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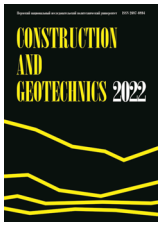

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ANALYSIS OF THE WATER SATURATION INFLUENCE ON THE STRENGTH CHARACTERISTICS OF ELUVIAL SOILS

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ABSTRACT

The problem of influence of water saturation on values of strength characteristics of eluvial mudstone-like clays and sandstones has been considered in the article. During water saturation of such soils significant deterioration of their strength properties can be observed. This complicates the process of arranging foundations on such bases. The purpose of this work is to compare the values of the strength characteristics of mudstone-like clays and sandstones of Perm city at natural humidity and in a fully water-saturated state. To achieve this goal, the following tasks have been solved: 1) the analysis of the problem study has been carried out; 2) laboratory testing methodology has been developed; 3) the results of laboratory tests have been processed and compared with the available data of tests on the field section; 4) the conclusions of the study have been formulated. According to the results of laboratory tests on a single-plane section, a decrease in the angle of internal friction by 28 % for water-saturated mudstone-like clays and by 23 % for sandstones was revealed. The decrease in cohesion values as a result of water saturation was 29 % for mudstone-like clay and 33 % for sandstone. According to archival data from field tests of mudstone-like clay pillars, the angle of internal friction decreased by 24.2 %, and the specific adhesion decreased by 65.4 %. The results of field and laboratory tests showed a significant decrease in the strength characteristics of mudstone-like clays and sandstones when saturated with water. The authors recommend performing foundation calculations on highly weathered mudstone-like clays and sandstones of Perm taking into account the possible deterioration of the construction properties of these soils. Assessment of the stability of slopes composed of weathered mudstone-like clays and sandstones requires an integrated approach and taking into consideration possible changes in the properties of these soils during water saturation.

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АНАЛИЗ ВЛИЯНИЯ ВОДОНАСЫЩЕНИЯ НА ПРОЧНОСТНЫЕ ХАРАКТЕРИСТИКИ ЭЛЮВИАЛЬНЫХ ГРУНТОВ

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АННОТАЦИЯ

Рассмотрена проблема влияния водонасыщения на значения прочностных характеристик элювиальных аргиллитоподобных глин и песчаников. При водонасыщении таких грунтов может наблюдаться значительное ухудшение их прочностных свойств. Это осложняет процесс устройства фундаментов на таких основаниях. Целью данной работы является сравнительный анализ значений прочностных характеристик аргиллитоподобных глин и песчаников г. Перми при природной влажности и в полностью водонасыщенном состоянии. Для достижения поставленной цели были решены следующие задачи: 1) выполнен анализ изученности вопроса; 2) разработана методика лабораторных испытаний; 3) обработаны результаты лабораторных испытаний и выполнено их сравнение с имеющимися данными испытаний на полевой срез; 4) сформулированы выводы по исследованию. По результатам лабораторных испытаний на одноплоскостной срез для водонасыщенных аргиллитоподобных глин было выявлено снижение угла внутреннего трения на 28 %, для песчаников – на 23 %. Снижение значений удельного сцепления в результате водонасыщения для аргиллитоподобной глины составило 29 %, для песчаника – 33 %. По архивным данным полевых испытаний целиков аргиллитоподобной глины на срез угол внутреннего трения снизился на 24,2 %, а удельное сцепление снизилось на 65,4 %. Результаты полевых и лабораторных испытаний показали существенное снижение значений прочностных характеристик аргиллитоподобных глин и песчаников при насыщении водой. Авторы рекомендуют выполнять расчеты фундаментов на сильновыветрелых аргиллитоподобных глинах и песчаниках г. Перми с учетом возможного ухудшения строительных свойств данных грунтов. Оценка устойчивости склонов, сложенных выветрелыми аргиллитоподобными глинами и песчаниками, требует комплексного подхода и учета возможного изменения свойств данных грунтов при водонасыщении.

Introduction

Mudstone-like clays and sandstones of the eluvial weathering crust are widespread in Russia, China, Europe, North and South America. The specific properties of these soils are a consequence of the uneven weathering of ancient sedimentary rocks, which changed their most important construction properties – strength and deformability [1–8]. As a result of weathering, eluvial soils with new chemical, mineralogical and granulometric composition, structure and texture are formed [9, 10]. If the eluvial soils contain a significant amount of clay minerals, then at their saturation, a significant deterioration in strength properties can be observed, which complicates the process of building foundations on such bases [11].

It should be noted that the existing studies cover soils formed in different geological times and having a different history of loading and different engineering properties. In this regard, the equations obtained by the authors [12–19] should be applied with caution to other regions. Therefore, the study of the engineering and geological features of eluvial mudstone-like clays and sandstones of the Permian age is relevant for the city of Perm and the Ural region.

The purpose of this work is to compare the values of the strength characteristics of mudstone-like clays and sandstones of the city of Perm at natural humidity and in a fully water-saturated state.

To achieve this goal the following tasks have been solved:

1) the analysis of the problem study has been performed;

2) laboratory testing methodology has been developed;

3) the results of laboratory tests have been processed and compared with the available data of field section tests;

4) conclusions on the study have been formulated.

Main part

Methods of experimental research

To determine the values of strength characteristics (internal friction angle and specific cohesion) of mudstone-like clays and sandstones, laboratory tests were performed according to the consolidated scheme in a single-plane shear device at natural humidity and in a fully water-saturated state according to the unconsolidated scheme. The obtained results of laboratory tests were compared with the available data of field section tests of mudstone-like clay pillars, which were carried out at the natural moisture content of mudstone-like clay according to the consolidated scheme and in the fully water-saturated state according to the unconsolidated scheme.

The results obtained and their analysis

The results of laboratory tests of mudstone-like clays and sandstones on a single-plane section are given in Table 1.

Table 1

Values of strength characteristics of mudstone-like clays and sandstones according to cross-section data in laboratory conditions

Таблица 1

Значения прочностных характеристик аргиллитоподобных глин и песчаников по данным среза в лабораторных условиях

Type of the soil	Specific cohesion of soil, kPa (average value)		Angle of internal friction, deg. (average value)	
	at natural humidity	in a water-saturated state	at natural humidity	in a water-saturated state
Mudstone-like clay	36	26	25	18
Sandstone	19	13	26	20

Single-plane section tests for mudstone-like clays revealed a 28 % decrease in the internal friction angle and a 23 % decrease in sandstones as a result of water saturation. The reduction in specific cohesion as a result of water saturation for mudstone-like clay averaged 29 %, for sandstone – 33 %.

The results of field tests of mudstone-like clay pillars on a single-plane section are presented in Table 2.

Table 2 shows that when mudstone-like clay is saturated with water in the field, a decrease in the values of the angle of internal friction and specific cohesion is observed. The angle of internal friction is reduced by 24.2 % and the specific adhesion is reduced by 65.4 %. Thus, the results of field tests are in good agreement with the results of laboratory tests, which also

showed a significant decrease in the values of the strength characteristics of mudstone-like clays at water saturation.

Table 2

Values of strength characteristics of mudstone-like clays based on the field cross-section data

Таблица 2

Значения прочностных характеристик аргиллитоподобных глин по данным среза в полевых условиях

Type of the soil	Specific cohesion of soil, kPa (average value)		Angle of internal friction, deg. (average value)	
	at natural humidity	in a water-saturated state	at natural humidity	in a water-saturated state
Mudstone-like clay	52	18	33	25

Such a decrease in the values of strength characteristics can be explained by the fact that eluvial soils are subject to swelling and soaking during water saturation. Particles in mudstone-like clays and sandstones are bound together by clay cement. With the water saturation of such soils, the ion-electrostatic transient contacts are destroyed, which leads to the disintegration of aggregates and microaggregates [10]. With water saturation of eluvial soils, the films of bound water around clay particles increase in volume, particles reorient relative to each other, soil porosity increases, its strength decreases and deformability increases. After the eluvial soil dries, it shrinks, but the primary structure is not completely restored. Thus, Permian eluvial soils are swelling soils and have a high resistance to shear forces under natural humidity, but during water saturation they lose their original structural bonds, break up into slab-like separates and become soaked.

Importance for the design of foundations on eluvial soils

The bearing capacity of the soil foundation is one of the most important factors that determine the structure of the foundation of a building or structure. For many years, the load-bearing capacity of the basement on weathered and fractured eluvial soils has been the object of many studies [13–19]. As a result, a number of theoretical and experimental solutions were developed to predict the bearing capacity of piles on weathered eluvial soils. However, an accurate assessment of bearing capacity of the pile and a reliable interpretation of the load transfer mechanism from the pile to the eluvial soil is still a complex problem and requires consideration of many factors. In the study [14] it was proved that bearing capacity of piles on weathered eluvial soils will be influenced by: structural features of the soil mass, the properties of the pile contact with the soil, and the depth of the pile embedding in the eluvial soil. The necessity to take into account all these factors complicates the solution of the problem of the interaction of pile with weathered mudstone-like clays and sandstones of the Permian age. Based on the results obtained in this work and earlier studies [13] it is recommended to perform calculations of foundations on strongly weathered mudstone-like clays and sandstones of Perm taking into account the possible deterioration of the construction properties of these soils.

Significance for Assessing the Stability of Slopes Composed of Eluvial Soils

One of the urgent problems in the active development of slope areas is the issue of ensuring the stability of slopes composed of eluvial soils, and their accident-free operation. Examples of

accidents on slopes include slope slides and deformations of buildings in Perm (28b Gashkova Street, 19 Ivanovskaya Street, 5 Kim Street, 2 Chekhov Street, 86 Frezerovshchikov Street, 30b Gagarin Blvd. and others). Assessment of the stability of slopes composed of weathered mudstone-like clays and sandstones requires an integrated approach and consideration of possible changes in the strength and deformation properties of these soils. The problem of water cut of such slopes requires the search for optimal methods of stability calculation as well as the development of rational solutions to eliminate the current emergency situations.

Conclusion

Laboratory tests on the single-plane section revealed a 28 % reduction in the angle of internal friction for water-saturated mudstone-like clays, and a 23 % decrease in the angle of internal friction for sandstones. The reduction in specific cohesion as a result of water saturation was 29 % for mudstone-like clay and 33 % for sandstone. According to archival data of field tests of mudstone-like clay pillars for the section, the angle of internal friction decreased by 24.2 %, and the specific adhesion decreased by 65.4 %. Thus, the results of field and laboratory tests showed a significant decrease in the strength characteristics of mudstone-like clays and sandstones at saturation with water.

Permian mudstone-like clays and sandstones are swelling soils and have high shear resistance under natural humidity, however, during water saturation, they lose their initial structural bonds, break up into slabby ones and soak. Therefore, it is recommended to perform calculations of foundations on strong-grained mudstone-like clays and sandstones of Perm city taking into account the possible deterioration of the construction properties of these soils. Assessment of the stability of slopes composed of weathered mudstone-like clays and sandstones requires an integrated approach and consideration of possible changes in the properties of these soils during water saturation.

Финансирование. *Исследование не имело спонсорской поддержки.*
Конфликт интересов. *Авторы заявляют об отсутствии конфликта интересов.*
Вклад авторов. *Все авторы сделали равный вклад в подготовку публикации.*

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