STUDY OF THE EFFECT OF SOIL CEMENT ELEMENTS WHEN STABILIZING ROADBED MODEL IN LABORATORY CONDITIONS

Purpose. Experimental studies allow determining the stress-strain state or bearing capacity of the tested soil body. A preliminary study of the results of model testing and experimental research allows us to find the optimal solutions and to justify the parameters of the chosen technology. The purpose of this work is to determine the effect of soil cement elements when stabilizing the roadbed on a weak subgrade using the soil tests in laboratory conditions.

Methodology. During the development of measures for the reconstruction and consolidation of soil bodies, their strength is tested using many methods. In all cases, we take into account the physical and mechanical characteristics of soils obtained as a result of research, as well as the existing regulatory documents. We performed the experimental studies by model testing in laboratory conditions. The model testing was based on the corresponding relationships between geometric sizes, mechanical properties of materials, loads and other factors on which the stress-strain state depends. During testing, the model was loaded gradually. We maintained each load level up to conditional stabilization of the soil deformation. We took the readings from measuring devices at each stage of loading after achievement of stabilization of soil mass deformations. We fixed the readings in the test journal.

Findings. During stabilization with soil cement piles there is an improvement in mechanical properties, which leads to a decrease in deformations by 2…3.5 times. Each test is accompanied with graphs of relative deformations-stress dependence, as well as deformation curves and compression curves. According to the results of experimental studies, it can be seen that when testing a model with cement piles, compared with a model without soil cement piles, the relative deformations of the samples taken prior to the experiment and after the experiment almost coincide, indicating a decrease in deformability under load. Originality. We proved that this stabilization type positively affects the stress-strain state of the soil body, by increasing its physical and mechanical characteristics. The obtained results allow for rational design of subgrade stabilization work with the help of modern technologies. Practical value. The in-depth analysis of the results of experimental studies opens up possibilities for theoretical synthesis and development of theoretical foundations, which will allow in the future avoiding, in the similar cases, the experimental verification of the stabilization type given for the relative type of soil. It is confirmed that this method of stabilization used can be applied in real conditions.

Keywords: roadbed; soil cement elements; trough study; soil tests

Introduction

Knowledge of the mechanical properties of soils is equally important for both the roadbed and the calculation of the rolling stock-embankment interaction.

It is clear that the mechanical properties of any soil, in different operation conditions, should vary significantly.

When calculating the interaction of subgrade soil with the track superstructure, the urgent task is to identify the parameters that determine the development of deformations in subgrade soil.

Modern production requires the ability of specialists to independently put and solve various fundamentally new technical problems, which cannot be done without mastering the basics of scientific research. Based on common research methods, we get the answer to the question where to start the study, how to treat facts, how to generalize them, which way to go from the facts to conclusions. When researchers have enough factual material, then as a means of solving this technical problem,
they use hypothesis – evidence-based assumptions put forward to explain any process which after checking may be true or false.

In the process of learning, experimental research is a necessary step in obtaining empirical knowledge.

Experiment is the most important part of scientific research. Its basis is a scientifically advanced experience with precisely calculated and controlled conditions.

The main purpose of the experiment is to identify the properties of the objects under study, to test the validity of the hypotheses, and on this basis to study widely and deeply the topic of scientific research [1, 8].

The development of modern computing systems and applications allow receiving answers to almost all questions pertaining to predict the behaviour and characteristics of stress-strain state of soil. However, there are problems when this is not enough, for example, there are no theoretically substantiated solutions, or the tasks themselves are rather complicated.

Experimental studies allow us to determine the stress-strain state or bearing capacity of the tested subgrade [2, 3, 4].

Most of the experimental studies should be performed on large-scale models, and only in special cases one should perform natural experiments. Preliminary study of the results of model testing and experimental research allows us to find the optimal solutions and to substantiate the parameters of the chosen technology in industrial conditions.

**Purpose**

Experimental studies of the roadbed construction, which is reinforced by ground-cement piles, are carried out to solve the following issues:

- analysis of the results of numerical and full-scale model testing with the purpose of obtaining the methodology of calculations at the design stage;
- definition of dependencies of soil body properties on the parameters of roadbed stabilization.

**Methodology**

Experiment is called a set of researches, which are united by one purpose, one system of restrictions in space and time.

The study is the realization on the object of certain conditions and rules. As a result of the experiment, an event occurs, the appearance of which is fixed by some parameter, which, as a rule, has a numerical definition and characterizes the result to a large extent.

The experiment is the most important part of scientific research. This is one of the main ways to gain new scientific knowledge. More than 2/3 of all labour resources of science are spent on experiments. The base of the experimental study is an experiment, which is a scientifically established experience or observation of a phenomenon in clearly defined conditions that allow it to be monitored, manipulated, reproduced every time when these conditions are repeated. The experiment differs from the usual, every day, passive observation by the active influence of the researcher on the phenomenon under study.

The main purpose of the experiment is testing the theoretical positions (confirmation of the working hypothesis), as well as a broader and more profound study of the topic of scientific research.

The experiment should be carried out as soon as possible with minimum costs at the highest quality of the results.

During the development of measures for the reconstruction and stabilization of soil bodies, their strength is tested using many methods. In all cases, we take into account the physical and mechanical characteristics of soils obtained as a result of research, as well as the existing regulatory documents.

The experiment method corresponds to the modern level of science, takes into account the experience gained earlier. The proposed method includes the justification of the research design, instrumental support, etc. [9].

Model testing is a method of studying any phenomenon by comparison with another phenomenon similar thereto, that is, the reproduction of the properties of an object on a specially reproduced analogue-model. There are mathematical model testing, physical model testing, model testing on mechanical models.

In this paper, simulation is an experimental solution to a problem and occupies an intermediate position between analytical calculations and field studies.

The model testing was carried out on the basis of the corresponding relationships between geometric sizes, mechanical properties of materials, loads and
other factors on which the stress-strain state depends [2, 7].

The design of the model allows providing the requirements of all normative documents regulating soil tests in laboratory conditions.

The model scale is chosen in such a way that the geometric dimensions, material characteristics, load, and other model parameters are interconnected by a system of equations that is a condition of similarity.

The preparatory phase included making up an experiment program, in particular the selection of independent and dependent variables, the analysis of the ways to achieve the testing integrity, the identification of the optimal sequence of experimental actions, the development of methods for fixing and analysing the results, preparing the necessary equipment, giving guidance to the test subjects, and forming a sample.

In accordance with the study tasks, the work program provided for soil tests in conjunction with ground-cement elements.

During the study the following procedure was performed:
1 – Arrangement of a constructive solution for soil body stabilization
2 – Assembly of load and measuring systems
3 – Test
4 – Disassembly of measuring and loading systems
5 – Removal of the soil body and examination of the soil cement elements.

The preparatory stage of experimental research is the construction of a control model. For this purpose, we used the laboratory trough of the DNURT laboratory, filled with soil in accordance with the roadbed transverse profile. Laboratory trough is a capacity of 0.65x0.25x0.12m, which eliminates the subgrade deformations, and, accordingly, their effect on the results of the study.

General construction of the trough with measuring devices is shown in Fig. 1.

During testing, the model was loaded gradually. The maximum load was 16 kg. The value of maximum pressure was calculated at R65 rails and 25t load per axle.

Each load level was maintained up to conditional stabilization of soil deformation. We took the readings from measuring devices at each stage of loading after achievement of stabilization of soil body deformations. We fixed the readings in the test journal. Upon reaching the maximum load, we un-loaded the tested model fixing the readings of the measuring devices.

Findings

We carried out the model testing in laboratory conditions using a standard trough filled with soil in accordance with the roadbed transverse profile. Laboratory trough is a capacity of 0.65x0.25x0.12m, which eliminates the subgrade deformations, and, accordingly, their effect on the results of the study [6, 11].
It should be noted that the soil properties correspond to complicated engineering and geological conditions, and the soil itself (loam) for laboratory experiments was sampled on the problem areas of the railway [5, 10].

After performing the control calculation of an unshaped roadbed, we obtained the maximum deformations of 5…8 mm.

The maximum relative deformations are 0.24…0.372 mm for the non-stabilized body, and 0.125…0.2 mm for the stabilized body (Fig. 3). Accordingly, when reinforced with soil cement piles there is an improvement in mechanical properties, which leads to a decrease in deformations by 2…3.5 times. Moreover, we can say that the residual deformations have at least half of the deformations of crushed stone bed (Fig. 4).

It should be noted that after the test all the piles remained in the initial state, no cracks, chips and other damages were detected (Fig. 5).

After each stage of the tests, we performed laboratory testing of soil samples before and after loading.

Each test is accompanied with graphs of relative deformations-stress dependence, as well as deformation curves and compression curves.

According to the results of experimental studies, it can be seen that when testing a model with cement piles, compared with a model without soil cement piles, the relative deformations of the samples taken prior to the experiment and after the experiment almost coincide, indicating a decrease in deformability under load.

The conducted experiments showed the increase in soil deformation as a result of the placement of soil cement elements, due to the soil consolidation. It can be assumed that the total deformation module of the entire body, taking into account stabilizing soil cement elements, will be much higher.

**Originality and practical value**

The paper considers the possibility of stabilizing the roadbed on a weak subgrade using the soil cement piles. We proved that this stabilization type positively affects the stress-strain state of the soil body, by increasing its physical and mechanical characteristics.

The in-depth analysis of the results of experimental studies opens up possibilities for theoretical synthesis and development of theoretical foundations, which will allow in the future avoiding, in the similar cases, the experimental verification of the stabilization type given for the relative type of soil.

The implemented stabilization of the roadbed with the soil cement elements will contribute to improving the track strength and state.

The obtained results allow for rational design of subgrade stabilization work with the help of modern technologies.
Conclusions

The experience of designing and operating the track structure has shown that over time it is necessary to take certain measures to improve the soil body characteristics to allow further normal operation of the roadbed.

When increasing the load on the weak subgrade as a result of the construction of the other track, back filling or increased axial load when changing the rolling stock, the process of settling and consolidation can continue again. Therefore, one of the most expedient and perspective variants of designing and reconstruction of embankments on weak subgrade is the subgrade stabilization using string cementation. The arrangement of soil cement piles allows providing short terms for roadbed stabilization, the possibility of quick putting into operation of the track section and small values of subsidence.

Soil cement elements that are widely used abroad, as well as in the construction of industrial and civilian facilities, can be applied for reinforcement of transport constructions, namely, when stabilizing both the roadbed and weak subgrade.

The use of model testing allows us to detect the stress-strain state of a soil body with any geometric and physical-mechanical characteristics.

The presented method of experimental research allows estimating objectively the real influence of soil cement elements on the soil body of the weak subgrade roadbed.

Thus, it is confirmed that this method of stabilization used can be applied in real conditions.

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ДОСЛІДЖЕННЯ ВПЛИВУ ГРУНТОЦЕМЕНТНИХ ЕЛЕМЕНТІВ ПРИ УКРІПЛЕННІ МОДЕЛІ ЗЕМЛЯНОГО ПОЛОТНА В ЛАБОРАТОРНИХ УМОВАХ

Мета. Експериментальні дослідження дозволяють визначити напруженого-деформований стан або несучу здатність ґрунтового масиву, що розглядається. Попереднє вивчення результатів моделювання й експериментальних досліджень дозволяє підібрати оптимальні рішення та обгрунтувати параметри обраної технології. Метою даної роботи є визначення впливу ґрунтоцементних елементів укріплення земляного полотна на слабкій основі за допомогою випробування ґрунтів у лабораторних умовах.

Методика. Під час розробки проєктів реконструкції та укріплення ґрунтових масивів виконується перевірка їх міцності за допомогою багатьох методів. В усіх випадках до уваги приймають фізико-механічні характеристики ґрунтів, отримані в результаті досліджень, а також діючі нормативні документи. Експериментальні дослідження виконувалися шляхом моделювання в лабораторних умовах. Моделювання здійснювалось на основі відповідних співвідношень між геометричними розмірами, механічними властивостями матеріалів, навантаженнями та іншими факторами, від яких залежить напруженого-деформований стан. При проведенні випробувань навантаження моделі здійснювалось поступово. Кожну ступінь навантаження витримували до умовної стабілізації деформації ґрунту. Зняття відліків із вимірювальних пристроїв на кожному ступені навантаження виконувалося після досягнення стабілізації деформації ґрунтового масиву. Результати експериментальних досліджень могли побачити, що при випробуванні моделі з використанням ґрунтоцементних паль, порівняно з моделлю без використання ґрунтоцементних паль, підвищення деформації елементів залежить від напруженого-деформованих стану. Результати експериментальних досліджень можуть бути використані для теоретичної оцінки можливості унікальних елементів укріплення ґрунту.

Наукова новизна. Доведено, що даний тип укріплення позитивно впливає на напруженого-деформований стан ґрунтового масиву шляхом підвищення його фізико-механічних характеристик. Отримані результати дозволяють рационально проектувати роботи з укріплення ґрунтової основи за допомогою сучасних технологій. Практична значимість. Поглибленний аналіз результатів експериментальних досліджень відкриває можливості для теоретичного узагальнення та розробки теоретичних основ, що дозволить у подальшому здійснити унікальні в аналітичних випадках експериментальної перевірки приведеного в роботі виду укріплення для даного виду ґрунту. Підтверджено, що використаний метод укріплення може бути застосований у реальних умовах.

Ключові слова: земляне полотно; ґрунтоцементні елементи; лоткові дослідження; випробування ґрунтів

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ОПРЕДЕЛЕНИЕ ВЛИЯНИЯ ГРУНТОЦЕМЕНТНЫХ ЭЛЕМЕНТОВ ПРИ УКРЕПЛЕНИИ МОДЕЛИ ЗЕМЛЯНОГО ПОЛОТА В ЛАБОРАТОРНЫХ УСЛОВИЯХ

Цель. Экспериментальные исследования позволяют определить напряженно-деформированное состояние или несущую способность рассматриваемого грунтового массива. Предварительное изучение результатов моделирования и экспериментальных исследований позволяет подобрать оптимальные решения и обосновать параметры выбранной технологии. Целью данной работы является определение влияния грунтоцементных элементов укрепления земляного полотна на слабом основании с помощью испытания грунтов в лабораторных условиях.

Методика. При разработке мероприятий по реконструкции и укреплению грунтовых массивов выполняется проверка прочности с помощью многих методов. Во всех случаях во внимание принимают физико-механические характеристики грунтов, полученные в результате исследований, а также действующие нормативные документы. Экспериментальные исследования выполнялись путем моделирования в лабораторных условиях. Моделирование осуществлялось на основе соответствующих соотношений между геометрическими размерами, механическими свойствами материалов, нагрузками и другими факторами, от которых зависит напряженно-деформированное состояние. При проведении испытаний нагрузки модели осуществлялись постепенно. Каждую степень нагрузки выдерживали до условной стабилизации деформации грунта. Снятие отсчетов с измерительных устройств на каждой ступени нагрузки выполнялось после достижения стабилизации деформаций грунтового массива. Фиксирование отсчетов по оборудованию отмечалось в журнале испытаний.

Результаты. При укреплении грунтоцементными сваями модели земляного полотна происходит улучшение механических свойств, что приводит к уменьшению деформаций в 2...3,5 раза. Для каждого испытания построены графики зависимости относительных деформаций от напряжения, а также графики деформаций и компрессионные кривые. Из анализа результатов экспериментальных исследований можно заключить, что при испытании модели с устройством грунтоцементных свай, по сравнению с моделью без устройства грунтоцементных свай, относительные деформации грунтов были меньше. Научная новизна. Доказано, что данный тип укрепления положительно влияет на напряженно-деформированное состояние грунтового массива, а также на его физико-механические характеристики. Полученные результаты позволяют рационально проектировать работы по укреплению грунтового основания с помощью современных технологий. Практическая значимость. Углубленный анализ результатов экспериментальных исследований открывает возможности для теоретического обобщения и разработки теоретических основ, позволит в дальнейшем избежать в аналогичных случаях экспериментальной проверки приведенного в работе вида укрепления для данного вида грунта. Подтверждено, что использованный метод укрепления может быть применен в реальных условиях.

Ключевые слова: земляное полотно; грунтоцементные элементы; лотковые исследования; испытания грунтов

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