the study carried out at the NS direction, according to the measurements taken at the direction no. MVER 32 from north to south, at point no. 32, silt and clay-intercalated sand unit and the silt unit were pushed to 7m, while they were previously 4 m-deep; at point no. 56, they were pushed to 9.5m, while they were previously 6.5 m-deep. Again, at points no. 16 and 80, the silt unit above the sand-intercalated gravel unit was pushed towards the surface. The differences between pre-detonation and post-detonation measurements reveal that the detonations carried out in the military area had affected the shallow soil. To clearly observe the unit, a test pit was drilled at approximately 150 m east of the MVER 32 direction and well no. OW5, near the shooting range (Figure 5). In the 10m-long, 4m-deep and 1m-wide pit, a 2.5m-thick clay unit was observed towards the surface and a dense silt unit was observed towards the lower levels. The units in the study area are generally in a horizontal position. However, as can be seen in Figure 5, there are deviations from the horizontal position in between the silt and clay units. This change in form is attributable to the impact of detonations on the loose and near-surface unit. Ground water in the study area is quite close to the surface. The data on drinking water and irrigation water in the region shows that these wells have high flow levels. Furthermore, the units near the surface were either poorly-consolidated or unconsolidated and mostly composed of sandy units, which may have contributed to the deformations due to detonations. In the regions where near-surface groundwater was observed, water between unconsolidated units tries to relieve the pore water pressure, which is built up during quakes, by pushing surrounding particles. This phenomenon is called liquefaction and usually occurs in units such as sand and silt units. As in the case in the study area, if it is surrounded by a plastic clay unit, water tries to move by pushing the unit. These types of deformations in the soil are attributable to liquefaction. Resistivity values show that the clay unit had very low resistivity (Figure 6). In this figure h represents the layer thickness, ρ represents electrical resistivity and AB/2 represents the distance between the two current electrodes.

Figure 5. Images of the test pit drilled near the shooting range

This can be attributed to the plastic properties of clay. Resistivity values of silt, silted-sand, sandy and silted-clay units were similar to each other. Resistivity values increased with increasing sand ratios in the units. The high resistivity values of graveled-sand units indicate that the units were firm within themselves. According to the measurements, the units from the surface to bottom layer were: between 0-1.3m, silt-intercalated sand; between 1.3-5m, gravel and silt-intercalated sand; between 5-30m sand-intercalated gravel; between 30-100m silt-intercalated sand; between 100-140m, marl unit.

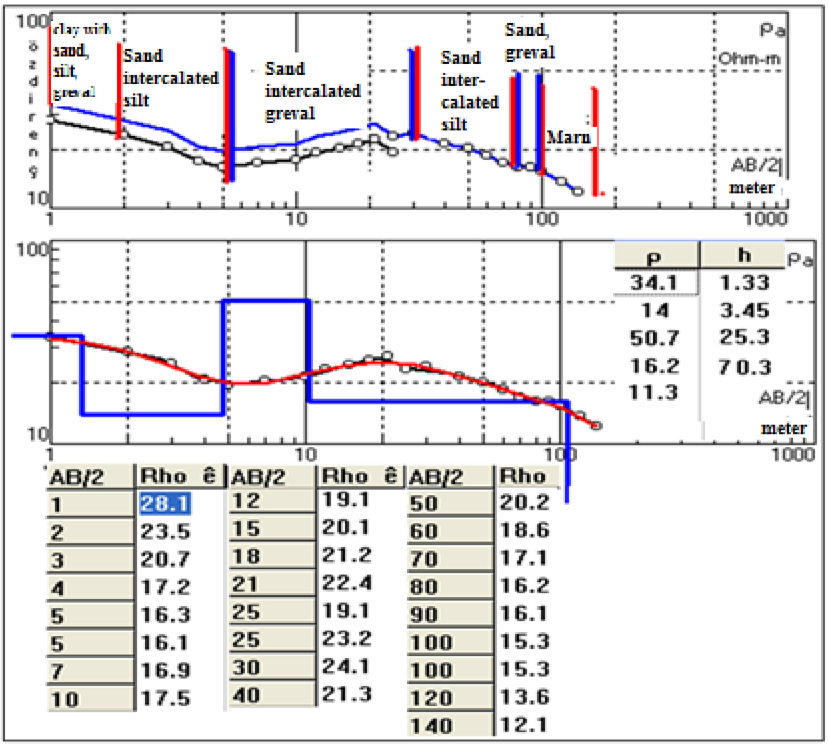


Figure 6. Electrical resistivity values of the MVER 32 measurement points

Table 2. Physical properties of the samples from the observation wells in the study area

OW	Depth (m)	Sieve Analysis (%)			wL	wP	Ip	Gs	Symbol
		Gravel	Sand	Fine					
1	1.5	0	67.06	32.94	43.74	17.56	26.18	2.55	SC
	4.5	0	86.18	13.82	50.46	22.33	28.13	2.60	SC
	7.5	0	52.31	17.69	49.60	20.13	29.47	2.59	SM
	10.5	12.17	74.62	13.21	37.40	14.63	22.77	2.64	SC
2	1.5	16.44	63.52	20.04	41.10	17.52	23.58	2.63	SC
	4.5	29.13	59.33	11.54	NP	NP	NP	2.69	SM
	7.5	23.75	53.24	23.01	NP	NP	NP	2.32	SM
	10.5	13.34	50.63	6.03	31.44	12.27	19.17	2.57	SW-SC
3	1.5	14.00	74.35	24.25	44.07	20.79	23.28	2.60	SC
	4.5	0.20	54.63	44.97	39.09	14.41	24.68	2.57	SM
	7.5	30.11	52.31	17.58	36.40	13.61	22.79	2.67	SC
	10.5	2.54	75.54	21.92	70.96	29.69	41.27	2.60	SM
4	1.5	0	43.13	56.87	53.13	28.20	24.93	2.57	CH
	4.5	9.57	55.48	34.95	69.00	40.47	28.53	2.59	SC
	7.5	0.07	58.81	41.32	64.94	35.43	29.51	2.81	SC
	10.5	0.21	25.82	79.87	49.97	27.35	22.62	2.57	CL
5	1.5	53.59	12.32	34.09	49.34	27.72	21.62	2.65	GC
	4.5	0	28.84	71.16	46.57	26.09	20.48	2.63	CL
	7.5	1.56	80.17	18.27	NP	NP	NP	2.69	SM
	10.5	0.85	56.11	43.04	38.97	15.23	23.74	2.65	SC

Certain physical tests were performed on the samples collected from the drills, which were drilled in the study area and later, used as observation wells, and their results are given in Table 2.

Table 2 shows that the first 10.5 m of the unit mostly comprise sand and clay. The clay samples were mostly highly plastic. Similarly, in the measurements at the MVER 32 point, sand formations were predominant and the clayed-units also showed plastic properties. These results agree with the classification made based on the USCS. Moreover, as can be seen in Figure 7, the deformations occurred on the buildings after the detonations at October 2013, also show that the units forming the soil were affected by the detonations.

Figure 7. The deformations observed in the study area after detonations

6. CONCLUSION

- Groundwater levels in the study area varied between 2.29m and 6.42m. This may have increased the deformations occurring during detonations.
- Water flow was observed at 50 l/s in the water well drilling wells in the study area.
- Vertical electrical sounding results give information about the subsurface strata as the resistivity obtained from different depths is indicative of the type of strata present (Baride Mukund Vasantrao et al., 2017). Therefore, this method was applied to investigate the effects of shootig tests.
- During studies, the samples collected from the test pits and drills showed that in its shallow-depth (0-20m), the unit was composed of either uncemented or poorly-cemented gravel, sand, silt and clay-interlayered mud. Especially gravel, sand and silt are good aquifers, thanks to their porous-permeable properties. Soil liquefaction during earthquakes can cause great damage of structures due to the loss of the soil strength and ground settlements. The permeability of sand is an important parameter affecting the porepressure buildup and dissipation during the liquefaction process [Tzou-Shin Ueng et al., 2017]. In the study area, mostly unconsolidated sandy units are observed. Also, the groundwater level is very close to the surface. It is thought that an area close to the study area causes damage on the floor of the continuous shooting tests.
- In Figure 4, according to the measurements taken at the direction no. MVER 32 from north to south, at point no. 32, silt and clay-intercalated sand unit and the silt unit were pushed to 7m, while they were previously 4m-deep; at point no. 56, they were pushed to 9.5m, while they were previously 6.5m-deep.

Again, at points no. 16 and 80, the silt unit above the sand-intercalated gravel unit was pushed towards the surface. The differences between pre-detonation and post-detonation measurements reveal that the detonations carried out in the military area had affected the shallow soil. Similar deformation traces are also observed in figure 5. According to these deformations, it can be said that detonations are effective in the shallow soil depth.

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MVER : Multielectrode Vertical Electrical Resistivity
ASTM : American Standards for Test Methods
USCS : Unified Soil Classification System
OW : Observation Well
GW : Ground Water
wL : Liquid limit
wP : Plastic Limit
Ip : Plasticity Index
Gs : Specific Weight