Systems to Protect and Improve the Behavior of Buildings Located In Macroporous Lands Susceptible to Wetting

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Abstract – Macroporous lands sensitive to wetting represent a category of sites with high vulnerability during construction exploitation. In this regard an effective measure is the protective shielding measures against the main factors influencing its behavior. The paper deals with a complex case study by both its importance functions and the fact that the objective analyzed is a part of historical monuments of particular value to the local community, namely the water tower in Braila Public Garden - România.

Keywords – *land porous sand lenses, monument, site protection.*

1. INTRODUCTION

The paper presents results of documentation research, studies and in situ research carried out by the authors (coordinated by university professor Ana Maria Grănescu as project coordinator) of the constituent materials and intervention techniques best suited for a water castle of patrimony value in the east of Romania. The paper focuses on the foundation soil and solution adopted for the building in order to modify its current function and to change it into an astronomical observer, increasing the life service of it and integrate it to the community again, transforming it into a building with utility for the society meanwhile preserving its technical value and beautiful architecture.

Water Castle in Brăila Public Garden is a building that is distinguished by a special elegance, both in architectural terms, and in terms of structural concept for which was declared a historic monument of local interest. The site is part of the category of those with a high degree of land vulnerability, being macroporic sensitive to moisture.

Built in 1912, the water castle is a very valuable construction and it represents a remarkable achievement of time, a symbolic construction. As stated in the documents consulted by the experts and authors, at the time of its creation, the Water Castle in the Braila Public Garden was the most modern water castle in Romania. The construction was made by remarkable personalities of the time: eng. Elie Radu, arch. Petru Antonescu, eng. Constantin Mironescu, eng. Germani, important representatives of science, who marked significantly through the objectives achieved at that time.

Based on these arguments, the local community wanted to re-function it as an attraction for the whole community, spaces for exhibiting museum objects, objects aimed at the history of Braila, the history of technology in the Lower Danube area, and the creation

of an astronomical observatory for the public. Braila. The exhibits are an expressive history of Brăila technique and science so that the visitor has the opportunity to inform and document in this regard. At the upper level of the castle it is proposed to use the existing spaces by the people of Brăila as spaces for astronomical observations.

The main argument of the observatory together with the spaces for exhibits was generated by the interest of the inhabitants of Brăila, of the tourists, to arrange such an objective with educational, informative but also agreement character. As it is known, the city of Brăila is located in the southeast of Romania, and is located in an area where we have the most serene nights in Romania.

The site is a macroporous soil sensitive to moisture that over time has been flooded by the exfiltration of water pipes.

The objective of the paper was to study this foundation and propose a solution for the situation encountered. From the field studies and the investigated bibliographic materials, it was possible to propose solutions to consolidate the foundation infrastructure to achieve the objective.

2. DESCRIPTION OF THE STATE OF PLAY OF STRUCTURE

The water castle (declared a historical monument) in the Public Garden - Brăila [1] was built in 1912, the resistance structure consisting of a general reinforced concrete screed 28m in diameter and 1.0 m thick and reinforced concrete pillars arranged perimeter (4 circles with a diameter of about 26m, 19m, 10m and 4.3m), in collaboration with reinforced concrete diaphragms. The castle tower initially comprised 6 high levels, the upper level at the dome being + 30.8 m, respectively 5 reinforced concrete floors.

Initially, the reinforced concrete screed was chosen so that the pressure on the soil does not exceed 0.9 kg / cm^2 (foundation elevation -6.1 m, and CT = -1.10 m). Over time, the strength structure underwent changes (additions), so that the total weight increased in several stages. Details on the evolution of the resistance structure of the castle, as well as intervention measures, are given in [1].

Among the modifications (additions) must be mentioned:

- extension of the basement on the entire surface of slab;
- extension of the ground floor, including the construction of two towers with access stairs and elevators;
- making additional floors between the existing ones;
- the ground filling in the basement, on a thickness of 1.4 m, the filling which is currently strongly moistened;
- execution in 1980 of some bunkers between axes 8 and 10, as solid fuel depots.

It is estimated that the current load on the screed sole is approx. 130 kPa; an exact calculation must be made after the detailed evaluation of the construction loads, within the resistance project.

It is observed that the location is located in the eastern part of the central area of Brăila, being delimited by Public Garden street, by Scaffolding street and the ridge of the slope whose slope descends towards the port and respectively towards the Danube river; the water castle is approx. 100 m from the ridge of the slope and at approx. 450 m from the Danube.

The elevation of the land on the site is 24.3 m NMR, through it middle passing the isofreamed curve (points having the same depth of groundwater) of 12.0m, as well as the

hydro-hypso curve (equal elevation of groundwater) also of + 12.0m [4]. The groundwater flow takes place towards the ridge of the slope and towards the Danube, respectively.

It should be noted that the average multiannual level of the Danube is + 3.68 m NMR, the maximum historical level measured being + 6.95 m (probably during floods). Based on the hydro-hypso curves [4], it is observed that the first groundwater level has convergent flow directions towards the circle delimited by the intersection of General E. Grigorescu street with Stefan cel Mare, Rahova and Plevna streets. The explanation of this phenomenon results from the analysis of section A-A respectively:

- the land in the central area of Brăila consists of 1-2 m of inhomogeneous soil filling, followed by 2-9 m of "dry" loess, sensitive to moisture and then of 1-2 m of moist loess;
- further develops 1-5 m of saturated loess (clay dust), under which appears the sandy horizon (generally dusty sand) in thickness of 17-20 m;
- inside this sandy horizon, on 1-6 m thickness, an intermediate clay (dusty clay) appears, but with an important interruption (almost 1 km) in the area mentioned before. In the area of this interruption, the first hydrostatic level flows preferentially to the second level (which has a lower piezometric level than the first) and from here to the Danube, which it feeds through the bottom of the riverbed;
- below the sandy horizon is the impermeable clay horizon (as the base layer of the area), which develops up to 30-40 m and even above.

Following the analysis of the piezomatic curves for the years 1964 - 2011 (from the profile taken through the Danube cliff near the A.I.Cuza street, it is observed that, contrary to expectations, the level in 1964 is 1-3 m higher than in 2011, resulting in the level piezometric of groundwater, at least in the vicinity of the cliff, is dependent on water fluctuations in the Danube.

3. INVESTIGATION RESULTS ON SITE

The stratification of the land was highlighted by geotechnical studies resulting in the following structure:

- 0.0 - 1.5 (2.4) m - wet clay soil filling, with brick fragments;
- 1,5 (2,4) - 11,2 (11,4) m - dusty yellow loess, sensitive to moisture ($i_{m3} = 9 \dots 3 \text{ cm / m}$), vigorous - hard, consistent in base (moist loess = dust clay);
- 11.2 (11.4) - 20.0 (20.2) m - medium dense sandy dust; the groundwater level is at the top of this layer (approx. 11.2... 12.0 m depth., depending on the season and the water level in the Danube);
- 20.0 (20.2) - 26.0 (27.0) - dusty, muddy clay; it separates the upper groundwater from the lower groundwater horizon (the latter is under pressure);
- 26.0 (27.0) - 30.0 (31.0) m - dense sand, in which the lower groundwater horizon is under pressure and which rises piezometrically up to 17-18 m depth from the land surface; this groundwater horizon feeds the Danube through the bottom of the riverbed;
- 30.0 (31.0) - over 40.0 m - waterproof clay horizon.

Under the conditions of "dry" loess, it has an allowable pressure of over 250 kPa; under saturated conditions the design pressure is reduced to approx. 125-130 kPa; as a result, it was necessary to take all measures so that the current groundwater level does not rise and moisten the loess located on the active area of the water castle screed.

The water castle in the Brăila Public Garden has withstood well over time, at least in terms of the foundation land. As it is known, in conditions of low humidity, loess is a good foundation. In wetting conditions it becomes a compact ground, and at a degree of saturation $S_r > 80\% = 0.80$ m when the loess is considered practically saturated, its structure can give way suddenly (the cementation between the particles gives way). The critical humidity (the one above which the settlements start to increase sharply) for the loess of Galați and Brăila is approx. 17.5%.

At the date of the refurbishment proposal, the loess under the castle raft had a degree of saturation $S_r = 0.46 \dots 0.65$, and if the humidity increases to 17.5%, the degree of saturation could become $S_r \approx 70\%$, which could had the effect of accentuating the settlements. It turns out that all the measures were aimed at preventing the increase of humidity in the ground (loess) under the screed [3].

The solution adopted was to make a sealing screen around the Castle and a loess pillow compacted over the pilots' heads, thus protecting the foundation ground against infiltration waters [1].

However, during periods of flooding, when the level of the Danube can increase by 2-3m, as well as over time due to losses from underground networks, it is possible that the loess will be moistened from the bottom up. For this reason, 2 wells have been provided equipped with pumps with sensors, which should start only in case of need, ie when the water level is at -12.50 m the pump starts; when the water level drops to -13.5 m it stops [2].

The sealing screen was made of perforated drill piles of simple concrete, sealed in a mixture with hydrated bentonite mud. The secant pilots were provided with a diameter of 62 cm and a plug of 11.0 m, arranged at an interax distance of 44 cm (between a primary and a secondary pilot), a total of 216 pilots. All pilots were drilled with recoverable tubing and are concreted as above.

The difference between primary and secondary pilots is the following:

- the primary pilots are executed in a first phase, at an interax distance of 88 cm;
- in the second phase, the secondary pilots return and are executed, drilling in the concrete of the primary ones.

The foundation slab of the Water Castle (designed and executed in 1910-1912) was placed with the sole at a depth of 5 m from the level of the natural land. Besides the need to embed the screed in the ground, another reason for this decision was to avoid as a foundation the soil from the surface, the most sensitive to moisture, with the highest porosity.

In order to avoid the large settlements of the Water Castle in case of wetting, the following solutions were analyzed:

- consolidation of the loess with earth columns, usual solution in the area; this solution is not possible because the columns under the foundation slab cannot be executed;
- injection of the ground under the foundation slab; this solution cannot consolidate the neighboring land with the foundation slab sole (except with horizontal drillings) and in addition it is expensive;
- making drilled piles of reinforced concrete for founding the foundation slab on piles; this solution is not recommended because, by making perimeter piles, the settlements in the field can be large, and perimeter small and the foundation slab cannot take over the bending moments that will appear in time.

We recommend the following technically and economically possible solution:

- a sealing screen is made around the foundation slab made with drilled piles securing simple, sealed concrete, by using hydrated bentonite mud;
- above the piles is made on the whole perimeter a loess pillow compacted in layers; in this way the land under the foundation slab is protected against infiltration waters;
- in order to prevent the loess from dampening, two depletion wells are executed, equipped with pumps with sensor to maintain the groundwater level at a controlled depth.

The calculation of the settlements was performed based on an approximate evaluation of the construction load, resulting on the sole of the p_{ef} scraper ≈ 130 kPa. It is necessary that the resistance project accurately calculates the loads so that, based on the actual pressure on the sole, to reassess the settlements. The above solution also prevents settlements caused by the possibility of liquefaction of saturated loess around the building, in case of earthquake.

Fig. 1. Images of the Water Castle in Brăila Public Garden

4. CONCLUSIONS

Following the study of the foundation land - a land sensitive to moisture, isofreamed curves and hydrozohypses specific to the Brăila site, following the analysis of piezomatic curves for 1964 - 2011 (from the profile taken through the Danube cliff near A I Cuza street, of groundwater, at least in the vicinity of the cliff, is dependent on water fluctuations in the Danube.

The proposed and adopted solution was the realization of a sealing screen around the Castle and a loess pillow compacted over the pilots' heads, thus protecting the foundation ground against infiltration waters. However, during periods of floods, when the Danube level can increase by 2-3 m, as well as over time due to losses from underground networks, it is possible that the loess will be wet from the bottom up and for this reason two wells have been provided. depletion equipped with pumps with sensors, which start only in case of need, ie when the water level is at -12.50 m the pump starts; when the water level drops to -13.5 m it stops.

5. REFERENCES

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