BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul **LIV (LVIII)**, Fasc. 4, 2008
Sectia
CONSTRUCŢII. ARHITECTURĂ

RESEARCH CONCERNING THE WATER SEEPAGE IN THE BASEMENT OF THE ORTHODOX CATHEDRAL OF BACĂU, ROMANIA

BY

ANCUŢA ROTARU*, PAULICĂ RĂILEANU and P. ROTARU[1]

Abstract. Most basement water problems appear and it is always necessary to prevent and to eliminate them. If these problems occur at a new and very important building, the solutions must appear immediately. The paper describes the research made at the Orthodox Cathedral of Bacău, Romania, from the point of view of the water appeared in the basement and in the Civil Defense Shelter in the early 2007. The research used the results of two geotechnical profiles, which show bedding consisting of a packing layer of 2.00 m thick, a fine sedimentary horizon of 6.00 m thickness and a coarse sedimentary horizon at −8.00 m depth. Groundwater is quartered in the coarse sedimentary horizon, the latter ranging from 10.00 m to 11.00 m below the Natural Ground Elevation. After the presentation of sources from where water could come, the paper presents some water leak mitigation methods to be used at the Orthodox Cathedral of Bacău.

Key Words: Orthodox Cathedral of Bacău; Water Seepage, Impermeable Plaster, Sewer with Oviform Section.

1. Introduction

The Orthodox Cathedral of Bacău located in City Center is a new representative building of the city, located at the intersection of N. Bălcescu and M. Viteazul streets with Union Avenue, in C seismic protection area. The Cathedral is considered the center of maximum concern into which converge the backbone roads and the main pedestrian circulation of Bacău City. For this reason, architecture and urban solutions of adjacent area of the Cathedral are extremely important and will become the defining characteristics of the urban municipality.

The integration of the Cathedral in the urban renewal of Bacău City will include major pedestrian directions, deviation of road circulation, marking off of Steven the Great statue, fountains, windowboxes and slabs, adjacent green locations, all to raise the value of the monumental Orthodox Cathedral and to emphasize its importance in the Central Area of Bacău City. The Cathedral occupies a free area resulting from demolitions in the area, having the following

*Corresponding author: *e-mail address:* arotaru@ce.tuiasi.ro

neighborhood: National Bank, ”Lucreţiu Pătrăşcanu” High School and George Bacovia Street.

The Orthodox Church has a length of 67.00 m, a width of 37.00 m and a maximum height of 63.00 m at the cross' base of the main dome. Construction lays on a surface of about 950.00 m^2. On the first basement of the building was arranged a Civil Defense Shelter; at the underground floor was located a chapel and an exhibition space with separate access, and from the Natural Ground Elevation rises the properly construction of the Cathedral (Fig. 1).

The building was conformed respecting the sequence of specific spaces of Orthodox churches from Romania. In the West were placed the threshold, the choir and the two scale towers that provides vertical circulation and access to both belfries. The pronave has two main entrances, on the North and South edges, and develops on multiple levels, being wreathed by a star-shape dome. With an opening of 24.00 m, the nave is the central part of the Cathedral, flanked by the two half-cylindrical lateral apses of 12.00 m diameter each, and by the reredos located beneath the triumphal arch of the altar. By a specific Byzantine architecture system of successive arches the dome of Pantocrator rises above the nave, wreathing the monumental space of the Cathedral.

Fig. 1. – Cathedral's dome from where rain infiltrates in the Civil Defense Shelter.

Architectonic ensemble is monumental and representative, being located in Bacău City, is an important religious center for the entire central area of Moldova. The realized substructure consists of a raft foundation located at -10.00 m on gravel. The resistance structure of the basement and underground floor forms a rigid box beneath the Natural Ground Elevation.

The superstructure was designed on six principal tubes of reinforced concrete placed at the nave's corners and at the belfry towers, on which downloads the entire system of domes and arches of the nave and pronave. The main tower rises from a major ring that connects the main 24.00 m opening arches of the nave and the Pantocrator dome is realized from a half-spherical 24.00 m diameter dome made of reinforced concrete. Being independent of the main structure the two lateral apses and the altar were made of a caisson-type half-cylindrical reinforced concrete structure. The roof is realized through a succession of wooden cylindrical or spherical shapes wrapped in golden copper plate.

The Civil Defense Shelter is done in the basement of the Cathedral. There also exists an underground floor in the Cathedral, which varies between -4.00 m, -5.25 m and -6.50 m from Natural Ground Elevation, comprising almost all the basement area excluding only the crypts zone.

2. Experimental

In early 2007 it was found that in some areas of the basement water was appeared. The water originated on the one hand from the existed holes remained in the exterior walls of the Cathedral from the inner formwork bracing and on the other hand probably from the base of raft foundations.

The inside water was pumped and extracted by means of pumps. The operation was done at short intervals of time.

The upper part of the area around the Cathedral was not arranged and it is possible that surface waters infiltrate into permeable ground leaking beside the walls and getting in through the inside wall holes [1].

Around the Cathedral there are some water pipes, sewage pipes and abandoned pipes that may have losses that will also be infiltrated into the ground [2].

At -5.25 m from the Natural Ground Elevation there is a granular material (gravel) which is permeable and allows the water movement from upper layers to deep layers and the lifting of hydrostatic water.

Some investigations were carry out in order to detect from where the water comes from, the source, the direction, and the quality of water that gathers in the basement [3].

In the first instance some field works were been done to the basement of the raft foundation by making some boreholes in order to clarify the situation related to the presence and ascension of water under pressure in the basement of the Cathedral. The conclusion was that there was no water under pressure beneath the raft foundation, which led to the idea of making some vertical drills from land surface to the raft foundation [4].

Analysing the two boreholes the following stratification results:

a) In F1 drilling the layer from -1.65 m to -5.65 m is filled with packing material having construction residuals put on a wet, plastic consistent, brown sandy clay layer with a thickness of 0.60 m. Under this layer it is a very wet, plastic consistent, brown clayey silt layer of 2.00 m thickness, seated on a little wet hard plastic striped gray brown clay layer with $CaCO_3$ of 2.90 m thickness. This clay has an uneven sandy gravel support. Groundwater is founded at -11.75 m from Natural Ground Elevation.

b) In F2 drilling, which is -2.35 m from Natural Ground Elevation, packing material of 2.40 m thickness located on a little wet, consistent, clayey brown silt layer with an interlayer between -5.50 m and -5.85 m of very wet clayey silt, almost saturated, was founded. This clayey silt is put on the same slightly moist, hard plastic, striped gray brown clay layer with $CaCO_3$ of 3.80 m thickness, which was found in F1 drilling. Underground water level is quartered in coarse sedimentary horizon at -11.15 m and streaked clay has the same small and medium sandy gravel as support.

3. Results and Discussion

The observation from the two drillings analysis was that the water inside the building is not hydrostatic water, but water founded in the mentioned moist layers [5], [6].

Fig. 2. – Massive seepage in the Civil Defense Shelter through the metallic sheaths of formworks.

Taking into account this situation in the first stage the holes of sheaths used in the implementation of infrastructure formworks were blocked off by injection of a particular material using a relevant technology (Figs. 2, . . . , 4). In the next stage impermeable plasters at infrastructure's walls were realized [7].

The Cathedral's exterior roof drains were strictly necessary to realize as soon as possible since in rainy periods the unsupervised rainfall waters are leaking through the elevator hole into Civil Defense Shelter.

At the same time, execution of earth excavations outside the Cathedral, where high moisture was observed, were proceeded, in order to ascertain the integrity and protection of waterproofing.

Fig. 3. – Seepage through the metallic sheaths.

Fig. 4. – Seepage with sediments from metallic sheaths.

The execution of four boreholes on the direction of the four sides of the Cathedral was commanded in order to identify the features of these waters.

The 250 mm water pipe located near the southeastern part of the Cathedral (the altar) was uncovered beginning from the existing sewer hub on a distance of about 150 m, in order to identify water losses from connecting pipes of former houses existing once on the August the 15th Street.

It was found that near the Cathedral there is a collector which collects residual water from an area of Bacău municipality which losses water. In the immediate vicinity of the Cathedral there are some water pipes which had to be monitored.

None the less that it was a dry year in the basement of the Cathedral was observed water coming through the holes of the walls. These holes were blocked off with a special mortar that can no longer allow water penetration.

4. Conclusions

From the presented field works and from the presentation of sources from where water could come, the following conclusions can be made:

1. The larger part of water comes from losses originating from sewer with oviform section as well as from surface water infiltrated in relatively low permeability layers located above the gravel. The carry over water penetrates in the basement moving beside the Cathedral's walls through the gravel layer.

2. Without vertical systematization there are reasons that weathered water penetrates through these shallow layers all time, driven by gravel at the Cathedral's foundation (Fig. 5). This situation imposes to carry out four vertical drains on the four sides of the Cathedral, aiming to collect water losses from feed lines and sewage pipes and any surface existing water penetrated in strata between ± 0.00 m and -5.10 m from Natural Ground Elevation as well. All connecting lines for Civil Defense Shelter infrastructure facilities will be realized before making such drainages using special waterproof techniques (failure of facilities' waterproofing led to Cathedral's crypts overflow during rainy periods).

Fig. 5. – Borehole through floating slabs of the Civil Defense Shelter.

If the direction and source of water are correctly identified, it is recommended to realize the drain on the ovoid side, may be renouncing at two of four drains.

Received, November, 2, 2008

„Gheorghe Asachi" Technical University, Jassy
Department of Transportation Infrastructure and Foundations
and
[1]*Technical Department*

REFERENCES

1. Meschyan S.R., Petrosyan T.L., *Water Seepage in Clay Soils with Large Dimensions of Specimens and Small Head Gradients*. Soil Mech. Found. Eng., **30**, *1*, 8–10 (1983).
2. Bethune G., Smajstrla A., *An Innovative Tailwater Recovery and Seepage-Water Interception System*. Proc. of the World Water and Environm. Resources Congr., Orlando, Florida, 2001.
3. Cedergren H.R., *Seepage, Drainage and Flow Nets*. John Wiley & Sons, Inc., New York, 1967.
4. Londe P., *Water Seepage in Rock Slopes*. Q. J. Eng. Geol. Hydrogeol., **6**, *1*, 75–92 (1973).
5. Harr M.E., *Groundwater and Seepage*. McGraw-Hill, London, 1962.
6. Verruijt A., *Theory of Groundwater Flow*. Macmillan and Co. Ltd, London, 1970.
7. Siu-Shu Lam E., *Water Seepage Problems in Multi-Story Buildings*. Proc. of the Struct. Congr., Long Beach, California, 2007.

CERCETĂRI ASUPRA SCURGERILOR DE APĂ DIN SUBSOLUL CATEDRALEI ORTODOXE DIN BACĂU, ROMÂNIA

(Rezumat)

Există multe situaţii de apariţie a apei în subsolul clădirilor şi este întotdeauna necesar să le prevenim şi să le eliminăm. Dacă, însă, aceste probleme au loc la o clădire nouă şi deosebit de importantă, soluţionarea acestora trebuie făcută imediat. Se descriu cercetările întreprinse la Catedrala Ortodoxă din Bacău, România, din punctul de vedere al apei apărute în subsolul clădirii şi în Adăpostul de Apărare Civilă la începutul anului 2007. Rezultatele cercetării s-au bazat pe două profile geotehnice, care evidenţiază o stratificaţie constând dintr-un strat de umplutură gros de $2,00$ m, dintr-un orizont fin sedimentar având grosimea de $6,00$ m şi dintr-un orizont sedimentar grosier interceptat la adâncimea de $8,00$ m. Pânza de apă freatică este cantonată în orizontul sedimentar grosier, nivelul acestuia variind între $10,00$ m şi $11,00$ m sub cota terenului natural. După prezentarea surselor de povenienţă a apei, se expun unele metode ce pot fi folosite în acţiunea de diminuare şi stagnare a scurgerii apei în subsolul Catedralei Ortodoxe din Bacău.