Geotechnical investigations for the oil Refinery in Novi Sad, Serbia

M. Djogo[1], Ph.D. and M. Vasić[2], Ph.D.

[1]Department of Civil Engineering, University of Novi Sad, Serbia, 21000 Novi Sad, Trg Dositeja Obradovica 6; FAX (0038121) 459-295; email: mitar@uns.ac.rs
[2]Department of Civil Engineering, University of Novi Sad, Serbia, 21000 Novi Sad, Trg Dositeja Obradovica 6; FAX (0038121) 459-295; email: vaske@uns.ac.rs

ABSTRACT

Detailed geotechnical investigations have been carried out within the grounds of the oil refinery in Novi Sad for the purpose of constructing a relatively large number of reservoirs for the storage and processing of oil. The first group of those structures is still in use, the second group is in limited use due to the occurrence of uneven settlement and the third group was destroyed during the 1999 bombing campaign. The destruction of these structures led to a significant infiltration of petroleum products into the soil causing environmental pollution. Geotechnical investigations were carried out in several stages to determine the characteristics of the soil and their influence on the stability and functionality of the structures. The reservoirs are 53 m in diameter. Apart from the reservoirs, the geotechnical investigations included other support structures as well. The oil refinery in Novi Sad was built on the alluvial plain of the River Danube. The Danube's alluvium sediments were investigated in detail up to a depth of about 25 m. Below the alluvium there is clay and marl from the Pliocene. The shallow zone of the alluvial sediments is made up of poor quality soil, and the more suitable sand and gravel lies deeper. The poor quality soil consists of lentiform sediments of mud and soft clay that are prone to increased settlement. That is the reason for the uneven settlement of many reservoirs. The settlement was measured geodetically. The most interesting data and certain specific features of the geotechnical investigations of the terrain for this type of structure have been presented in the paper.

Keywords: alluvial sediments, geotechnical investigations, settlement

1 INTRODUCTION

The oil refinery was built in the southern part of the Pannon plain in Serbia. The great European river Danube flows by the refinery. Alluvial sediments from the Danube are present in the surface part of the terrain up to a depth of 25 m. Below them are Pliocene sediments. Muddy sediments are the most unfavorable for the founding of reservoirs, tanks and other structures. As a rule, these are deposited in the shallowest part of the Danube's alluvion. These muddy sediments have had an influence on the appearance of tilting in the structures as well as their uneven settlement (Milović and Djogo 2005). The layout of the structures within the refinery and its position relative to the river Danube are shown in Figure 1.

The first phase of the investigation involved the entire area of the refinery. In subsequent phases the investigation of terrain was carried out on the micro locations of the individual structures within the refinery. The entire surveyed area of the refinery was investigated in great detail (Vasić and Djogo 2007).

2 THE DANUBE'S ALLUVION IN THE AREA OF THE OIL REFINERY

The Danube's alluvion is about 3 km wide. Its thickness is between 20 m and 25 m. In the surface area of the alluvion up to a depth of about 5 m are the youngest Danube sediments where there are thicker or thinner lentiform muddy layers and clayey sediments with organic matter. In some areas there are no muddy sediments. Below the mud there are sands which possess favorable characteristics. These sands are present at depths between 5 m and 20 m. The deepest zone of the Danube's alluvion is made up of gravel. Below the Danube's alluvion are the Pliocene marls and clays. A free groundwater aquifer, which is in direct hydraulic connection with the Danube, was formed in the Danube's alluvion.

Figure 1. The layout of the oil refinery

3 INVESTIGATING THE TERRAIN FOR THE OIL REFINERY'S STRUCTURES

Prior to building the oil refinery in Novi Sad, several dozen investigative boreholes were made to depths between 8 m and 20 m along with other appropriate investigations. In the course of these investigations it was pointed out that prior to the construction of the aforementioned structures it would be necessary to conduct additional geomechanical investigations in order to gain a full insight into the conditions of founding each individual structure. A large number of the structures was constructed, but the proposed additional geomechanical investigations were never carried out. During the exploitation of these structures, this proved to have been a serious mistake. Namely, the bad soil below the foundation was not removed, which would have been very easy and inexpensive to do during the construction phase.

Comprehensive terrain investigations involved investigative boreholes and static penetrations. These investigations determined that certain parts of the refinery did not contain the unfavorable muddy soil. Figure 2 shows only one typical experimental static penetration diagram (CPT). The diagram shows that the terrain consists only of sands without lentiform muddy layers.

Most of the area covered by the refinery consists of muddy soil and humus which were not removed below the foundations of the structures. Figure 3 shows just one typical experimental static penetration diagram. This diagram shows that the terrain contains a lentiform layer of mud up to a depth of 5 m. It is this poor soil that causes the occurrence of uneven settlement in the structures.

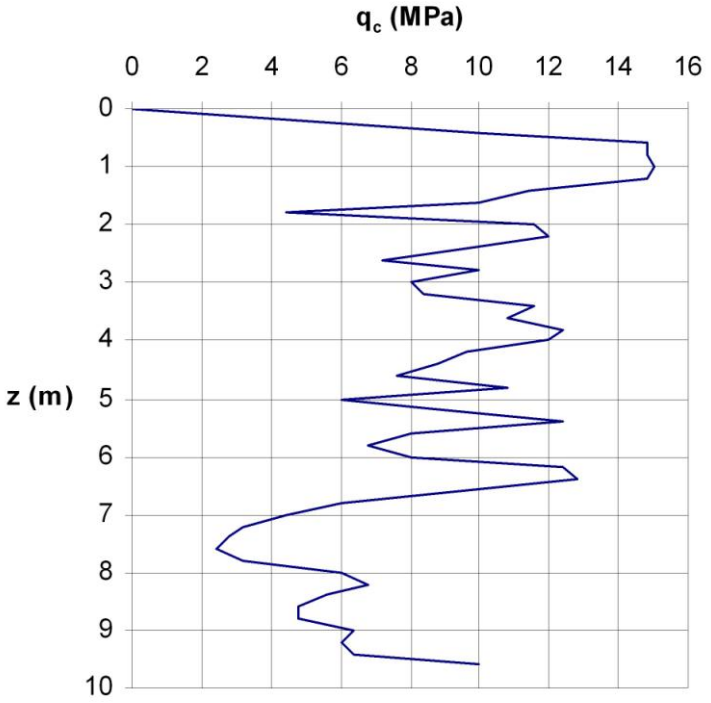

Figure 2. CPT diagram for reservoir G16

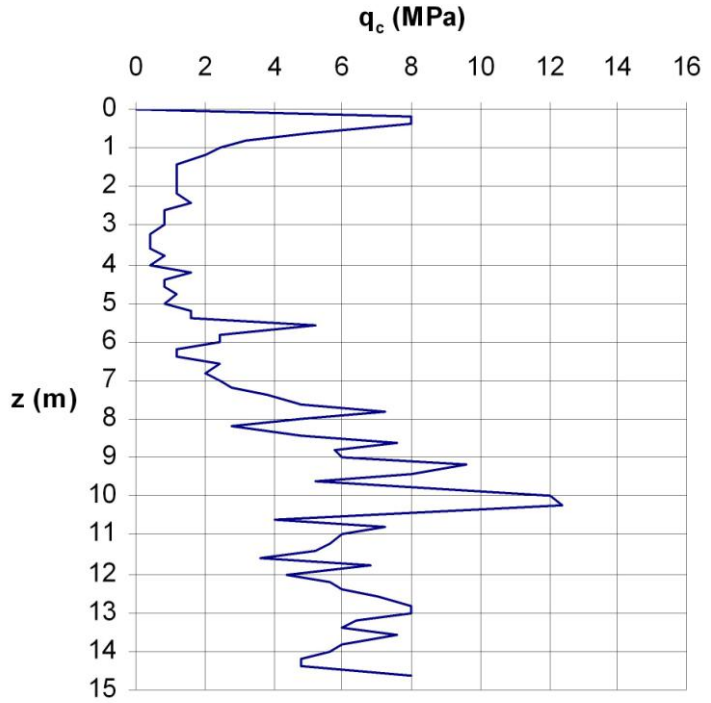

Figure 3. CPT diagram for the tall Visbreaking column

In this paper the refinery structures have been classified into three groups. The first group of structures does not exhibit uneven settlement. The second group is in partial use due to the occurrence of uneven settlement. The third group was damaged during the 1999 bombing campaign.

The first group of structures was constructed on a relatively homogenous sandy soil. The calculated values of the absolute settlement of the reservoirs' concrete foundation rings are between 1.7 cm and 4.8 cm. These reservoirs do not exhibit significant differential settlement. These structures are used without any limitations.

The second group exhibits uneven settlement. One reservoir and a neutralizing tank will be shown further on. Reservoir N9 is 53 m in diameter. It was constructed on non-homogenous soil made up of mud and sand. According to the geodetic measurements, the differential settlement of this structure was 56 mm during the filling test phase and 73 mm after 10 years of exploitation. An analysis of the geodetic measurements carried out during a period of 10 years, which includes filling and draining the reservoir, has led to the conclusion that the extent of settlement has been decreasing with time.

The damage on the old neutralizing tank was caused by inadequate funding on poor soil and cracking of the tank due to uneven settlement and by the aggressive effect of the liquid in it. It was determined that the deformation and damage were very severe. The tank is unevenly settled so that one end sank by 9 cm compared to the other end. There are numerous cracks in the tank, and the damage along the cracks and the damage to the concrete in the walls and the floor slab are extremely severe. Caverns formed along certain cracks in which the reinforcement was completely destroyed along with the concrete. Due to the specific need for the tank to remain in function and the extremely difficult and expensive repairs, it was proposed that a new neutralizing tank be constructed.

The new tank was constructed next to the old one. The old tank has not been used since the new one was constructed. This prevented the further pollution of the environment. Investigations of the new tank determined that the poor muddy soil must be replaced with large-fraction stone. This would prevent the errors which accompanied the founding of the old damaged neutralizing tank. Figure 4 shows characteristic experimental static penetration diagrams for both tanks. In penetration zone CPT1 below the old tank, there is poor soil, which was not replaced, up to a depth of 4.2 m from the surface of the terrain. On the opposite end of that tank the poor soil extends to a shallower depth. Such terrain composition led to the uneven settlement and cracking of the tank followed by the leaking of an aggressive fluid and its harmful effect on the concrete, reinforcement and the environment. In the case of the new tank, the poor soil had completely been removed in the foundation digging phase.

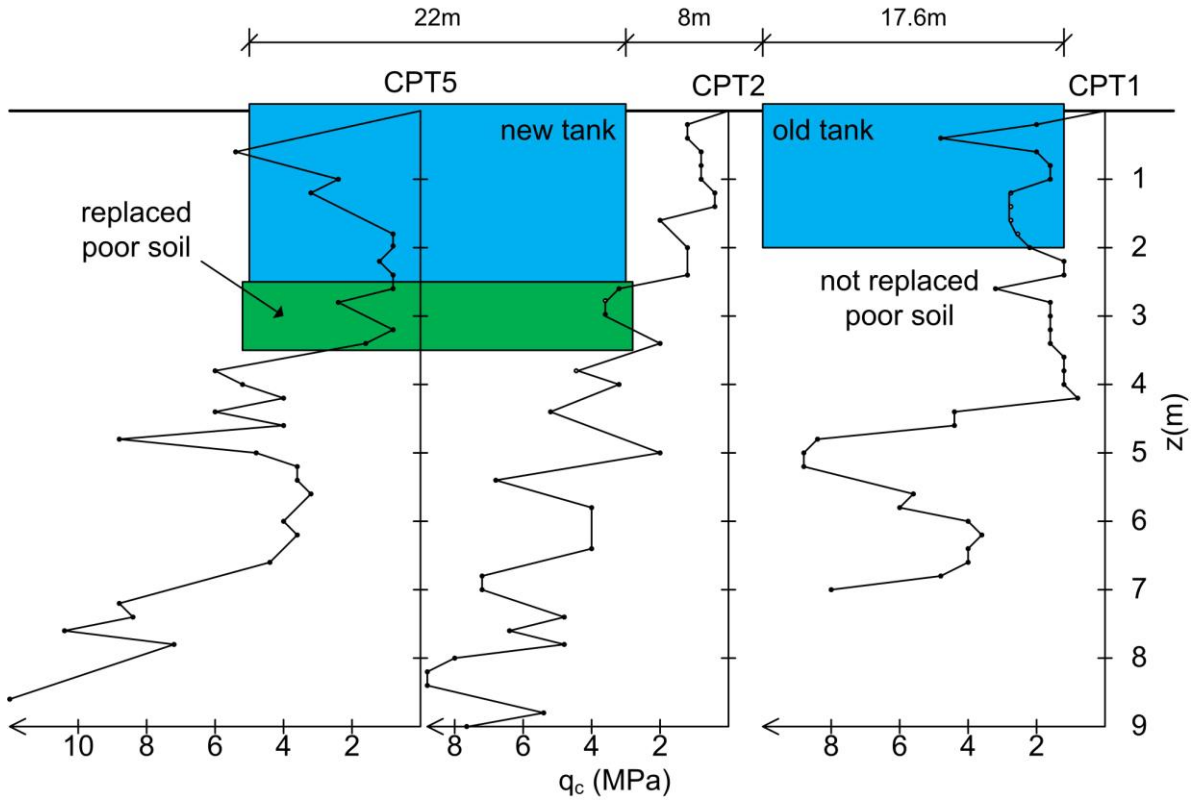

Figure 4. CPT diagrams for the new and old neutralizing tanks

The third group of structures was damaged in the 1999 bombing campaign. Afterwards, a large number of reservoirs was rebuilt and their exploitation was resumed. The presented case here is that of reservoir N5 with a volume of 10000 m^3, which received a direct hit in the foundation. As a result, the foundation soil below the reservoir was weakened in the bomb's blast radius. During the rebuilding of the reservoir, this foundation soil was not sufficiently repaired. This was confirmed by the measured extent of settlement in reservoir N5 during its test filling (Figure 5).

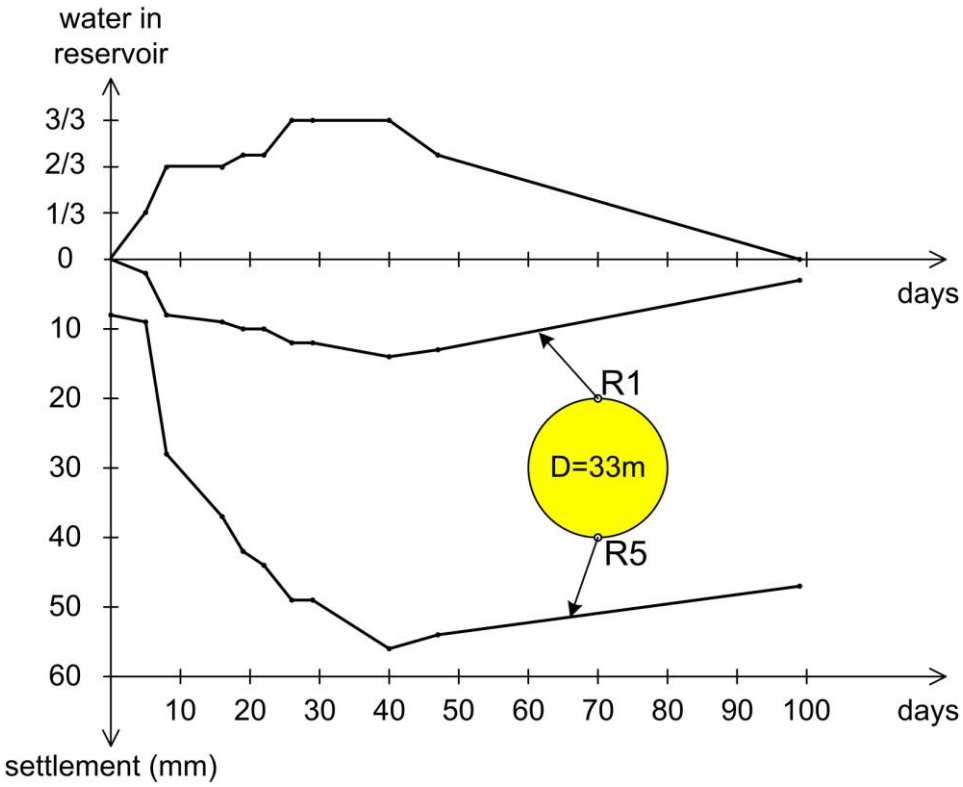

Figure 5. Diagram of the settlement of reservoir N5 during its test filling

The settlement diagrams show that there is significant differential settlement which is the consequence of the insufficiently prepared foundation terrain and the properties of the foundation soil. The increased settlement on measuring point R5 was located in the area where reservoir N5 received a hit during the bombing campaign.

4 CONCLUSION

The structures of the oil refinery in Novi Sad were constructed on the Danube's alluvial plain. The shallow part of the alluvion has muddy sediment layers up to a depth of 5 m, while sands and gravels possessing favorable characteristics can be found deeper. In the course of founding the structures, uneven settlement and tilting of the structures occurred in each location where the mud was not replaced by superior soil.

5 ACKNOWLEDGEMENTS

This work was financially supported by research grants No. TR36043, TR37017 of the Serbian Ministry of Science and Technological Development.

REFERENCES

Milović, D., and Djogo, M. (2005). "Errors in foundation engineering." Faculty of Technical Sciences, Novi Sad, 438 pp.
Vasić, M., and Djogo, M. (2007). "Some specific aspects of geotechnical testings of the terrain for reservoirs of oil derivatives." Proc. Symp. on Geotechnical aspects of Civ. Eng., Soko Banja, Serbia, 403-408.