MODERN TECHNOLOGIES OF SOIL IMPROVEMENT - CASE STUDY OF A MAJOR CONSTRUCTION PROJECT

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1. Introduction

These days investors that are planning the construction of a new industrial plant are primarily interested in good accessibility of the potential site on which the future construction will take place. The site, chosen for future investment, should be localized as close as possible to the buyers market or to transportation routes that will allow quick and cheap delivery of raw material for production and transport of ready goods produced in the factory. Industrial sites, assigned for production purposes, in regional master plans, are often localized in areas with relatively complex geology and ground conditions. Investors planning major enterprises, having found a well localized industrial site, are often forced to carry out their construction project on land having very complex ground and water conditions. Planning the construction of an industrial plant on such a site requires very detailed geotechnical investigation giving information on soil and ground water conditions. Results of geotechnical investigations presented in the form of a report or documentation are later on used as a basis for soil improvement projects and successful construction of future buildings.

In this paper authors present a case study of a large scale construction project at a site that has a very favorable location but relatively poor ground conditions.

2. Short description of the industrial plant.

The industrial plant that is currently constructed at the site is a paper mill. The buildings of the factory have 28 000 m² in footprint area. All buildings are one floor structures without basements. The production hall is constructed in steel structure and is covered (roof and side walls) with lightweight sheet panels. The warehouse and storage building is in steel structure, covered with the same lightweight panels. An office building of about 300 m² is attached to the production building. An area of approximately 25 000 m², around the factory buildings, is paved and designed for access roads and parking space. The production process in the paper mill producing paper of 15-30 grams per square meter is organized in the following stages:

- transport and storage of raw materials,
- preparation of paper pulp,
- production of paper in rolls on the paper machine,
- production of final products from the tissue lightweight paper,
- packing and transport of ready products to storage building,
- storage of ready products.

A footprint of the production buildings is shown on the general layout - figure 1.

3. General description of the site.

The site on which the paper mill plant is currently constructed is located in a special economic zone in the Western part of Poland. The site is easily accessible from major communication routes i.e. motorways and railroads. Geographically the economic zone is situated in close vicinity of the German border, and within a short distance of one of Poland's major seaports enabling easy and cheap sea transport to any destination in Europe and other continents. Other advantages of the industrial site, located within limits
Fig 1. Paper mill layout.

Fig 2. Typical geotechnical cross section.
Fig 3. Cross-section of soil treatment phases and underground foundation structures
1. Loose natural sandy soils
2. Improved layer of soil by vibro exchange and replacement methods.
3. A layer of 40 cm of cobble stones.
4. A layer of 60 cm of gravel.
5. Surface layers of floors, roads or parking areas.
6. Pad Footing under columns.
7. Diaphragm slurry walls.
9. Slab foundation of the paper machine.
10. Technological basement under the paper machine.

<table>
<thead>
<tr>
<th>Number of layer</th>
<th>Type of soil</th>
<th>State of soil</th>
<th>Cohesion $c_s$ [kPa]</th>
<th>Friction angle $\phi$ [°]</th>
<th>Odeometric modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>II C</td>
<td>fine, medium sand (Pd,Ps)</td>
<td>0.25, -</td>
<td>-</td>
<td>29.2</td>
<td>38000, 47500</td>
</tr>
<tr>
<td>II D</td>
<td>fine, sily sand (Pd,Pr)</td>
<td>0.40, -</td>
<td>-</td>
<td>30.0</td>
<td>52000, 65000</td>
</tr>
<tr>
<td>II G</td>
<td>medium, coarse sand (Ps,Pr)</td>
<td>0.25, -</td>
<td>-</td>
<td>31.5</td>
<td>62000, 68900</td>
</tr>
<tr>
<td>II H</td>
<td>medium sand (Ps)</td>
<td>0.40, -</td>
<td>-</td>
<td>32.2</td>
<td>80000, 88900</td>
</tr>
<tr>
<td>III A</td>
<td>silt, clayey silt ($\pi,Gr$)</td>
<td>- , 0.20</td>
<td>16.0</td>
<td>-</td>
<td>29500, 49200</td>
</tr>
<tr>
<td>III B</td>
<td>silt ($\pi$)</td>
<td>- , 0.30</td>
<td>13.0</td>
<td>-</td>
<td>23000, 38300</td>
</tr>
</tbody>
</table>

Fig 4. The basic physical and mechanical parameters of the main soil layers.
of the economical zone, are: availability of power and energy supply, water and sewage systems etc.

All the above stated advantages influenced the investors decision to locate his production plant in the economic zone. On the other hand the site that was chosen for construction of the production plant, is located on grounds that can be described to have relatively poor ground and water conditions. The site of approximately 100,500 m² is located about 1 km from the Odra River, on lowland area. The ground surface is approximately 12 to 14 m above sea level. The site which was formerly agriculture land had not been previously invested in.

The described area belongs to the Freienwald Valley (Oberbruch). The Freienwald Valley spreads mainly on the left bank of Odra River, on the territory of Germany, and boarders with Gorzowska Valley. This region is the largest mesoregion of the Torun-Eberswald Prevalley.

4. Soil and groundwater conditions.

Geotechnical investigation undertaken at the site were based on:

- in situ investigations i.e. 55 boreholes to the maximum depth of 20 m; dynamic sounding in 26 locations to the depth of 7 m; 10 trial pits to the depth of 2.5 m; sampling of undisturbed and disturbed soil samples from boreholes and trial pits; surveying measurements; installation of piezometers and water observation wells.
- laboratory testing: analysis of physical and mechanical soil parameters; chemical analysis of ground water and soil samples.

Location of boreholes is shown on the general layout on figure 1.

Results of geotechnical investigations enabled the description of local geology and existing soil and ground water conditions. A small fragment of a typical geotechnical cross-section is shown on figure 2. Undertaken investigations covered the Quarternary top deposits linked to the existence of the Torun-Eberswald Prevalley. In the vertical cross-section several levels of river accumulation can be observed depending on water flow in climatic changes that took place. The following geotechnical layers were recognized:

- I – man made ground and humus from ground surface to the maximum depth of 0.8 m,
- II – layers of Holocene river deposits formed in the river-bed facies. The deposits, investigated to the depth of 20 m³ were mainly sands of diversified granulation and density. Fine and medium sands are the dominating deposits, their index density was determined in the range of 0.15 to 0.50. Top sand layers were very loose with an index of density in the range of 0.15 to 0.25.
- III - layers of Holocene river deposits formed in flood water facies. The dominating deposits of these layers are: silt and clay. The index of liquidity of these soils is in the range of 0.20 to 0.30.

Basic physical and mechanical parameters of soil deposits found within the geotechnical layers are shown in table 1.

Ground water was present and observed in all 55 boreholes. The water was in the form of free surface and it stabilized at the depth of 1,0 to 1.5 m below ground surface. Chemical analysis of samples taken from several locations indicated that the water was not aggressive to basic building materials especially concrete.

5. Implemented soil improvement and foundation techniques.

Results of the geotechnical investigations carried out at the site clearly indicated that the soil and ground water conditions can be classified as difficult for construction of the paper mill plant. Successful construction and operation of the plant required implementation of several soil improvement treatments and special foundation solutions for the weighting 120 tons main paper machine. In order to enable the construction process and successful operation of the industrial plant the following actions were undertaken:

- A topsoil layer of humus and man-made soil of approximately 0.80 m was stripped and taken away from an area of 60,000 m².
• Uncovered layer of sandy soil was densified by several; passes of a 12 ton vibrating tamping roller.

• Vibroflotation and vibro exchange techniques to the depth of 8 m were implemented on an area of approximately 8,000 m². Improvement of loose soil layers by the vibro method was necessary for foundation of the paper machine. Loose sands with an index of density in the range of 0.15 to 0.25 was successfully densified to levels of 10 exceeding 0.70.

• Construction of concrete diaphragm slurry walls was required for proper foundation of the paper machine securing a 6 m deep technological basement under the machine.

• A layer of 40 cm of cobble stones was built in on the whole area of 60,000 m²; the stones were placed in 20 cm layers and densified by the 12 ton vibrating tamping roller.

• On top of the cobble stones a 60 cm layer of gravel was constructed. The gravel was placed in 20-30 cm layers and densified to the Proctor density index exceeding 0.98%. (98%).

• Construction of footings for the production, storage and administration buildings.

• Construction of a slab raft foundation, integrated with the concrete slurry walls, for the paper machine.

• Construction of reinforced concrete floors in factory buildings and construction of surface layers of roads and parking areas.

Diagram 3 shows a schematic picture of the soil treatment techniques which were applied, and allowed for the successful construction of the paper mill factory.

6. Conclusions

The example of soil improvement and treatment methods described in this paper is one of many projects that were undertaken in Poland within the last few years. This particular case, in which the authors of the paper were engaged, is particularly interesting because of the large scale of the project. Scarcity of industrial lands, that have a location acceptable to investors, will definitely have an significant impact on the development and application of many modern foundation and soil improvement techniques.

References