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Experimental and Numerical Studies of Geotextile Encased Stone Columns in Geological Conditions of Perm Region of Russia

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Abstract
The paper provides information about improvement of the weak clay soil with geotextile encased stone columns. The paper presents materials about the relevance of this technology for applying in Perm region of Russia. The article presents an overview and analysis of existing experimental studies on the subject, which allows identifying the area of the current study which aim is applying this technology to improve the weak bases of foundations of buildings and structures in geological condition of Perm region. Also paper considers the problem of estimating of deformations of improves soil base. Experimental studies consist of tests with use of triaxle equipment and stamp tests of big-scale models of geotextile encased stone columns. The conclusions about the effectiveness of geotextile encased stone columns were made on base of the results of experimental studies and analysis of existing materials. Also paper presents areas of possible cost-effective application of technology and the results of numerical simulation of test cases with using the finite element method.

Keywords: geotextile, experiments, encased stone columns, numerical simulation, soil improvement

1 Introduction

Buildings and structures often have serious problems with uneven or excessive settlements and overall stability in case of geological conditions of soft soils. Using the methods of soil improvement can overcome all these problems. One of the methods which can have significant effectiveness in such case is applying geotextile encased stone columns (GESC). This technology increases bearing capacity and reduces settlements of soil. GESC allows working in very soft water-saturated soils. Relevance of such methods of ground improvement is now significantly increases due to the extensive use of geosynthetics in construction practice. Also economic development forces us to build different constructions on sites that were previously considered as not profitable due to ground conditions. In

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Russian conditions, the construction can be carried out at a considerable distance from the populated area. The delivery of the monolithic reinforced concrete to the construction site can be too expensive or technically impossible in such cases. Prefabricated reinforced concrete with combination of GESCs (for improvement of base) can be used in such condition for construction of foundations of different building and structures. Such technology has additional relevance in geological condition of Perm region of Russia. Application of soil piles and stone columns is a mechanical method of improving so it is most effective in clay soils, which predominate in the Perm region. Geotechnical conditions of the Perm Region of Russia Federation are presented by soft water-saturated clay soils with high deformability and low bearing capacity. Geological conditions Perm varied due to different genesis, lithology, non-uniform degree of weathering of rocks and sediment deposition conditions. Permian bedrock mainly represented by three lithological varieties: argillites, sandstones and siltstones. In these strata species not observed any regularity, they replace each other, interbedded or form at certain stages of areas with homogeneous layers of considerable thickness. The bedrock surface covered with alluvial-diluvial Quaternary sediments, which can be divided into the following lithological types: man-made layer, alluvial marsh sediments, alluvial loam, sandy loam, clay, sand alluvial deposits, alluvial coarse layers. In geomorphological respect in the city clearly distinguished floodplain, four floodplain terraces and high plains. Soft clay soils are most widespread at the IV floodplain terrace, on which is located most of the city Perm, one of biggest Russian city. Typical characteristics of subgrade of IV floodplain terrace of the city Perm shown in Table 1 below.

Name of the soil	thickness (m)	density, (g/sm^3)	c, (kPa)	φ, (град)	E_0, (MPa)
Alluvial loam with soft consistency	6-13	1,74-2,02	9-25	18-24	2-14
Gravel soil with sand filling	0,3-4	2,0-2,28	0-1,2	30-44	20-38
fractured argillite (claystone) with layers of siltstone	-	2,1-2,5	100	19-24	25-58

Table 1 Typical characteristics of subgrade of IV floodplain terrace of the city Perm

Many others sites of Perm region are similar in features because there are a huge number of rivers, marshes and lakes on its territory. This fact led to widespread alluvial deposits and as a result widespread weak clay soils. These geotechnical conditions lead to the fact that even the lightly loaded buildings have to be used pile foundations. The length of the piles is selected so as to penetrate the entire thickness of soft soils because lay hanging piles in silty clay soils of such consistency is riskily.

It was determined the direction of the current study, namely the use of GESC for construction of foundations in Perm region. These constructions (GESC) are the most rigid and most effective for reducing settlemets, and under certain conditions may act like a substitute for the classic piles. Soil piles are now widely used as a method to improve the weak soil base under the embankments. Application of modern geosynthetics can significantly improve the performance of classic soil piles and helps to avoid the disadvantages associated with the constancy of cross-sectional geometry of the pile during production and exploitation of soil base. This fact drives as to consider using it for construction of foundations.

A large number of scientists are engaged in research in this area: Alexview 2012, Castro 2011, Gniel 2009-2010, Kempfert 2006, Kraev 2008, Paul 2004, Ponomaryov 2004, Paul 2004, Trunk 2004, Raitchel et al 2012, Almeida 2013, Ghazavi 2013. Authors draw conclusions about the great effectiveness of this method for decreasing of settlements of the soft soil according to the results of all the studies.

An important component of future research is to examine work of GESC for improvements of bases of foundation of buildings and structures. In such case the main objective of improvement is limitation of deformation due to regulatory norms of Russia. GESC not wide spread in Russia and