ENGINEER

international scientific journal

ISSUE 2, 2025 Vol. 3
E-ISSN
3030-3893
ISSN
3060-5172

A bridge between science and innovation

TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university

ENGINEER

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E-ISSN: 3030-3893

ISSN: 3060-5172

VOLUME 3, ISSUE 2

JUNE, 2025

engineer.tstu.uz

TASHKENT STATE TRANSPORT UNIVERSITY

ENGINEER

INTERNATIONAL SCIENTIFIC JOURNAL
VOLUME 3, ISSUE 2 JUNE, 2025

Founder of the international scientific journal "Engineer" – Tashkent State Transport University, 100167, Republic of Uzbekistan, Tashkent, Temiryo'lchilar str., 1, office: 465, e-mail: publication@tstu.uz.

The "Engineer" publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

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Tashkent State Transport University had the opportunity to publish the international scientific journal "Engineer" based on the **Certificate No. 1183** of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. **E-ISSN: 3030-3893, ISSN: 3060-5172.** Articles in the journal are published in English language.

Assessment of the influence of strength and deformation characteristics of saline soils on the foundations of buildings and structures

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Abstract: In the article, the results of scientific research related to the assessment of the impact of strength and deformation properties of saline soils on the foundation of structures, the evaluation of emergency situations of buildings and structures that occur during the use of saline soils in the world and in our country, emergency situations taking into account the change in the level of salinity due to the long-term influence of water monitoring, information on carrying out engineering-geological and hydrogeological research works for the safe and efficient operation of buildings and structures in areas where saline soils are scattered in our country. In the construction of buildings and structures in the countries of the world where saline soils are distributed, during the period of their use as a basis, the issues of forecasting and reducing the consequences of emergency situations that may occur due to changes in engineering-geological and hydrogeological conditions are of great importance. The studies of the assessment of emergency situations expected during the use of saline soils serve the socio-economic, sustainable development of countries with areas where such soils are distributed. Certain progress is being made in carrying out engineering-geological and hydrogeological research works for the safe and efficient operation of buildings and structures in areas where saline soils are scattered in our country. In particular, in the regions of Bukhara, Jizzakh, Syrdarya, Khorezm, Fergana and the Republic of Karakalpakstan, saline soils have been thoroughly studied and evaluated based on the determination of engineering-geological and hydrogeological factors.

Keywords: soils, saline soils, strength, deformation, physical-mechanical properties, coefficient of filtration, constructions, underground water, hard-to-dissolve salts, sulfate-chloride salinity, chloride-sulfate salinity, sulfate salinity, sodium salt

1. Introduction

In the construction of buildings and structures in the countries of the world where saline soils are distributed, during the period of their use as a basis, the issues of forecasting and reducing the consequences of emergency situations that may occur due to changes in engineering-geological and hydrogeological conditions are of great importance. In this regard, measures are being taken to assess and forecast emergency situations through comprehensive research and to reduce them in the areas where saline soils are spread. The studies of the assessment of emergency situations expected during the use of saline soils serve the socio-economic, sustainable development of countries with areas where such soils are distributed [1,2].

A number of scientific studies related to the assessment of emergency situations of buildings and structures that occur during the use of saline soil are being carried out in the world. Special attention is paid to the assessment of emergency situations, taking into account the change of the salinity level due to the long-term influence of water, to the improvement of measures that ensure the safe use of buildings and structures during their use.

Certain progress is being made in carrying out engineering-geological and hydrogeological research works for the safe and efficient operation of buildings and structures in areas where saline soils are scattered in our country. In particular, in the regions of Bukhara, Jizzakh, Syrdarya, Khorezm, Fergana and the Republic of Karakalpakstan, saline soils have been thoroughly studied and evaluated based on the determination of engineering-geological and hydrogeological factors [3,4,5].

2. Research methodology

To date, theoretical and practical studies on the study of the amount and type of salts contained in saline soils on the basis of buildings and structures, as well as modeling of their effect on accounting indicators, have been widely studied by scientific centers, universities and scientific research institutes of leading countries. During the operation of buildings and structures built on saline soils, man-made level of underground water is formed under the structure due to natural and artificial factors. The rise of the underground water level and the wetting of the foundation soils cause uneven subsidence of the structure, leading to emergency situations, resulting in excessive costs. Based on this, taking into account the specific engineering-geological and hydrogeological conditions of saline soils, the research of changes in physical-mechanical properties of soils due to their wetting is one of the important issues of today [4, 8].

3. Results and Discussion

Major researchers of the world and our country have

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conducted research on the effect of the amount and type of salts in the saline ground base on its physical and mechanical properties. The results of their scientific research are included in several regulatory documents aimed at ensuring the integrity and safe operation of buildings and structures in areas with saline soils. However, in the developed regulatory documents, changes in their physical and mechanical properties due to leaching of salts contained in saline soils have not been fully studied and paid attention to. The analysis of the emergency situation of some objects in the conditions of Uzbekistan shows that the factors affecting the change in the values of the physical and mechanical properties of the foundation soils used in the calculation of the stability of buildings and structures (for example: long-term water seepage, salt content, etc.) are not sufficiently taken into account. At the same time, as a result of the conducted research, it is shown that the actual subsidence of the existing structures increased by 1.5-2.0 times compared to the design when saline soils were wetted and water seeped for a long time. Taking into account that the construction of many buildings and structures in the conditions of Uzbekistan, where saline soils are widespread, these scientific research works are aimed at assessing the changes in engineering-geological and hydrogeological conditions as a result of the leaching of salts contained in the soil during the moistening of these areas, the issues related to the strength of buildings and structures and their safe use allows to solve. Saline soils are divided into the following types: chloride, sulfate-chloride, chloride-sulfate, sulfate and soda, as well as according to the degree of salinity: low salinity, medium salinity, strong salinity and extremely strong salinity [5, 6]. Scientific novelty of research is is the following:

- the changes in the salinity of soils under the influence of natural and man-made factors in the research object were determined, schematic maps of their hydrogeological and engineering-geological conditions were made, and the change in the filtration coefficient was evaluated;
- the strength, deformation and seismic properties, the decrease of the initial plastering and alkalinity level from the engineering-geological indicators of saline soils were determined under the influence of moisture;
- the dependence of soil strength and deformation indicators on the types of salinity, the level of initial plastering and alkalization was determined, and their mathematical expressions were developed;
- as a result of leaching of saline soils in Pakhtakor district of Jizzakh region and long-term exposure to water, the conditional resistance is reduced by 1,2-1,6 times and the additional settlement of the foundation increased by 1,5-2,0 times in dependent on such conditions.

Table 1 shows the amount of salinity of saline soils by district in Jizzakh region of the Republic of Uzbekistan.

Table-1

Classification of soil salinity by districts in Jizzakh region, % (according to V.M.Bezruk)

№	Regions	Weak salted (from 0,3 - to 1,0)	Moderately salty (from 1,0 to 5,0)	Strong salted (from 5,0 to 8,0)	Extra salted (>8,0)
1	Jizzakh	2,4	1,2	-	-
2	Sh.Rashidov district	-	2,7	3,1	-
3	Pakhtakor district	1,2	17,5	24,3	26,7
4	Zafarabad district	2,1	13,1	14,3	12,9
5	Dostlik District	2	12,1	12,2	11,9
6	Arnasoy district	2,6	12,8	13,5	12,8
7	Mirzachol district	1,6	13,7	12,9	12,3
8	Forish district	-	2,6	1,8	1,2
9	Ghallarol district	3,2	2,5	-	-
10	Bahmal district	-	-	-	-
11	Zomin district	-	-	-	-
12	Zarbdar district	1	1,1	-	-
13	Yangiabad district	-	-	-	-

In different natural conditions of Uzbekistan, in the areas of the Mirzachol plains, saline soils of different quantities and composition are found. The most common salts in soil are the following: $NaCL$, $Na_2SO_4 \cdot 10H_2O$, $MgSO_4 \cdot 7H_2O$, $MgCL_2 \cdot 6H_2O$, $CaCL_2 \cdot 6H_2O$, $NaHCO_3$, $Na_2CO_3 \cdot 10H_2O$, $CaCO_3$ ва $CaSO_4 \cdot 2H_2O$. The amount and quality of these slightly soluble salts determine the physical and mechanical properties of soils. Sources of salinity of saline soils are mineralized waters that evaporate and release a certain amount of salt, the process of enriching the composition of rocks with salts. In the territory of Uzbekistan, in particular, in the desert regions of the Jizzakh region, there are mainly sources of two types of salinity, that is, strong and extremely strong. At the same time, salinization of soils without the influence of groundwater from saline rocks is also observed. From Table 1 above, we can see that the amount of highly saline (24.3%) and extremely saline (26.7%) soils in Pakhtakor district of Jizzakh region is much higher than in other regions. In recent years, deformation of civil and industrial buildings built on saline soil due to the increase in the construction volume of buildings and structures in arid and semi-arid regions has been observed a lot. A distinctive feature of saline soils is the change in the physical and mechanical properties of such soils during the process of water saturation and alkali leaching of salts. Today, in the desert regions of Jizzakh region, especially in Pakhtakor district, saline areas are rapidly expanding. From the experience of building industrial and civil structures on saline soils, as a result of wetting and long-term seepage of water from the foundation, unacceptable deformation of the foundation and loss of bearing capacity are observed. Due to leaching of salt from them and changes in mechanical properties, the bearing capacity of the base decreases (Figure 1,2).

Fig. 1. Sinking of the structure as a result of water seepage into the foundation of school 14 in Pakhtakor district, Jizzakh region

Fig. 2. The crest of the base of the structure as a result of the salinity

The most salinization of irrigated lands is observed in this district, therefore it was considered appropriate to conduct research in this area. It should be emphasized that there have been no systematic studies on the influence of groundwater on the engineering-geological properties of soil in Pakhtakor district of Jizzakh region. Based on the results of this scientific research, the standard value of the volumetric weight of the particles of saline soils depending on the salinity description is presented in Table 2.

Table 2

The standard value of the volumetric weight of the particles of saline soils depending on the description of salinity

Amount of salts, %	Volumetric weight of soil particle, g/sm^3, in types of salinity						
	NaCI	*$NaSO_4$*	*Na_2CO_3*	*$MgCl_2$*	*$MgSO_4$*	*$CaCI_2$*	*NaCl + $MgSO_4$*
0	2,67						
3	2,66	2,67	2,65	2.65	2,67	2,67	2,67
5	2,66	2,67	2,64	2,64	2,65	2,65	2,65
7	2,64	2,64	2,62	2,62	2,64	2,63	2,64
10	2,64	2,61	2,59	2,59	2,62	2,61	2,62

The leaching of salts and the rate of its continuation are closely related to the properties of saline filtration. Many studies on the filtration properties of saline soils show that the process of changing the filtration coefficient is complex due to the dissolution and leaching of salts. Methods for determining the filtration coefficient of soils in laboratory conditions are carried out according to GOST 25584-2016. Filtration coefficient: represents the permeability

https://doi.org/10.56143/engineer-tstu.v3i2.77 A bridge between science and innovation

characteristic of the soil with respect to a certain amount of filtered water. Also, the linear filtration law is equal to the uniform pressure gradient and the filtration rate of water. The process of determining the filtration coefficient of soil samples is presented in picture 3.

Fig. 3. Procedure for determining the filtration coefficient of soil samples

In laboratory conditions, it was found that the filtration coefficient is correlated with the plastic number and porosity coefficient of the soil as follows:

For porosity coefficient $0,65 \le e_0 \ge 0,85$ and values of plastic number $0.65 \le I_p \ge 17$:

$$K_f = -1,05 \cdot 10^{-7} + 1,86 \cdot 10^{-6} / I_p, \quad (sm/sec). \qquad (1)$$

For porosity coefficient $0,55 \le e_0 \ge 0,65$ and values of plastic number $3 \le I_p \ge 14$:

$$K_f = 9,02 \cdot 10^{-9} + 2,33 \cdot 10^{-7} / I_p, \quad (sm/sec). \qquad (2)$$

For porosity coefficient $0,55 \le e_0 \ge 0,65$ and values of plastic number $3 \le I_p \ge 14$:

$$K_f = 3,50 \cdot 10^{-9} + 2,55 \cdot 10^{-7} / I_p, \quad (sm/sec). \qquad (3)$$

On average, the following expression was adopted based on the results of all experiments (the range of variation of porosity coefficient $0,45 \le e_0 \ge 0,85$, the range of variation of plasticity number:

$$K_f = 8,73 \cdot 10^{-9} + 2,37 \cdot 10^{-7} / I_p, \quad (sm/sec) \qquad (4)$$

For sandy soils, the filtration coefficient depends on the amount of particles smaller than 0.1 mm. The following relationship was determined for values of porosity coefficient $e=0.65 \div 0.75$:

$$K_f = 2,64 \cdot 10^{-4} - 6,33 \cdot 10^{-6} \cdot G \quad (sm/sec), \qquad (5)$$

here: G- the percentage of particles smaller than 0.1 mm in size.

The linear approximation of the results of the experiments conducted on sandy soils with a porosity coefficient of 0.45 to 0.55 (the content of clay particles smaller than 0.1 mm in size from 4.5 to 8.5 %) was determined by the following expression:

$$K_f = 10^{-5} - 1,488 \cdot 10^{-7} \quad (sm/sec) \qquad (6)$$

In saline areas, subsidence and suffocation may occur due to the use of the structure or changes in the underlying hydrogeological conditions. Easily and moderately soluble salts can also be washed away, and the type of ground changes due to the release of salts from the foundations of structures (for example, when examining the ground of the foundation - solid soils, when examining the structure in a state of emergency - loose soils). As a result of water saturation and alkali leaching of such soils, the values of their deformation and strength characteristics are significantly reduced. The analysis results of the studies show strong salinity of the subsoil and leachate soils. This situation can be explained by the rise of mineralized underground water to the surface of the earth through the capillaries in them. In such conditions, an increase in the amount of salt in the surface layers of soils is observed.

4. Conclusion

In a number of areas of Uzbekistan where saline soils are spread, we can observe the decrease in the strength of the foundation soils as a result of the rise of groundwater and flooding of the area, as a result, the increase in the emergency condition of buildings and structures. It is desirable to conduct experiments related to studying the laws of changes in their strength during filtration washing of saline soils based on observed buildings and structures, as well as studying the microstructure of saline soils. It is necessary to give recommendations and suggestions aimed at ensuring the strength of the foundation of the developed structures and stability to deformation based on the results of researches on determining the deformation and strength of saline soils. It should be noted that when designing structures in such soils, it is necessary to take into account the decrease in strength and deformation characteristics caused by the wetting of the foundation of the structure and the leaching of easily, moderately and difficultly soluble salts. The main risk of construction on saline soils is dissolution of salts due to water filtration, deterioration of soil structure, and decrease in strength, as a result of which uneven settlement occurs. It is necessary to take into account not only the amount of salinity of the soil with the permissible quantitative criterion of salts on the basis of the structure, but also the change of indicators of their water-chemical and physical-mechanical properties due to wetting and alkali leaching. As a result of our research, the following conclusions were reached:

1. These studies indicate early damage to buildings and structures as a result of changes in the engineering-geological conditions of saline soils in the territory of our country, and require a thorough and deeper study of the properties of soils.

2. Alluvial-proluvial soils are mainly distributed in the studied areas, their salinity ranges from 1.2% to 1.8% in sands, from 1.5% to 15.8% in supes, from 2.4% to 18.5% in loams. , it was determined that it varies from 1.25% to 5.8% in clays. The groundwater level is 1.2-2.8 meters deep. Under their influence, the strength indicators of the foundations of buildings and structures decrease from 20 to

50%.

3. When water seeps from hard-to-dissolve saline soils, especially gypsum, for a period of 12 to 24 months, their strength values and the amount of salts in them, that is the degree of salinity, decrease by 70-80%, which in turn leads to a decrease in the stability of the foundation of buildings and structures and subsidence.

4. Based on the fact that the conditional resistance calculated as a result of leaching of saline soils and long-term exposure to water may decrease by 1.2-1.6 times and the additional settlement of the foundation may increase by 1.5-2.0 times under such conditions, an appropriate measure to ensure the strength of buildings and structures - it is recommended to use events.

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