Experience of geosynthetical material application for karst danger reduction of building base

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ABSTRACT: In territory of Russia the karst has very much a wide circulation, especially in regions Povolozhja and Urals Mountains. Wide application now geosynthetic materials in geotechnical practice, from our point of view, open new ways to the solution of the given problem. In offered paper experience designing of the foundations the buildings of sports complex in territory with active development of a karst is observed

1 INTRODUCTION

The process of karst formation (caving) is one of the forms of chemical rock efflorescence. Limestones and plaster stones are especially subjected to this process. Cavities, interstices, caverns and caves of different sizes are formed in rock mass being subject to ground water solution. Karst is widely spread on the territory of Russia, mainly in the Volga and Ural regions. Latent (depth) type of karst is considered to be most dangerous. In this case, karst forming rocks lying at a considerable depth are overlapped by unsolvable but permeable rock mass. While designing the project on the territory with active karst formation builders have to make a complicated decision on the necessity of applying special protective actions. Otherwise, the lack of such actions can lead to accidents and collapses of buildings and engineering constructions that were built with no account taken of karst processes.

The following methods of antikarstic protection are used in the engineering practice of karst building:

- planning measures;
- diversion of surface water run-off from buildings;
- the arrangement of drainage systems;
- the arrangement of watertight diaphragms;
- soil solidification;
- the arrangement of rigid reinforced foundations and monolithic belts in buildings.

At present wide application of geosynthetic materials in geotechnical construction opens new ways in the solution of the given problem. One of the fields of geosynthetic material application is reinforcement of soil basements to lower their deformability and increase bearing capacity. Geosynthetic grids and high-strength woven geo textile fabrics fulfill such functions. Moreover, they are mated in case of ultimate tensile loads in their structures when cauldron starts to appear under them in the body of a soil basement.

In this article the design expertise of sports complex foundations on the territory with active karst development is considered.

2 CHARACTERISTIC OF THE REGION OF CONSTRUCTION

The complex consists of severeral buildings including a water-pool and gyms to do sport (sports halls).

According to the data of engineering-geological survey the site of construction refers to unstable territory having intensity rate of cauldron formation from 0.1 to 1.0 over 1 km^2 a year with a diameter of up to 4.0 m.

On the construction site the following rock stratifications are revealed (top-down):

1. Filled-up ground – firm loam.

1a. Filled-up ground – soft, plastic, semigravel, peat covered loam.

2. Semisolid loam – soft, plastic, with lenses of sandy loam and clay.

2a. Loams from stiff to fluid plastic, with lenses of stiff-soft plastic clay and with single inclusions of crushed stone.

3. Gravel- pebble ground with up to 40% of loamy filling aggregate.

3a. Sand of average size particles, average density, wet.

3b. Gravel-leaved sand.

4. Falling-in karst formations represented by gruss- crushed rock with loamy filling aggre- gate.

5. White, jointy, efflorescent plaster stone.

6. Bluish-grey, jointy, efflorescent anhydride.

Basic soil characterictics are given in Table 1.

Table 1. Basic physico-mechanical characteristics of soils

Stratum number (№)	Density ρ (kN/m^3)	Angle of internal friction φ (°)	Specific adherence c (KPa)	Deformation modulus E (MPa)	Design resistance R (KPa)
1	16,7	24	17	1,3	-
1a	11,0	-	-	-	150
2	18,5	21	17	6,0	-
2a	19,1	24	22	7,0	-
3	17,1	38	-	30,0	350
3a	19,3	-	-	-	400
3б	19,8				400
4	21,7	-	-	-	-
5	21,8	-	-	-	-
6	28,3	-	-	-	-

Fracture-karst water was seen at a depth of 37.0 m. At the same time, it was noticed that water inflow was rather small due to weak jointing of water-containing anhydrides.

The main ground water supply is atmospheric precipitations.

Additional supply is obtained at the expense of river water in hydraulic connection with which fracture-karst water is found.

In accordance with its chemical composition the water is sulphate-calcic, sulphate-calcic-sodium-chloride, sulphate-calcic-magnesium, average-aggressive in terms of sulphate content to Portland cement.

3 FOUNDATION

Monolithic reinforced concrete foundation plate and monolithic reinforced concrete crisscross strips (ribbons) of 600 mm thick were used as the sports complex building foundations.

Technical decisions on the base and foundation work were made with taking into consideration the space-and- planning parameters of the underground part of the building and engineering-geological conditions of the construction site.

As the main antikarstic actions the following constructive decisions were designed:

1. Building foundations are monolithic reinforced concrete foundation plate and monolithic reinforced concrete crisscross strips with the length of antikarstic cantilever of 4.0 m;

2. Change of foundation soil properties by means of reinforced sand-gravel bed in order to reduce deformations in the base of the foundation plate;

3. Continjuous horizontal waterproofing and geosysthetic drainage material laying;

4. Horizontal glue waterproofing of basement (technical cellar) floors with its placement onto outside walls.

4 DESIGN OF THE FOUNDATION PLATE BASE

In order to lower base deformations under the foundation sand-gravel bed of 100 m thick reinforced by geosynthetic material was designed. The material is placed under the sand-gravel bed and drawn tight to the stops. The minimum overlapping of adjacent grid strips is 400 mm.

Before designing the foundation base we compared the properties of different materials.

As a result, Tensar Basetex, high-strength woven geo textile fabrics, was chosen as the most suitable material for the certain conditions of construction.

The design was done with the help of PLAXIS programme at two stages – constructrion (Fig. 1) and upkeep (at maximum loading) – on the two most loaded sections (Fig. 2 and 3): for two variants of foundation bed – with reinforcement using geotextile and without it.

Karst cauldrons were simulated by means of “weakening” (reducing stress-strain and deformation properties) the part of the soil under the foundations in three places – under consoles (“left” and “right”) and under the most loaded part of the foundation.

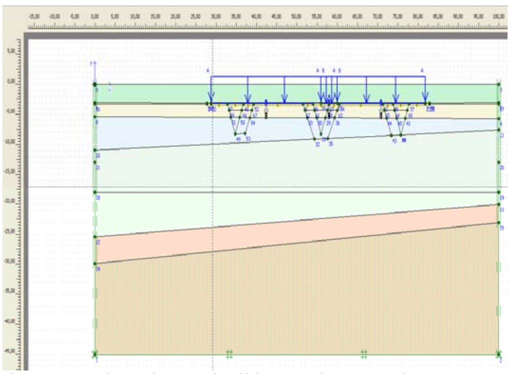

Figure 1. Design scheme of soil base at the stage of construction.

The scheme with soil “weakening” rather than switching some clusters was chosen for the necessity to control points displacement on the surface of the ditch. The weakened part was taken 4.0 m wide. Tensar Basetex 600/50 was chosen as geotextile fabrics (breaking stress at rupture under 10% material lengthening: longitudinal – 600 kN/m, lateral – 50 kN/m).

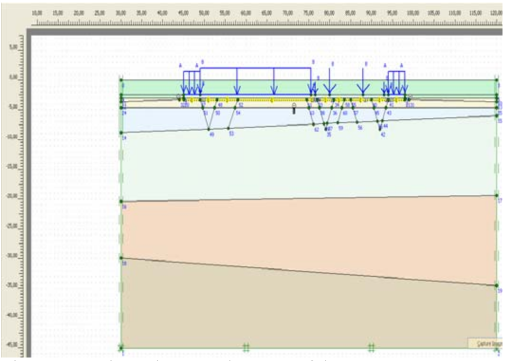

Figure 2. Design scheme at the stage of dangerous cross-sectional upkeep 1.

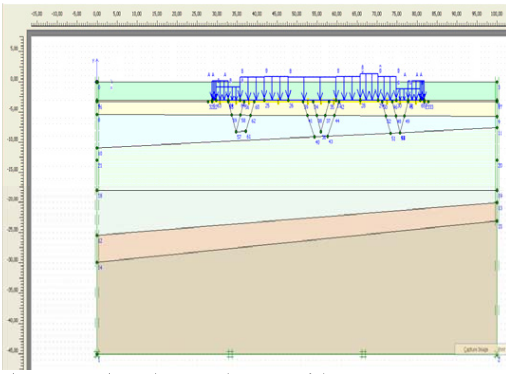

Figure 3. Design scheme at the stage of dangerous cross-sectional upkeep 2.

Design at the stage of construction was done in a dredged foundation pit by two variants:

1) without base reinforcement;

2) with base reinforcement.

When simulating the cauldron with the help of the “weakening of the soil the following maximum values of the settlement on the pit surface were obtained;

- without reinforcement 250 mm;
- with reinforcement 101 mm.

The scheme of bottom pit settlement when developing cauldron without foundation bed reinforcement and with it using geo textile fabrics is given in Fig. 4.

As it is seen from the results obtained, the surface settlement s only when reinforcing the base are lower than those specified by Russian building norms (12sm), that is, base reinforcement with geo textile fabrics Tensar Basetex 600/50 allows to considerably lower the surface foundation settlement when the cauldron is forming and thus it allows to prevent the initiation of emergency situation.

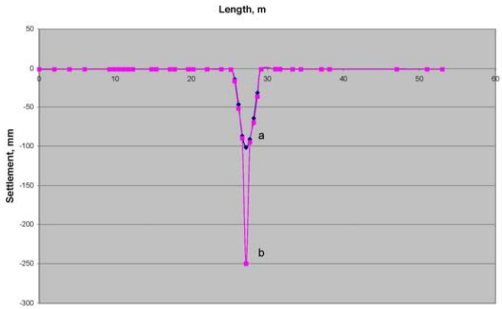

Figure 4. Scheme of bottom pit settlement: a- reinforced. b - unreinforced.

When designing the base function under maximum operating loads, it was defined that in the case of foundation plate and foundation cross application, of 600 mm each, maximum settlement s before appearing the cauldron of 4.0 m in diameter equals 71 and 111 mm, respectively, irrespective of the fact whether the base is reinforced or not. Relative settlement difference is 0.002 for the plate and 0.003 for the foundation cross.

Maximum settlement values according to design were obtained after the development of cauldron (the caldron was formed close to the console). They are 73 mm for the plate (relative settlement difference is 0.002) (Fig. 5), 116 mm for the foundation cross (relative settlement difference is 0.003) (Fig. 6). In this case, reinforcement by geotextile fabrics practically does not lead to settlement reduction, either.

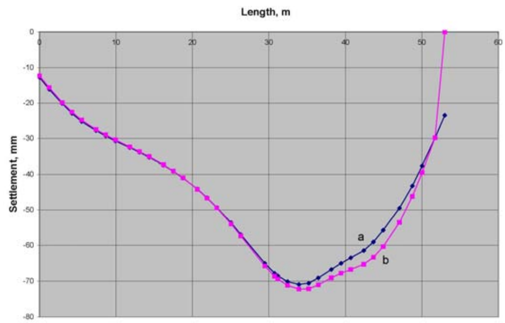

Figure 5. Foundation plate settlement pattern following dangerous cross-section 1: a – before downfall, b – after downfall

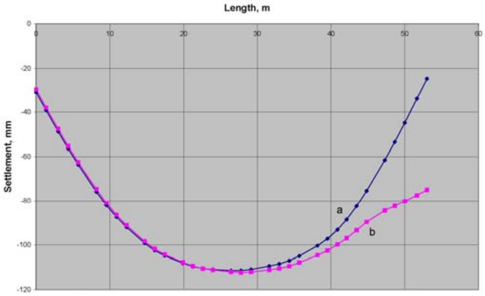

Figure 6. Foundation plate settlement pattern following dangerous cross-section 2: a – before downfall, b – after downfall

5 CONCLUSION

The calculations we had done showed that at the structure upkeep stage the designed foundation plate could sustain loads even without soil base reinforcement. But at the construction stage, when the foundation plate is not placed yet or is not stable enough, the lack of base reinforcement can initiate emergency situation. Just these very arguments persuaded the customers to adopt our decision to reinforce the soil base.

High short-term and long-term strength of material Tensar Basetex allow to use it when building structures on karsts

The application of this high-strength material allows to solve the problem of uneven settlement above karsts during the long period and avoid potential disastrous effects.

Engineering decision to reinforce the soil allows to prevent the appearance of uneven deformations in soil base and critical tensions in foundation structures when in the process of building upkeep karst cauldron appears. Moreover, it is one of the antikarstic measures.

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