Caverns in the Ground Under Thermal Power Plant, Caused by Static Electricity and Chemically Aggressive Water

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CAVERNS IN THE GROUND UNDER THERMAL POWER PLANT, CAUSED BY STATIC ELECTRICITY AND CHEMICALLY AGGRESSIVE WATER

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ABSTRACT

A relatively rare phenomenon is discussed in the bellow report. Some deformations and subsidences of the road pavement and of some facilities of the plant for chemically contaminated water in Sofia Thermal Power Plant are examined here. A danger of demolishing of large ponds of sediment water, as well as of incidences with the high steel poles for high voltage were highly possible to happen if current situation is retained.

Various studies with this topic have been conducted - geophysical, such as geo-radar, electro-tomographical and drilling ones (with short boreholes). Laboratory and field studies of the ground have been also executed together with a historical review of the construction and reconstruction; different aspects of topography and geological history of the area were also discussed.

The site is located on the right bank of a small river, and the ground is swelling clay dust on layers of sand and silt. Under the site, there is a dense network of pipes, cables and ducts of various installations available, but a few have on hand accurate information about their disposition.

The comparison of hypotheses and conclusions of the analysis show very interesting combination of a bunch of diverse factors' influences, i.e. the geological structure, depression curve, chemical aggression of water, electrostatic catalysis and corrosion of steel pipelines, suffusion, etc. There are caverns and unsealed areas in the ground, formed by collapses of flooring and threatening the sustainability of some of the equipment.

Measures have been taken to fill the voids and unsealed areas by injecting cementations grout, and also to prevent further development of these adverse processes. The ground under the foundations of endangered facilities was reinforced.

INTRODUCTION

It is known that unexpected emergencies of equipment and facilities may often occur in the industrial areas as a result of their continuous work under high pressures and different weather conditions.

While the operation of the chemical installations, there is additional risk of inadvertent release of active substances that react to the ground structures. When a site has a large number of underground aqueducts built during different periods of time, sometimes their technical condition is lost by the staff, which is leading to accidents. A similar case is discussed in this report. The phenomenon is relatively rare in practice and deserves the attention of specialists in the operation of this type of equipments.

And so it is about the site of the Water Treatment Plant of the largest Thermal Power Station in Sofia, the capital of Bulgaria. Noticeably increasing deformations in the laid asphalt occurred there. They were happening in different spots and were threatening the stability of neighboring facilities. A danger of demolishing of large settling ponds of contaminated water was also spotted. Rolling and steel poles for high voltage in the middle of the site were in danger as well (Photo 1).

Photo 1: Rolling and steel poles for high voltage

II. DESCRIPTION OF THE GROUND

The site of the plant has size of 2000 m2 and is located on flat terrain on the banks of a small river. The old flooring was of concrete and it was cracked in many places (Photo 2), while a few spots have experienced gaps underneath.

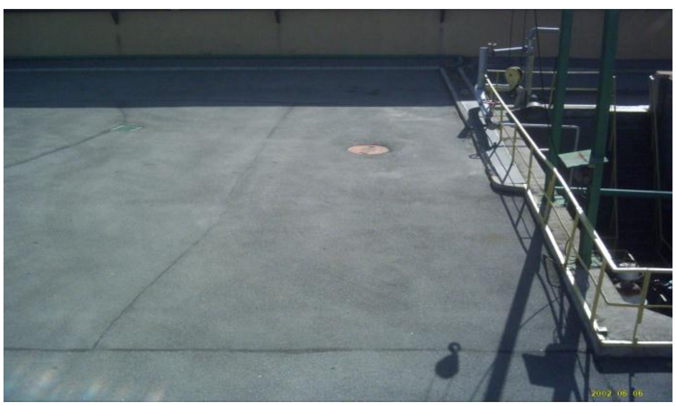

Photo2: Old flooring cracked in many places

Simultaneous impact of seeped chemical solutions in soil and electrolytic effect of static electricity from steel poles has led to suffusion of the first layer beneath the ground. Dangerous water drainage went to the nearby river. Deformation modulus of the ground under the road has decreased in average of 70 MPa to about 6 MPa.

Recently, the site was coated with asphalt and shaft covers of the canals were painted in different colors according to the flow diagram of the facilities to which they belong (Photo 3).

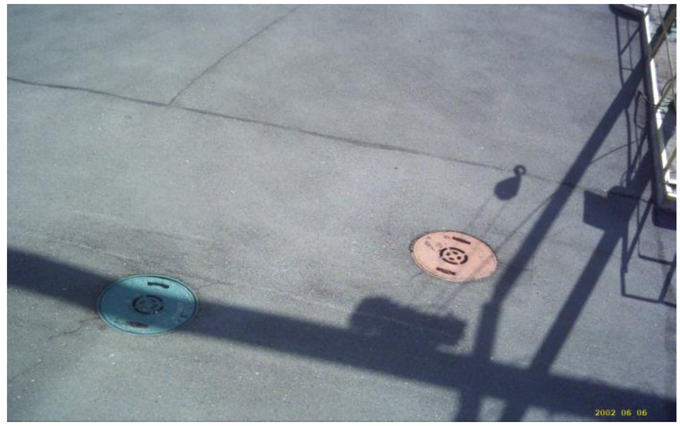

Photo 3: Channel with shaft covers, painted in different colors

The technical state of Water Treatment Plant's facilities is good after a fresh hydro-insulation. Caverns that are buried in gravel and covered with pavement were detected at two places below the surface. The first such area is the one in the southeast corner of section Y-II under the concrete pavement where we can feel a gap while knocking and the visible surface is cracked and collapsed. Electric poles for high voltage are two and yet no visible deviation from the vertical position is noticed.

III. RESEARCH METHODOLOGY

The methodology selected to study the site is not possible to destroy the repaired new smooth asphalt and is not allowing the detection of randomly located under the ground hollow areas.

After inspection of the site, consecutive series of geophysical surveys were executed. First site was studied with geo-radar. Afterwards, a plan with contours of the in gasket zones was prepared for the site (Fig. 4).

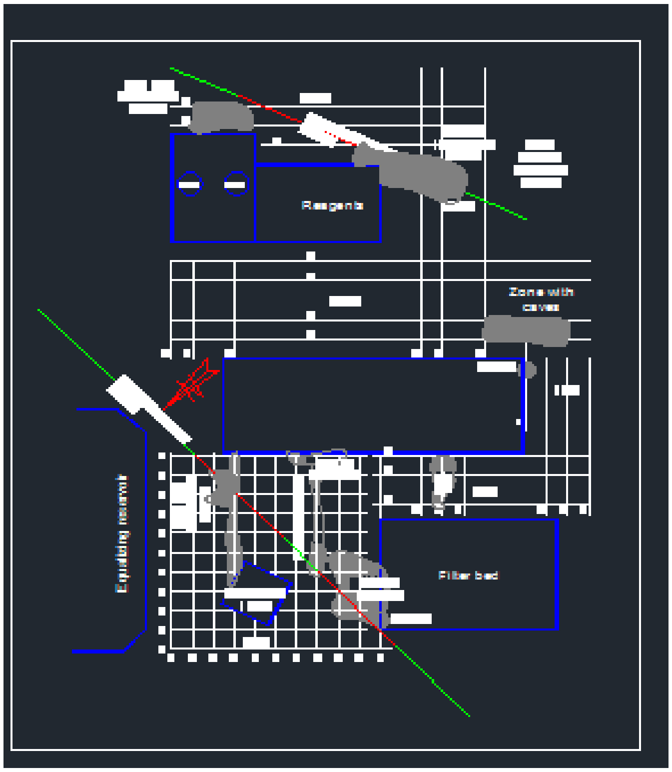

Fig.4: Problematic zones draught

According to the results of the geo-radar survey and due electro-tomography method abilities, two profiles of the problem zones were also created. (Fig. 5 and Fig. 6). The depth of the studied area was 6m.

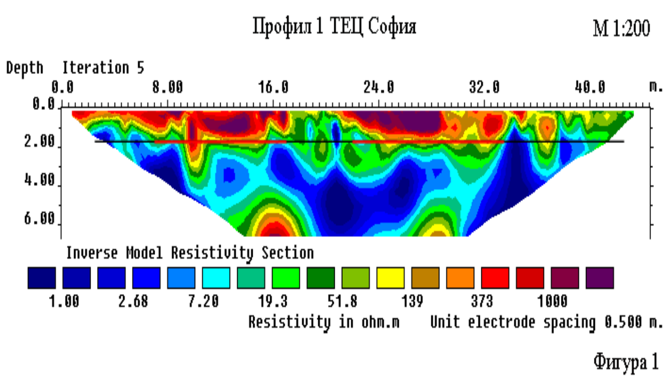

Fig. 5: Electro-tomographical profile 1

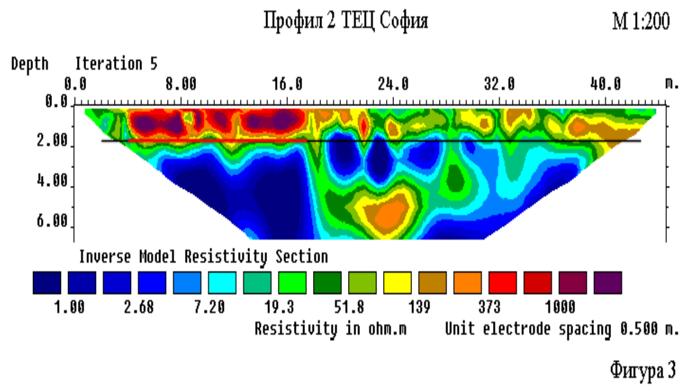

Fig. 6: Electro-tomographical profile No. 2

The plans for underground connections, like canals and aqueducts were compared with the survey results about the problematic zones and both were taken into consideration.

The third phase of the instrumental field studies consisted of 12 short drillings deep 2m to 3m each, for direct identification of the nature and parameters of hollow areas under pavement. Samples taken from the ground were analyzed in a laboratory.

A brief historical overview of the construction and reconstruction of underground installations and facilities was carried on due to interviews with employees of the entire Thermal Power Plant.

Together with the technical staff of the plant we have defined hazards in any new equipment failures.

IV. RESULTS FROM STUDIES

Due to its location - on the right bank of a small river, the ground is dust swelling clay on layers of sand and silt. Under the site, there is a dense network of pipes, cables and ducts of various installations and there isn't accurate information about their entire disposition.

A comparison of hypotheses and analyses' conclusions show very interesting composition of a number of diverse factors influences, i.e geological structure, and depression curve, chemical aggression of water, electrostatic catalysis and corrosion of steel pipelines, suffusion and/or other.

The findings of the preliminary geo-radar study, and namely the one about the zones with decreased density in the ground, which are also unevenly situated, are confirmed in more details by the electrotomographic profiles (Fig. 5 and 6). They naturally lie down below the studied pavement and reach a depth of about 2m.

These zones are caverns and probably a result from both geology (silt and inconsistent water level in hydraulic gradient adjacent to the river) and chemical aggression occurring in the wastewaters composition of acids and bases. This water, most probably, has penetrated the site from the tanks surrounding the plant. Obviously, a layer of silt lies under the surface, and it is very thin, very sensitive to water and responsible for the surface subsidence. As an additional factor for the reduced density we can point out the suffusion caused by the hydraulic gradient at high underground water level adjacent to the river that naturally drains the shore.

The gaps from the round openings of the tubes, which are located at a depth of 5-6 m. are visible on electro-tomographic profiles (Fig. 5 and 6). These low-lying holes have no influence on the reported falls.

The analysis of the electro-tomographic profiles and georadar study (Fig. 4) shows ane and the same results and gives a more accurate picture of the shape, location and extent of the density of problem areas.

Further to these analyses, all of the most typical places with lower density at the site were tested with exploratory drilling, deep 2m. It was found (Fig. 7), that under the pavement there are saturated plastic clay and silt in a liquid consistency with a capacity of approximately 130cm. The layer is located at a level of approximately 70cm to 200cm below the ground. Another powerful layer of plastic clay is available beneath the low silt at a depth of 2m - moist, in plastic consistency, relatively homogeneous, with normal density zones, which reaches a depth of more than 6m.

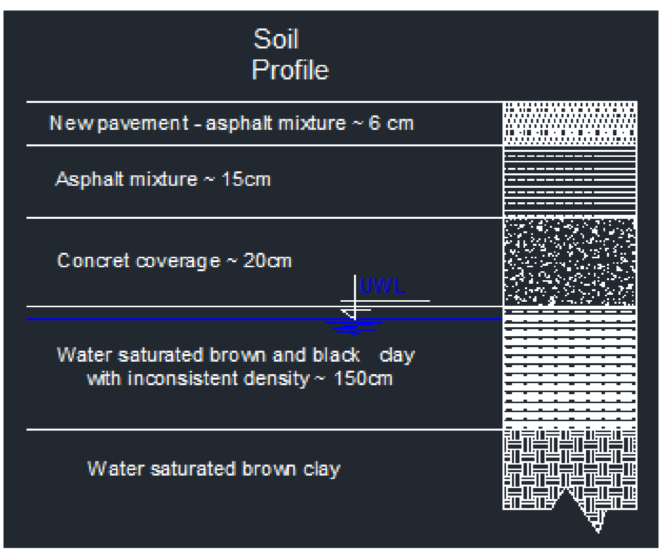

Fig. 7: Profile of ground foundation

In general, the platform is built on weak soil of plastic clay and silt, which is a prerequisite for the accidents. Looking at (Fig. 8), we can make an assumption that the position of the site falling in zones with lower density below the surface. It is almost the one outlined by the georadar.

The interviews with staff of the plant clarify that hydro isolations of pools and tanks with active chemicals were recently replaced, because people have been noticing significant fluid leakages through the cracks at the construction fringes. It became clear to all, that chemical aggression has catalyzed the process of internal land erosion around the tank and resulted in an increase of walls and flooring deformations. Proof of the above are the cavities (fig. 4) with a volume of about 1m3 in two places just below the surface of the ground - at the intersection of axis 99 with pins 94 and 95 and at the intersection of axle 90 with pins 91 and 92.

Another important factor for catalysis of internal erosion and possible breakthroughs in steel pipe is the movement of static electricity from the grounding of both steel ladder for high voltage in the middle of the site. Geodetic measuring show that the pillars were not tilted or collapsing by that particular moment in time.

V. MEASURES TO STRENGTHEN THE GROUND

Strengthening and restoration works were designed to impair the surface of the asphalt pavement and the current state of construction equipment to a minimum. A number of cables and pipelines, which should not be affected, are lying under the flooring. Therefore, the idea of current pavement demolishing and weak layer replacement was out of question.

According to the survey results, it was suggested to do an application program for injecting of cement grout into caverns and problem zones with lower density.

The aim was to stop further development of these adverse processes. This injection grout was compacting mud, draining water from the pores of the soil and increasing the bearing capacity of the ground several times., The injection pressure from a technological point of view is low - under 1atm., in order to avoid lifting (swelling) of the surface. Control of the deformation was done by the work operators, who were adjusting pumping with every visible surface bulging. A schematic diagram of the above amplifying injection drillings is shown at Fig. 8.

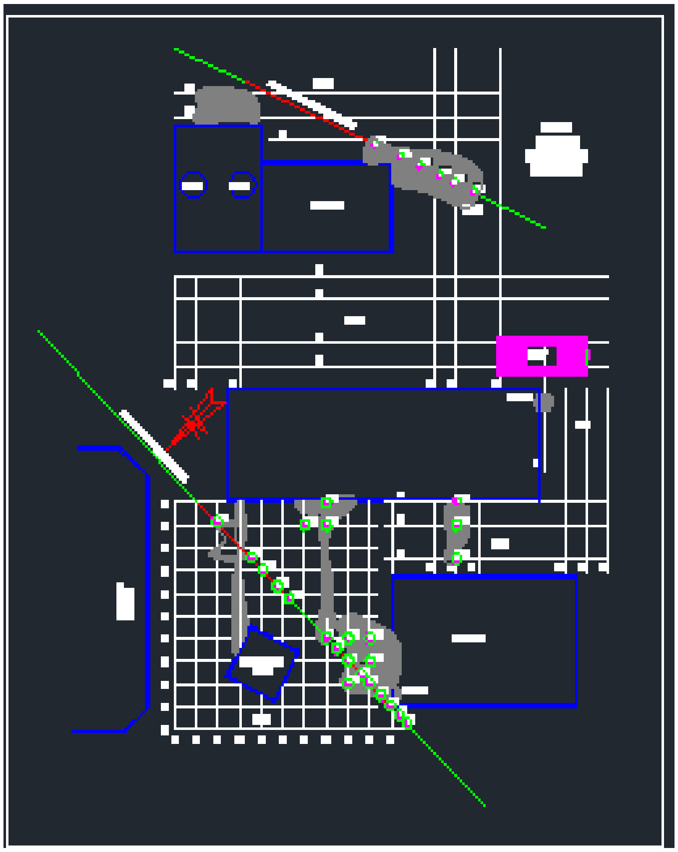

Fig. 8: The application plan of the injection drillings

Drilling mouths were closed with cut kernels from the surface after the completeness of applications and thus restored the smooth surface of the ground. The later strengthened the surface beneath the foundation of facilities in danger.

Measurements "in situ" with dynamic penetrometer (SPT) to control the healthy parts of the ground and those with reduced density were also performed in the site. Measurements were carried out both before and after the injections. The comparison of results showed that the effect was achieved within required parameters. The initial mean values of deformation modulus of weak ground base were about 6 MPa and those of the healthy ones - about 65 to 70 MPa. Mean deformation modules on the ground under the road structure are shown in Table 1 bellow.

Injection pressure was about 2 ATM and so the injected solution got very well infiltrated into the soil, and sharp boundaries between areas with contrasting density were not evident. The values of the deformation modules of healthy and injected sectors got relatively close - from 70 MPA to 80 MPA. The values scattering measured for the different sectors remained within 12%.

Researched Sector	Deformation modul E0
Healthy Ground	68,2 MPA
Ground with low density	6.1 MPA
Injected Ground	79.8 MPA

Table 1: Results of SPT measurements of mean deformation modules

VI. CONCLUSIONS

Caused surface deformation by weak and muddy land in a depth of 70 cm to 200 cm below the ground did not allow usage of traditional fortifying methods like seismic and drilling techniques.

The most rational solution for the above described problem was to inject weak areas with cement grout under controllable pressure. The injections stopped leaking of chemicals into the soil, caverns were filled in and stability of the site was restored. The plant performs its normal function, there is no risk to the sustainability of buildings and facilities.

The injecting method allowed us to keep the continuity of the plant working cycle, which was one of the most important condition to keep.

The modulus of deformation decreased to value under 80 MPA and so, which is comparable to that of a healthy soil base - 70 MPA.

The usage of the above-mentioned method gave us the opportunity to benefit from its short time of operation, accurate visual picture of the profile, tindependence of various confounding factors, and its relatively low cost. Therefore it is becoming more and more popular in Bulgaria - for a period of three years, cavities, faults and other anomalies in the ground of several old and prestigious public buildings have been eliminated through micropilot injections.

In addition, geo-physical studies through the electro-tomography method are constantly improving and becoming widely used in constructions and reconstructions of grounds in the urban environment, and not only for searching minerals and other.