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THE NECESSITY OF USING THE EXHAUSTION SYSTEMS IN ORDER TO REALIZE CONSTRUCTIONS IN LANDS WITH HIGH LEVEL OF GROUNDWATER

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Abstract: Exhaust system successfully implemented for the ISHO Living project in Timisoara (a residential complex on Bega's shore where the tallest building in Timisoara is being built, with 20 floors, and the groundwater level is high). In order to evacuate the site water, so that the land on which the development of ISHO Living is being built to be a safe one with adequate working conditions, an exhaust system was implemented, designed and monitored. In the first phase, the project required a geotechnical study and a hydrogeological study. The hydrogeological study was performed with experimental pumps used to design a scheme from which to result foundations realized in dry areas. The geotechnical study was prepared in order to establish the stratification, the physical-mechanical characteristics of the land in the active area and the founding conditions for the block construction with the height regime of B + Gf + 20 F / B + Gf + 4F. The entire depletion plant (boreholes, pumps) has been dimensioned so that the groundwater is kept at least 30 cm below the digging quota in the foundation pit. In order to achieve the evacuation of groundwater, a number of 13 holes were dimensioned at a depth of 12 m, respectively 16 m.

Keywords: exhaustion system, groundwater, boreholes, pumps.

1. INTRODUCTION

Groundwaters can often be a major obstacle for construction projects. They prevent safe , efficient and cost-effective excavations in order to raise the building. Exhaustion is the process of lowering groundwaters level to allow digging under perfectly valid conditions, which means on dry land. These depletions can be considered as an integrated part of the construction work.

Exhaust drilling (also known as drying) means removing water from the soil in order to be able to carry out constructions with deep foundations. Thus, they appear where large excavations are occur and the groundwater level is high.

Geotechnical boreholes are tubed and used as pumping boreholes (monitoring). Through them, the radius of influence of each borehole and the direction of aquifer flow can be determined quite accurately. In the same time, the drying time can be estimated. They are usually executed perimetrically and the pumps entered are of high flow. It's important that they work without stopping. If after several days of pumping the groundwater level continues to drop very slow, it's necessary to replace the pumps with others that have higher flow rates. At the completion of the underground works, the boreholes must be cemented / closed / armored. [1]

1. What happens if an exhaustion system is designed and executed incorrectly?

- if the water level cannot be lowered to the desired level during the projected tie period, delays occur in the execution of the works, the budgets are exceeded, penalties for exceeding the execution schedule appear and lawsuits are filed in the court.
- may cause defective design or incorrect execution of depletion works, respectively exaggerated sizing of it.
- may cause explosion of the bottom of the excavated pit, in case of deep excavations, due to the water pressure in the lower aquifer. [2]
- land settlements may occur in the case of compressible land, as a result of the water drainage. The initial phase of the field study should contain both detailed geotechnical information and hydrogeological information. Execution of depletion systems based on insufficient data due to "limited budgets" can cause such problems, with the most serious repercussions on neighboring buildings.
- land subsidence may occur in the case of compressible lands, as a result of water evacuation.
- in rare cases, the water supplies in the area of the sites where exhaust systems are executed can suffer because some boreholes can be left without water. The same can happen with the vegetation of a neighboring park, if an exhaust system works for a too long period of time.

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2. What does an exhaustion project contain?

In order to develop a depletion project, the first phase is to realize a geotechnical study and a hydrogeological study.

2.1. What does a hydrogeological study contain?

A. General data:

-> name and location of the construction site; the name of the investor / beneficiary, the general designer and the specialist designer for hydrogeological study; the name and address of all the units participating in the hydrogeological research, specifying the category of work in which they were involved; technical datas provided by the beneficiary and / or designer regarding the envisaged construction systems.

B. Information about the land from the site:

-> general geological data; geomorphological, hydrographic and hydrogeological framework; data on seismic zoning; hydrogeological data; the history of the site and the current situation; conditions regarding the vicinity of the work (neighboring buildings, traffic, various networks, vegetation, dangerous chemicals, etc.); framing the objective in "Risk areas" (such as: earthquakes, landslides, floods); findings on water catchments existing in the area; the possibility of establishing the protection zones of the groundwater sources. [3]

C. Presents hydrogeological information

-> presents: the field works performed; the methods, tools and equipment used; the calendar data between which the field and laboratory works were performed; stratification highlighted; ground water level and character of the aquifer layer (with free level or under pressure); name of the authorized/accredited laboratory that performed the tests/analyzes of the soil and of the water in case of the boreholes research, with a copy of the laboratory authorization and the annex of the authorized/ accredited laboratory tests; reports on laboratory and field tests including test bulletins, charts, graphs and tables regarding the results of the experimental work; synthetic sheets for each drilling, comprising: description of the identified layers, synthetic results of geotechnical laboratory tests; bulletins or centralizers for chemical bulletins; situation plans with the location of the research works, maps with the geological, geophysical and hydrogeological particularities of the site; geological, geophysical, hydrogeological sections; table with experimental pumping data; other data resulting from the works undertaken.

D. Calculations of the data obtained

-> boreholes indication diagram based on stationary pumping data; calculations of the hydrogeological parameters for the aquifer layer: hydraulic conductivity, transmissivity, radius of influence, aquifer .The necessary steps in order to realize a geotechnical study are the following:

inspection of the site, obtaining the plans and the design theme, obtaining information about: the destination, the height regime of the future construction, the foundation type and dimensions, the pressure transmitted to the land (the beneficiary will necessarily transmit the site plan); if there are buildings thickness, aquifer type (with free level, under pressure or mixed);

In addition to the data mentioned above, an exhaustion project must also contain:

-> design of exhaustion works: boreholes, drainage, acicular filters; speed of water flow in the borehole, critical sanding rate, critical leveling, risk evaluation for hydrodynamic entrainment of the sands (suffusion, internal erosion, outcrops, hydraulic rupture and sand discharge, liquefaction); calculation of the boreholes number required and the optimum distance between them so that, by simultaneous pumping in the interference, lowering of the water level to arrive at the desired level; calculation of the depressure with acicular filters in case of poorly cohesive soils such as sandy dusts and fine dusty sands, with relatively low permeability, susceptible to hydrodynamic entrainment; positioning and equipping piezometers in the monitoring system; requirements regarding the pumping program; pumped water drainage solutions; duration of the exhaust system; program of monitoring the exhaustion system, before, during and after the exhaustion; measures to ensure the functioning of the exhaustion system in situations of major force (interrupting the supply of electricity, damage to components,etc.); work safety and security measures; decommissioning of exhaustion works; the floor planer; list of technical regulations and standards used in drawing up the project. [4]

2.2 What does a geotechnical study contain?

The purpose of the geotechnical investigation is to provide the information necessary for an adequate and economical design of the construction works, specifying the following elements:

-> the succession of the geological layers that make up the foundation ground and their physical-mechanical parameters within the active area of the foundations; signaling some special conditions of the site or of the difficult grounds to establish; hydrogeological conditions, establishing the seismicity parameters and the freezing depth of the investigated area; establishing the geotechnical category of the work; recommendations regarding the design and execution of the building, conditioned by the characteristics of the foundation land.

If a geotechnical study is required, the client will have to specify the following information:

-> a footprint of the construction floor; the surface of the land on which the construction will be located; the inclination of the land; the proximity of the water field (lake, brook, river); common walls with existing buildings; the height regime of the building (basement, ground floor and the number of floors); geographical location where the construion will be built.[5] .Documents required to issue a geotechnical study:

-> acts of property, urbanism certificate, area layout plan, technical brief of architecture (if it's possible).[6]

o already built , their foundations must be studied.

o based on archive data, geological maps, dimensions and building importance class, the work program will be established and the appropriate research equipment will be chosen;

o the execution phase of the field works will be next, that will include the actual research: mapping the area, drilling, penetration surveys, ditches, seismic datas, topometric measurements, pumping in boreholes and other tests in situ, as needed;

o the samples taken will be transported and analyzed in the specialized geotechnical laboratory, MLPTL certified;

o after that, we have to interpret the data from the field and from the laboratory, in order to elaborate the geotechnical study with conclusions;

o the geotechnical study must be verified and approved at the A.f. requirement (strength and stability of the foundation ground of constructions and earth massifs) by a certified verifier;

o and finally, handing over the technical documentation to the beneficiary.

Geotechnical study categories:

-> Preliminary geotechnical study (PGS), Geotechnical study (GS), Detailed geotechnical study (DGS)

2. CASE STUDY

Exhaust system was successfully implemented for the ISHO Living project in Timisoara

(a residential complex on Bega's shore where the tallest building in Timisoara is being built, with 20 floors, and where the groundwater level is high)

In order to evacuate the site water, so that the land on which the development of ISHO Living is being built to be a safe one with adequate working conditions, an exhaust system was implemented, designed and monitored. In the first phase, the project required a geotechnical study and a hydrogeological study.

3.1.The hydrogeological study

The hydrogeological study (shown in the figure below: Figure 1) was performed with experimental pumps used to design a scheme from which to result foundations realized in soils without water.

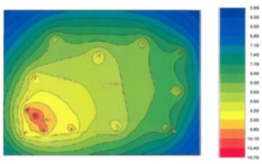

Figure 1. Hydrogeological study

To interpret the pumping and to recovery the dates, standard methods specific to the hydrogeological conditions identified in the enclosure area were used. In general, it was found that pumping boreholes have a lower efficiency, which generated piezometric jumps with different values. This situation can substantially change the values calculated for the hydrogeological parameters, so that the values resulting from the interpretation of the data from the observation boreholes or from the recovery periods were preferred.

3.1.a. Hydrostructure characteristics

In the area of the investigated site, 13 lithological units with different hydrogeological features have been identified as follows [7]:

o superior aquitard (leaky-acvifer), constituted of fillings, sands intercalations, clays, dusty clays, sandy clays, clay dust with thicknesses of 6-10 m.

o upper aquifer, formed of two aquifer horizons with cumulative thicknesses of 12 - 14 m, constitued of sands with vertical grano-classification and which have elements of gravel at the bottom and fine sand or clay sand at the top. The two aquifer horizons are separated by an intercalation of generally sandy clays with thicknesses of 2 - 4 m. The total thickness of the package of aquifer horizons and clay intercalations is about 16 m.

o aquitard, constituted of dusty clays, volcanic plastic clays, sandy clays with thin intercalations of clay sand; the thickness of this aquitard is about 6 m.

o lower aquifer with ascensional character, formed by 2-3 aquifer horizons with cumulative thickness of 7–10 m. The predominant particle size fractions are of medium-coarse sand. The lower part of this aquifer is represented by a fine horizon (sandy clay or clayey sand). Between the aquifer horizons there are intercalations of sandy clays with thicknesses of 4.7-5.5 m each. The total thickness of this package that includes aquifer horizons and clay intercalations is about 13-15 m. At the base of the lower aquifer, a layer of clay on thicknesses of 3.5-5.0 m was identified.

=> The boreholes has stopped at a depth of 50 m.

3.1.b. Hydrodynamic testing

For the hydrogeological investigation of the site, a group of 4 boreholes was executed. All the drillings have opened only the upper aquifer, considering that the lower aquifer doesn't significantly influence the buildings construction.

3.1.c. Hydrogeological parameters

The hydrogeological parameters were determined by interpreting the data resulting from three sets of experimental pumps. The average values obtained for transmissivity (T), hydraulic conductivity (k) and storage coefficient (S) are:

T = 368 m2 / day, K = 38 m / day, S = 0.0092;

*3.1.d.*Drainage schemes

In order to realize the hydrogeological protection of the excavations necessary to realize the constructions designed on the site, a network of 13 holes was elaborated for the drainage scheme of the aquifer. The drills will operate in interference with flow rates of 5 l / sec and will achieve the leveling required after 1-2 days of operation. Depending on the drying stage, between 4 and 7 boreholes will operate simultaneously, the volume of water discharged daily being between 1 700 - 3 000 m3.

Due to the presence of the Bega river in the southern part of the site, the stationary regime is reached quickly, 1-2 days after the beginning of the pumping.

*3.1.e.*Recommendations

The drainage of the hydrostructure from the investigated area implies the creation of a complex drainage system whose efficiency depends on:

efficiency of drainage works (drilling) and monitoring the evolution of the surface.

3.1.e.1. Efficiency of drainage works

The hydrodynamic efficiency of the drainage works (drilling) affects the costs of the drainage process (number of drilling, energy consumption, duration of drainage, etc.).

The implementation of drainage drilling with low hydrodynamic efficiency results in high costs and difficulties in reaching the target (lowering the level to the projected quotas).

All boreholes must be dug to depths of 20-22 m. Boreholes executed in a dry system will have a tubing / filter diameter of at least 140 mm and will be equipped with filters from 3 m depth to the final depth. The working rate of a drill will be 5 l / s.

3.1.e.2 Monitoring the piezometric surface

The morphology evolution of the piezometric surface of the aquifer allows the real-time calculation and signaling the danger of increasing the peizometric level at unacceptable levels in case of improper functioning of the drainage system (interruptions of the electricity supply, deterioration of the submersible pumps, etc.).

Monitoring the morphology of the piezometric surface of the drained aquifer is necessary throughout the execution of the works.

In order to monitor the piezometric level inside of the enclosures which will be dried, the hydrogeological drilling carried out during the in situ pumping tests can be used.

3.2. The geotechnical study

The geotechnical study was prepared in order to establish the stratification, the physical-mechanical characteristics of the land in the active area and the founding conditions for the block construction with the height regime of B + Gf + 20 F / B + Gf + 4F. The research program indicated by the beneficiary aimed at covering the entire site and included specific works for:

○ identification of the stratigraphic sequence

○ determination of the physical-mechanical characteristics of the foundation land in the section of the active area

○ specifying the position of the hydrostatic level

○ establishing the conditions for the design and execution of foundation works on the proposed area.

The establishment of the geotechnical category in which the work is framed was made taking into account the indications of the normative NP 074-2014.[8]

Table 1. Establishment the geotechnical category

Factors taken into consideration	Framing	Points
Land conditions	Medium plots	3
Groundwater	Normal exhaustion	2
The importance category of the building	Normal	3
Vicinity	Risks free	1
Seismic zone	a_g = 0,20 g; T_c = 0,7 s	2
Geotechnical Risk	Moderate	11

⇨ From the table presented above results the classification of the work in geotechnical category 2 - moderate geotechnical risk.

During the research for the geotechnical study, the geological map of the area was also taken into account.

Considering the purpose for which the geotechnical study was elaborated, the following were considered as necessary:

-> 4 geotechnical boreholes with depths between 20-50 m; 4 hydrological boreholes with depths between 10-25 m; 6 dynamic penetration tests with 20 m deep cone.

Note: The depletion project was prepared based on the information taken from the geotechnical study mentioned above. Subsequently, a detailed geotechnical study was elaborated that was used to realize the infrastructure projects - foundations: to dimension the slab foundation and the pilots.

3.3. Exhaustions

The company employed to do the work was required to compile an adequate depletion plan to facilitate the construction of 2 blocks (B+Gf+20F, respectively B+Gf+6F) in the vicinity of Bega River.

The groundwater existent on the site was evacuated with 13 holes (see figure 2), which led to the decrease of the groundwater aquifer. There were no precautions in the execution of the exhaustion because no buildings are in the immediate vicinity.

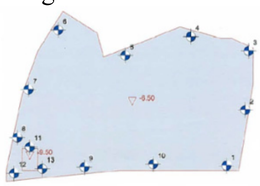

Figure 2. Water drainage plan

Soil erosion may occur if the depletion process is not performed correctly, resulting in a number of problems. Of course, protecting the work area should be on the list of priorities of each intervention team, as well as ensuring maximum safety of the place.

Construction projects are often planned in advance and any small delay can drastically change the initial plans. An experienced company knows how to properly plan and execute a depletion work so that the works from the site to be realized in optimal conditions.

In the case of the ISHO Living project, the boreholes were made with 300 mm diameter pipe. Initially, according to the project, 10 boreholes up to the depth of 12 m were provided. For safety, the groundwater level being high, but also taking into account the vicinity of the Bega River, the beneficiary requested the supplementation with another 3 boreholes of the same diameter, but up to a depth of 16 m. These were equipped in the configuration provided by the designer, respectively with pumps up to 5.5 kW. Each borehole was equipped with lower and upper level sensors to maintain water at optimum depth for excavation. An automatic alarm system has also been provided which will notify by GPRS call any failure of a pump or interruption of the power supply.

The entire depletion plant (boreholes, pumps) has been dimensioned so that the groundwater is kept at least 30 cm below the digging quota in the foundation pit.

Technical data:

-> depth of groundwater: 4 m; depth of the aquarium: 17 m; water level removed: 13 m; execution time of the exhaust system: 14 days; the date on which the spillage started was: 01.01.2018.

The discharge of 309,924 m3 / day water resulting out of the exhaust system from the site organization was made in the sewer geysers located on Splaiul Protopop Meletie Draghici street.

3.4 Monitoring and exploitation of exhaustion procedure

3.4.1. The equipment used drilling equipment

The drills were mechanically executed and dried with a 700 mm pipe operated by a Bauer hydraulic system mounted in front of the drilling machine. The excavation were performed on the inside of the metal pipe with the help of cable operated grabs.The filter column, respectively the “blind” had a diameter of 300 mm and a slot size of 0.75 mm. The filtration sand placed in the area of the filters had 1.2 - 2.8 mm. At each borehole, a borehole sheet was drawn up in accordance with the soil lithology. It was also mentioned the description of the equipment used from the point of view of the piping.

The borehole equipment was made according to the project, but also based on the discussions with the designer regarding the lithology of each individual drilling.

Figure 3. Pumps installation and commissioning

After the desanding of the boreholes and the test pumping, the solid flow for each borehole was determined using a real-time measuring device.

The solid flow determination of the pumped water from the borehole was performed as follows:

o After the drilling was completed and the installation columns was laid, the desanding of the borehole start with the help of a dirty water pump (it absorb coarse material up to 10 mm in diameter).

o After the sand removal, each borehole was individually checked to ensure that the quality of the extracted water was met. The quality condition of the drilling was that the maximum content of solid flow in the extracted water to be 0.01 g / l.

Figure 4. Dirty water pump

The equipment was provided with a filter on the middle side and a vessel with a capacity of 1 liter, which retains the materials with a very small granularity during the pumping.

Figure 5. Sand particle retention filter

Figure 6. Flowmeter with the maximum accuracy of 0.0001m^3

The time required to filter 1,00 m3 was approximately 2h. After this step, the entire amount of water inside the vessel was transferred to a standard cone and left until the sand granules were sedimented at its base.

Figure 7. Sedimentation benchmark of fine particles from the extracted water

Figure 8. Sedimentation cone-Value 1.00 ml.-1.80 gr

After particles sedimentation, the value from the graduated cone in ml of sand / m3 was read and turned into gr. of sand / m3.The result obtained in the image above is 1.8 gr./m3 <10 g / m3.

After obtaining the maximum permissible solid flow rate, the pumps were installed for the long-term pumping of the borehole.

The electrical pump connection system was composed of a main panel from which individual cables have left for each secondary panel in which the pumps were connected. In a secondary panel were connected 4 or 5 pumps, each having its own safety and thermal switch. The electrical connection system was designed so that the failure of one pump to don't affect the operation of the other pumps from the exhaust system.

All the boreholes drills, through the electrical panels, were connected to an alarm system that automatically triggers in case that a pump has failed. The alarm system would emit through GPRS a call to 2 phone numbers announcing the location of the site and in which electrical panel a pump has stoped working.

Figure 9. Small panel with alarm system and two secondary electrical panels

3.4.2 How to monitor and control

The boreholes tracking was realized by measuring / reading the following parameters:

- the hydrostatic level in piezometeres was determined using the freatimeter;
- the hydrodynamic level in each borehole was determined using the freatimeter;
- the solid flow was verificate with the installation mounted on the discharge pipe;
- was checked the position of the collecting pipes regarding the joints and the positioning;
- was checked the cables position and the electrical panels in order to avoid certain dangers as: accidental cutting, breaking.

After verification, according to the hydrostatic level in piezometers, respectively the hydrodynamic one in the boreholes, the debits from the boreholes were modified so we can maintain an optimum level recommended by the planner.

3.4.3 The staff responsible and the procedure in the event of damage

For the possible damage during the pumping periods, was designated a person who can intervene to remedy the problems. Through the GPRS alarm, the system signals not only the failure of a pump, but also the interruption of the power supply from the city network (in this case, it will be switched to the backup generator that will automatically start).

The operation of the system is relatively simple:

- If the pump stops for some reason, the alarm system will makes a call with a pre-recorded voice message to the 24/7 service phone and to the company manager's phone.

- In the pre-recorded message is specified the name of the site and the number of the electrical panel in which the problem occurred.

3. CONCLUSION

For the ISHO Living project, regarding the lowering of the groundwater on the footprint of the buildings that are being built, a number of 13 boreholes were dimensioned at a depth of 12.00, respectively 16.00 m. Given the location and the succession of the works in the immediate vicinity of the two buildings of 6 and 20 floors, a possible solution was taken into consideration regarding sealing and keeping in optimum conditions of the boreholes that were not affected during the excavations, in order to dimension a new exhaust system that will serve to the rest of the buildings from the site. Drills that will be used later will have to reach pumping rates similar to the initial ones in order to be considered in a subsequent calculation.

As the developed residential complex is located on Bega's shore, the groundwater level is high. To stop the groundwaters in order to complete the foundations of the buildings, exhaustion systems were used successfully. The depletions are functional and currently because the infrastructure works have not been completed. [9]

Figure 10. Photos during the boreholes installation

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