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The Use of Bored Injection Piles ERT in the Liquidation of an Emergency Situation of the Building

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Abstract

The occurrence of ill-judged construction of two-storey building in a zone of geotechnological influence what brought it into critical condition is described. Well-timed accepted emergency prevention activities which include strengthening of foundation by using continuous flight augerings piles and safety actions like the arrangement of prestrained lags from 8 high-tensile reinforcement ranges, what encloses on the side of the chancel retaining walls from 2 ranges of Ø350 s continuous flight augering piles created by electric-discharge technology allowed to save from collapse architectural monument of federal building.

Keywords: Strain cracks; Strain rate; Continuous flight augering pile; Electric-Discharge Technology; Extraordinary commission.

Introduction

Any proposed construction [1,2,4,5] in the zone of geotechnical influence requires special consideration, both at the stage of making a design decision and at the stage of construction. All possible construction risks should be analyzed. This article provides a clear example of disregard for the laws of soil mechanics, geotechnics, and technology for the construction of buildings and structures, because of swhich an emergency arose.

So, in 2004, in April, vertical cracks of a deformation nature appeared on the outer walls of the building of the Cheboksary Vvedensky Cathedral (Figure 1). The first defects appeared at the level of the attic on the walls of the northern and southern parts of the Cathedral, i.e., the building of the temple split into two parts. The crack opening rate reached 10÷15 mm/day. An emergency was created, which led to its possible collapse. The promptly created extraordinary commission ascertained the cause of the accidental deformations of the Cathedral and the influence of the construction of the building of the residence of the Bishop of Cheboksary and the Chuvash diocese from the side of the altar at a close distance from the temple. The construction of a two-storey brick building on strip foundations with prefabricated hollow-core floor slabs began in the autumn of 2003.

In April 2004, it had only foundations without overlapping the ground floor, i.e., its foundation was frozen throughout the winter period of 2003-2004. Thus, the deformation of the Cathedral began just at the time of thawing of the foundation. The commission found that, most likely, the building of the Cathedral was set in motion because of the process of squeezing soil from under the soles of the foundations. The following activities were promptly organized: geotechnical monitoring of crack development (Figure 2); inspection of the technical condition of the emergency building, in order to identify the residual bearing capacity, as well as engineering and geological surveys. The construction of the Vvedensky Cathedral (1651) is a brick building, with dimensions in the plan of 37.4×35.3 m (Figure 1). It consists of the main part-a temple with a height of 13m with an apse up to 4.5 m high, three chapels with apses. The height of the aisles is 4.2 - 4.5 meters. The apse consists of semicircular protrusions, covered with a vault and oriented to the east. The foundations of the Cathedral are shallow - striped rubble on lime mortar. Depth 2.0 – 2.4 m. One of the points of emergency response measures is the development of a working project for strengthening the foundation of the foundations.

According to the results of surveys carried out by the State Unitary Enterprise «ChuvashGIIZ» in 2004, the following engineering-geological elements (IGE) lie on the territory of the Vvedensky Cathedral: IGE 1 - bulk soil (tQIV), lying to a depth of 0.8-1.8 m.

- **IGE 2**: is loess loam ($prQ_{III)}$, which has subsidence properties to the entire depth, mainly of a tight-plastic consistency (with a plasticity number I_p = 9%). It is distributed throughout the site to a depth of 4.0–6.5 m. The value of its relative subsidence ε sl varies from 0.01 to 0.032 when soaked under a load of 0.2 MPa, and the initial subsidence pressure is P_{sl} - from 0.055 to 0.2 MPa. The type of soil conditions in terms of subsidence is the first.
- **IGE 2a:** is loess loam ($prQ_{III)}$ of soft-flow consistency, generally non-subsidence (ε_{sl} = 0.0072), which retains weak subsidence properties in rare small volumes of soil. It is distributed mainly in the eastern part of the site.
- **IGE 3:** is a proluvial-deluvial loam ($pdQ_{III)}$ from a semi-solid to a tight-plastic consistency, in the eastern part it is a soft-plastic consistency. It occurs everywhere, increasing in thickness to 4.5 m in the northern part of the site.
- **IGE 4**: wood and crushed stone ($pdQ_{III)}$) with sandy-loamy aggregate.
- I**GE 5**: clay silt (P_2t). Opened in the southern part. It has a capacity of about 1.0m.
- **IGE 6**: dusty sand (P_2t) with layers of fine sand.

Figure 1: Crack above the window opening of the temple (northern facade).

Figure 2: The graph of the expansion of the deformation crack at the level of the cornice of the wall of the northern facade (lighthouse 1).

Analyzing the results of engineering and geological surveys, it can be concluded that the physical and mechanical properties of the base soils have deteriorated. Particular attention should be paid to the low value of the modulus of total deformation E_o = 2.1 MPa, for layer 2a - loess loess soft-flow consistency (s. By the decision of the extraordinary commission for the development of emergency measures, NPF «FORST» was entrusted with the development of a project to strengthen the foundation of the foundations of the Cathedral building, including the chapels and the altar. Two types of bored injection piles were considered: these are bored injection piles manufactured without seals of the walls of the well and bored injection piles with compaction of the

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soil of the walls of the well are piles-ERT. The determining factor in making a decision on the choice of the type of bored injection pile was their bearing capacity. Thus, the bearing capacity of the bored injection pile-ERT on the ground exceeds by approximately 65% the bearing capacity of the bored injection pile without sealing the walls of the well. It is known that when carrying out reconstruction work or, if necessary, the device of a bored injection pile of reinforcement due to insufficient bearing capacity of the base is guided by the following algorithm:

- The satisfaction of the condition $Ps_{IImt} \leq R$ will be checked, where P_{IImt} is the average pressure under the sole of the foundation; R s is the design resistance of the bearing layer of the base.
- if the condition is not satisfied, claim 1 determines the external load at the level of the center of gravity of the foundation sole required for transfer to bored injection piles here A is the area of the sole for columnar foundations A = $N = Đ_{\ddot{a}\hat{i}\ddot{i}} \cdot A = (\frac{P_{IImt} - R}{R})\grave{A}$, l·b, and for strip foundations - A = b·1.

Based on the foregoing, the number of piles without compaction is 1.6 times more than bored injection piles-ERT. Given that the cost of one m / m of the above-mentioned piles is not much different from each other, the cost of work to strengthen the base would increase by 1.6 times. Analyzing the previous, as a variant of reinforcement, the ERT bored injection piles, 11 m long (considering embedding in bedrock soils and the passage of the foundation body with a depth of 2.5 m Ø 180 mm by core drilling. At the same time, the number of piles within the area of the Cathedral is different, for example: under the apse 2 piles / m; under the walls of the temple - 4 piles / m; under the walls of the vaults - 16 piles. In total, more than 800 bored injection piles were designed (Figure 4). The hypothesis proposed by us that the deformation of the Cathedral occurred because of squeezing the soil from under the sole of the foundations was confirmed in the process of strengthening the base. It turned out to be valid for the section of the plan of the Cathedral from the wall of the iconostasis to the altar inclusive (Figure 3) (in the direction of the extension of the residence of Vladykas). The probability of extrusion turned out to be high, due to the presence of a soft-flow plastic loam with a modulus of total deformation E 0 = 2.1 MPa under the sole of the foundations of the Cathedral. When installing bored injection piles-ERT [3,5] along the wall of the iconostasis, excess costs of fine-grained concrete were found. For example, with a geometric pile volume of ≈ 0.3 m 3, concrete consumption reached 5.0m^3. It should be noted that there is no decrease in levels in wells filled with concrete before electro-hydraulic processing. During electrohydration, a sharp decrease in levels was found at the level of the bottom of the foundations, which confirms the presence of voids under the sole, thereby filling the voids with fine-grained concrete. As a result of the work carried out on the installation of bored injection piles-ERT, cementation of the base of the foundations of the wall of the iconostasis and the altar took place at the same time (Figure 5). At the same time (again from the premise of squeezing the soil out from under the sole of the foundations), a project was developed for fencing the soil from two rows of bored injection piles with a pitch of 0.5 m between them Ø 350 mm with a strapping belt on top of the piles (Figure 4a), as well as the reinforcement of the building with the help of prestressed puffs of eight rows at the level of the eaves.

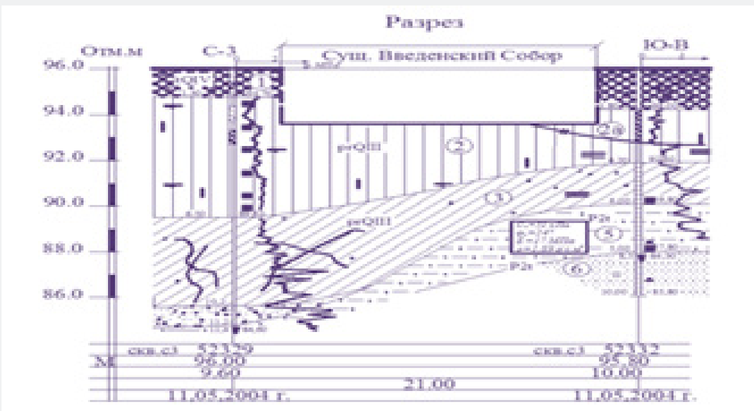

Figure 3: Engineering-geological section.

Findings

The considered emergency arose because of the construction of the building of the residence of the Bishop of the Cheboksary and Chuvash Diocese in the zone of geotechnical influence, because of which in April 2004 vertical cracks of a deformation nature appeared on the outer surfaces of the walls of the building of the Cheboksary Vvedensky Cathedral. The defects that arose at the level of the attic floors and frolicked further on the northern and southern facades split the building into two parts in the west-east direction. Thus, there was a threat of collapse of the building of the Cheboksary Vvedensky Cathedral.

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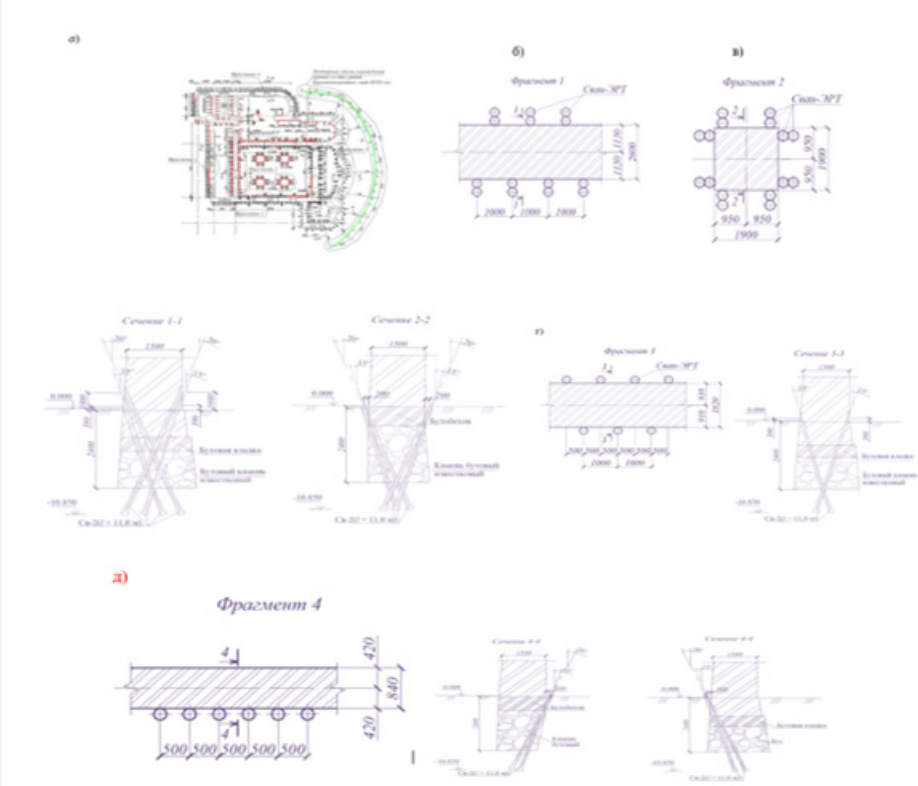

Figure 4: Scheme of the location of bored piles when strengthening the base and foundations of the Vvedensky Cathedral. Symbols: dots of red and black colors - bored piles reinforcing the base and foundation; green points - bored piles of the retaining wall on the eastern side of the temple: a - plan of piles - EDT, b, c, d, e - fragments with sections 1-1, 2-2, 3-3, 4-4.

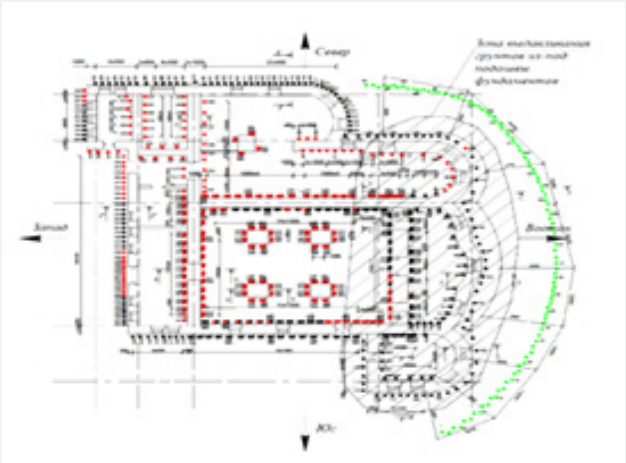

Figure 5: The zone of cementation fixing of the base.

The rate of crack development was established in the range of 10÷15 mm/day. An urgently created emergency commission for the development of emergency measures to save the historical and cultural monument of federal significance established that the cause of the deformation of the Cathedral was the influence of the construction of the residence building of the Bishop of the Cheboksary and Chuvash diocese next to the temple. The following works were urgently carried out:

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- Engineering and geological surveys.
- The technical condition of the Cathedral building was examined;
- emergency measures have been developed, including strengthening the foundation of the foundations, strengthening the building with prestressed puffs of 8 rows of high-strength screw reinforcement along the outer perimeter at the level of the eaves.

As a result of engineering and geological surveys and the results of a technical survey, the presence of cavities under the sole of the foundations of the eastern parts of the building (the wall with the royal gates, the walls of the altar) was revealed. The implementation of the developed emergency response measures made it possible to prevent a pre-emergency situation. When the opening of the maximum crack to 357 mm was reached, the deformations of the Cathedral ceased. The cathedral is still in operation without accidents.

Summary

The analyzed accidental event appeared due to constructing residence building of the Grace of Cheboksary and Chuvash episcopate in zone of geotechnological influence, consequences of which in April 2004 on wall external surfaces on Cheboksarsky Vvedensky Cathedral deformational vertical cracks appeared. Those cracks at the level of the attic floor and further to the North and South facades split the building into two parts in the direction "West-East". Thus there was a threat of Cheboksarsky Vvedensky Cathedral building collapse.

The rate of cracks growth was established in the range of 10-15 mm per day. Urgently the set up special commission on development of actions on rescue of monuments of history and culture of Federal significance was determined that the cause of deformation of the Cathedral was the effect of the construction of the building of the residence of the Grace of Cheboksary and Chuvash episcopate near to the Church. Urgent works

- Engineering-geological surveys.
- Examined the technical condition of the building of the Cathedral's s
- Developed emergency sanctions that include strengthening of foundations, strengthening of the building by using prestrained lags from 8 high-tensile reinforcement ranges on the outer perimeter at the level of the eaves. As a result of engineering-geological surveys and results of the technical examination the presence of cavities under the sole foundations of the Eastern parts of the building is revealed (the wall with the Royal doors, walls of the chancel). The implementation of emergency actions helped to prevent the precrash situation. Upon reaching the unlock crack to 357 mm deformations of the Cathedral ceased. The Cathedral operated until now trouble-free.

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