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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК РЕСПУБЛИКИ КАЗАХСТАН»
ЧФ «Халық»

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Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

ЧФ «ХАЛЫҚ»

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

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RESEARCH AND LABORATORY METHODS FOR DETERMINING COARSE SOILS AT THE EXPERIMENTAL SITE DURING THE CONSTRUCTION OF AN EARTH DAM

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Abstract. The aim of the field research was to develop a method for laying and compacting coarse soil material and determining the maximum soil density and optimal moisture content. Based on these studies, technical specifications for the construction of thrust prisms are drawn up. Based on experimental data coarse soils were laid. During the experiment, the authors determined the granulometric composition of the soil, the density of the soil and the moisture state of the soil. The article discusses the laboratory method based on the research, the maximum soil density, optimality and moisture conditions of the soil. Laboratory sealing was carried out using a vibration installation 300mm in diameter and standard SOYUZDORNII sealing equipment. During field work the soil was compacted with various SANY rollers weighing 27 tons. Finally, the maximum density and optimal soil moisture were identified. The result of the work was compaction in layers with a density of 2.117 t/m3, 2.13 t/m3, 2.28 t/m3 with a layer thickness of 50, 70 and 80 cm, respectively. The soil was compacted in six to eight passes along one path using a 27-ton roller.

Keywords: granulometric composition of soil, dam, coarse soils, field research, soil moisture, density, filtration properties

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ЖЕР БӨГЕТІ ҚҰРЫЛЫСЫНЫҢ ЭКСПЕРИМЕНТАЛДЫ АЛАҢШАСЫНДА ІРІ СЫНЫҚТЫ ГРУНТТАРДЫ ЛАБОРАТОРИЯЛЫҚ ӘДІСІН ЗЕРТЕУДІ АНЫҚТАУ

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Аннотация. Біздің далалық зерттеу жұмысымыздың мақсаты ірі сынықты грунт материалын төсеу және тығыздау әдісін әзірлеу, максималды тығыздық пен грунттың оңтайлы ылғалдылығын алуды және оны анықтауды қамтамасыз ету болды. Осы зерттеулердің негізінде призмаларды пайдалану арқылы, оның техникалық шарттары жасалады. Қазіргі уақытта қолданылып жүрген әдістер біздің тәжірибелік жұмысымыздың мәліметтері бойынша ірі сынықты грунттарын төсеу жұмыстары жүргізілді. Тәжірибелік жұмыста біз оны анықтадық: грунттың гранулометриялық құрамын, грунттың тығыздығын және оның ылғалдылық күйі анықтадық. Мақалада біздің зерттеулерімізге негізделген зертханалық әдіс, грунттың максималды тығыздығы, грунттың оңтайлылығы және ылғалдылық жағдайлары қарастырылды. Біздің зерттеуімізде тәжірибелер жүргізіліп, ірі сынықты грунттар әр қабат сайын төселді, сол қабаттарында жүргізілген зертханалық және далалық тәжірибелердің нәтижелері талқыланды. Зертханалық жұмыста диаметрі 300 мм діріл қондырғысын және стандартты СОЮЗДОРНИИ жабдығын пайдалану арқылы жүзеге асырылды. Дала жұмыстары кезінде грунт салмағын 27 тонна болатын түрлі SANY тығыздағыштарымен тығыздалды. Соңында максималды тығыздық пен грунттың оңтайлы ылғалдылығы анықталды. Бұл жұмыста тығыздығы 2,117 т/м^3, 2,13 т/м^3, 2,28 т/м^3 қабат қалыңдығы тиісінше 50, 70 және 80 см қабаттарда нығыздау кезінде нәтиже берді. Грунт 27 тонналық тығыздағыш арқылы пайдаланып, бір жол бойымен алты-сегіз өткелде тығыздалды (Artykbaev et al., 2020).

Түйін сөздер: грунттың гранулометриялық құрамы, бөгет, ірі сынықты грунт, далалық зерттеулер, грунттың ылғалдылығы, тығыздығы, фильтрациялық қасиеттері

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ИССЛЕДОВАНИЕ И ЛАБОРАТОРНЫЕ МЕТОДЫ ОПРЕДЕЛЕНИЯ КРУПНООБЛОМОЧНЫХ ГРУНТОВ НА ЭКСПЕРИМЕНТАЛЬНОЙ ПЛОЩАДКЕ ПРИ СТРОИТЕЛЬСТВЕ ЗЕМЛЯНОЙ ПЛОТИНЫ

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Аннотация. Целью данных полевых исследований была разработка метода по укладке и уплотнению материала крупнообломочных грунтов, а также определение максимальной плотности грунта и оптимальной влажности. На основе этих исследований в дальнейшем составляются технические условия на строительство упорных призм. По данным эксперимента была проведена укладка крупнообломочных грунтов. В экспериментальной работе исследователи определили гранулометрический состав грунта, плотность грунта и влажностное состояние грунта. В статье рассмотрен лабораторный метод по проведенным исследованиям, максимальная плотность грунта, оптимальность и влажностные состояние грунта. Лабораторная герметизация осуществлялась с использованием вибрационной установки диаметром 300мм и стандартного герметизирующего оборудования «СОЮЗДОРНИИ». В ходе полевых работ грунт уплотнялся различными катками типа «SANY» массой 27 тонн. В конце были выявлены максимальная плотность и оптимальная влажность грунта. Результатом работы стало уплотнение слоями плотностью 2,117 т/м^3, 2,13 т/м^3, 2,28 т/м^3 при толщине слоя 50, 70 и 80 см соответственно. Уплотнение грунта производилось за шесть-восемь проходов по одному пути 27-тонным катком.

Ключевые слова: гранулометрический состав грунта, плотина, крупнообломочные грунты, полевые исследования, влажность грунта, плотность, фильтрационные свойства

Introduction

In recent years, coarse-grained soils have been used in a wide variety of elements of soil structures. In industrial-civil, hydrotechnical, water management and road construction, their share is 75 % or more. In this case, the main task is to make soils in layers (Hardin, 2023).

For the first time, granulometric analysis, as a quantitative method, was applied in the XVII century in geology to study clastic sedimentary rocks. At the same time, a set of sieves (1704) were be used to classify the material along with grinding (1692). At the beginning of the XIX century the method of soil sieving through a set of sieves and the method of grinding for granulometric analysis (1805g.) was worked out and described. For the first time, a centrifugation method was developed to separate grains by size. The introduction of graphic images of the results of granulometric analysis dates to the same time. Thus, by the beginning of the XX century the methods of granulometric analysis of granular materials were sufficiently justified.

In this work, the basic requirements and the granulometric composition of the soil in mining industry was created based on numerous studies, the theory of crushing, grinding and screening of minerals. The main provisions of it can be used by other industries .

Usually, high-quality materials for the coating device were determined by such characteristics as strength, density, humidity, and soil deformation. To comply to the standards of soil coatings for each facility and conduct extensive experimental studies to demonstrate these standards for coatings in the dam we use coarse-grained soils.

The material in any zone of a rock-soil dam is determined by its strength, deformability and filtration properties, to meet these requirements, the granular composition of the soil must be determined at the construction stage. The density of coarse soil and its granulometric composition should be determined during experimental work. Therefore, the accuracy of determining the granulometric composition of coarse-grained soils is of great importance .

Earthen and stone-filled dams have become the main form of high dams due to their adaptability to various terrain conditions, on-site extraction of material, structural simplicity, and ease of construction. Coarse-grained soils, widely used as embankments in the construction of dams, are a class of gravel soils of wide gradation with widely varying grain sizes, and particle destruction under high loads is very common. The destruction of particles causes significant deformation of the dam, which, in turn, leads to cracking of the surface layer increasing seepage in neighboring positions. These problems endanger the safety of dams, which becomes a relevant topic for a project aimed at building earthen and stone-filled dams. In the construction of high dams the deformation and destruction effect of coarse soils should be controlled.

Tan et al. (Baibolov et al., 2022) found that the angle of internal friction and adhesion of coarse-grained soils tended to increase and then decrease with increasing coarse-grained content, porosity changed accordingly, which, in turn, caused differences in the dilatation characteristics of soils with varied sizes of grain. After comparing the current appropriate boundaries and different soil particles limiting particle size distribution in soils, Hardin (Alai et al., 2012) proposed the particle destruction rate for a theoretical description of the effect of soil particle destruction, which was widely used by researchers. Alai and Mahbubi (Fard, 2020) noted that the destruction of particles directly changed the gradation of soil particles and affected a number of physical properties, such as the structure of aggregates of soil particles, the degree of occlusion and friction between particles.

Various methods are used to study the granulometric composition of coarse-grained soils, of which the most used are the standard sieving method on sieves with round holes and the linear measurement method. The linear method for determining the granumetric composition can be described as follows: on the open surface of the structure (slope, pit wall, etc.), several lines are outlined using slats or stretched ropes. At the intersection of each line, the sums of the particle lengths of all fractions are calculated. For each particle, only the length that is located on the intended line is calculated, but it belongs to the fraction of the entire section (Artykbaev et al., 2019).

In the practice of construction, the granulometric composition of the soil with various coarse-grained materials where the size of individual pieces reaches 500, 1000 mm or more is determined. To determine the mechanical characteristics of coarse-grained soils in laboratory conditions, they resort to identification of the granulometric composition of the soil from the natural soil.

Based on the study and analysis of numerous experiments and dependencies, we have developed a method for composing model mixtures that characterizes the composition and condition of the soils under consideration more objectively (Ghorashi et al., 2023).

When using modeling methods for coarse-grained soils, it was determined that the dimensions in the sieve should not exceed 5 mm for simulated and full-scale soils. The size of the largest fraction was the size of the sieve particle. Therefore, the graph of the granulometric composition was determined with two points: the percentage of fine-grained soil we always calculated the maximum density. In this case, we use a modeling technique that eliminates arbitrariness when assigning sieves from 5 to 60 mm.

Research materials and methods.

This is relevant for earth dams in which large-block soils are used. It is known that large-block soils are used to support prismatic structures, which on average account for 70% of the total construction and installation work. We studied coarse soils under various loads, with various soil properties, in which they were used for a dense subgrade, and this is considered the main stage of construction, since its effectiveness depends on it (Hristova et al., 2021). In field conditions at the experimental site, the density was determined by the pit-hole method. At the same time, the volume of the pit was determined by pouring water onto a pre-lined polyethylene film 0.3 mm thick (Fig. 1) (Ibragimov et al., 2021).

Figure 1 – Determination of density using the “pit-hole” method of the first layer after two passes with a smooth roller with a vibrator turned on

The aim of the research was to develop and select a layout for the dam in the field. In which it ensured its maximum density and optimal humidity. To determine this, we set goals to be achieved in laboratory conditions. After laboratory studies, we compared them under natural (field) conditions. In which the density and moisture content of coarse soils was determined.

Laboratory compaction, unlike field conditions, was carried out not by rolling, but by compacting the soil using a standard compaction device. In order to save money, the filling of the experimental embankment was carried out directly at the construction site on the left bank of the Pskem River. For these purposes, the plant layer was cut off on a horizontal section, leveled and the surface was compacted with a 27-ton smooth SANY roller. The planning of the base was carried out subject to possible deviations from the base horizon of up to 5 cm.

The size of the platform was 110x110 m. Passage vibration action was 5–7 times per track. The cleared area was leveled at 10 m intervals at each point to align the measured cross-section. The site was leveled using thrust prisms and experimental backfilling for the first and second layers of core filtration.

Contour landmarks were installed; as an orientation, the F16–40 armature, a 1.5m long rod was used to show the platforms and alignment. Then the density of the soil base was determined using the split ring method. Currently, stone-filled dams are the most urgent issues of the earthworks. Studies of the behavior of coarse-grained materials under high loads are of particular importance for stone-earth dams.

Since the strength and stability of the structure depends on the properties of the soil, the choice of soil properties to be used in the construction of earthworks on the dam is determined by an important component in the design. At the Pskov HPP facility, we determined the density and humidity of the soil using a prism. The facility will use support prisms for the enclosure, which is located at the height of the dam with a distance of 2–3 km.

The soil was transported by large-capacity dump trucks of the BelAZ type with a lifting capacity of up to forty tons. Laboratory and full-scale compaction of coarse-grained soils was carried out at the site. In the experimental plots, the soil was bulldozed into uncompacted layers with a thickness of 50cm, 70cm and 80 cm. After leveling, water was supplied from a water carrier with a volume of 200 liters.

In the facility, the soil was laid with smooth rollers weighing 27 tons at a low speed; in each second pass, two pits were made in each layer and the density was measured using the pit depth method. (Fig.2). Sampling of stones and the results and discussion of measurements were carried out as described below.

The layers were selected from the surface as follows: a carefully aligned horizontal pad1.5x1.5 m was prepared, within which a metal frame1.1x1.1m was installed, through which a "pit" passed to the depth of density determination. The volume of the pit was measured by pouring water on a black film (Ibragimov et al., 2020).

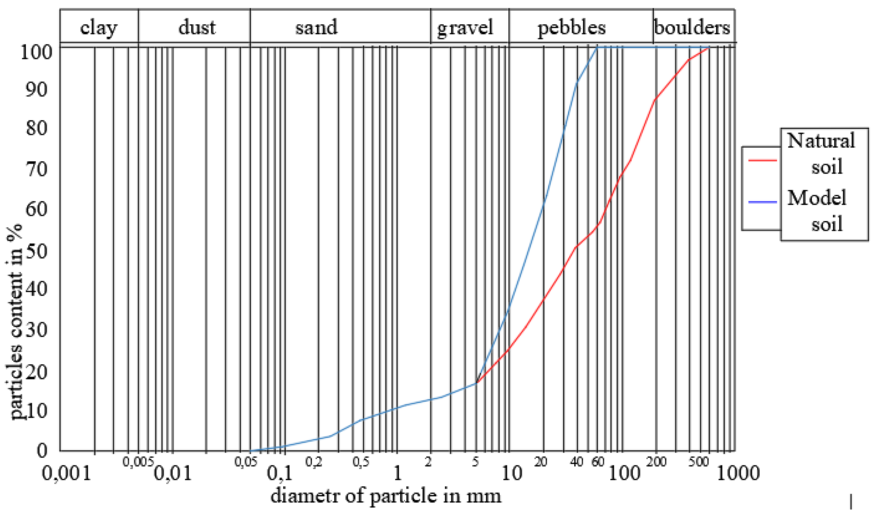

Figure 2 - Simulated soil method

The density of the soil is determined by

$$p\frac{w}{d}=\frac{P}{V}$$

where: p-weight ground, kg; V-volume, l; $p\frac{w}{d}$ - soil moisture.

Moisture in the coarse-grained soil does not have a significant effect on the density of the soil, so we should be careful in the presence of more than 5 % finely dispersed soil (fr<5 mm). It is necessary to measure and adjust its moisture content of all soils of the samples. The humidity in the selected materials is determined and dried in an oven of 2 kg to a thickness of less than 20 mm.

The samples were determined in accordance with the maximum size of the material contained in it and is determined by GOST 28514–90. The assessment of the quality of the underlying natural soil is carried out according to the general curve of the granulometric composition determined by seeding in the field laboratory conditions.

To study large-block soils on the body of the dam, we must know the granulometric composition, mechanical, physical properties, and design characteristics of soils. The use of such soils is difficult due to factors such as labor intensity, particle size, sample volume and the need to use extensive measuring equipment (Tang et al., 2018).

We evaluate the sealing capabilities of large-block soils carried out on standard sealing equipment according to standard sealing techniques in accordance with regulatory requirements. At the same time, the sizes of individual grains reach 700–1000 mm.

This forces the experimenter, when studying coarse-grained clastic soils in laboratory conditions, to switch to modeling the granulometric composition of natural soils and conducting experimental determinations on model mixtures. The work on modeling the granulometric composition of soils is carried out in such a way that the model mixture can be used in laboratory equipment of an acceptable size. At the same time, the properties of the model mixture should correspond as much as possible to the properties of the natural soil (Kronik, 2017).

Based on the experimental studies of large-block soils, it can be concluded that the diameter of the equipment to the maximum size of the mesh fraction is at least 5d max for equipment ≥5 dmax. For standard equipment dmax=300 mm, the maximum screen size should be 60 mm. When specifying the granulometric composition of the model mixture, it is recommended to observe the fraction from 5 mm to 10 mm in size. On the graph you can see the granulometric composition of the full-scale mixture, 2 points are fixed-the fine-grained fraction and the maximum fraction (Fig. 3). The experiment of large-block soils was carried out by JSC "Gidroproekt"

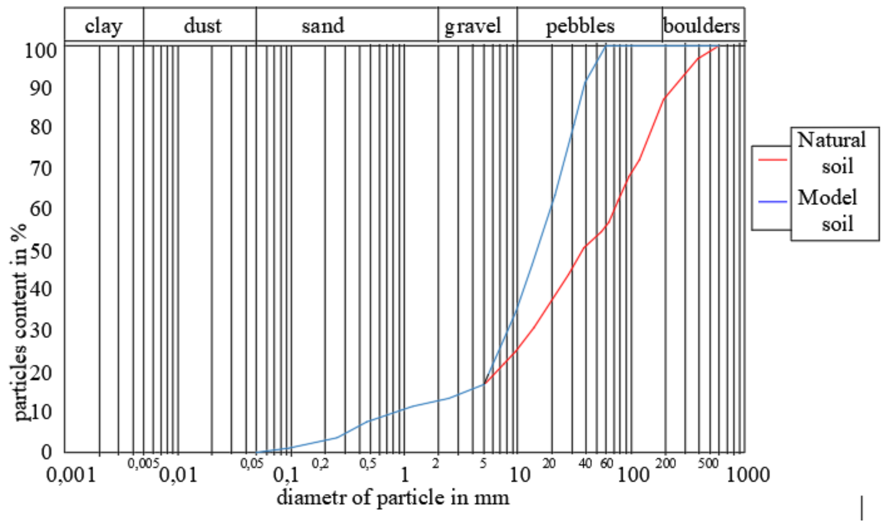

Figure 3 – Modeling of large-block soils

When using the method of modeling large-block soils, the proportion of 5 mm or more should be the same for simulated and natural soils. The maximum fraction should be determined by the small size of the box. The graph shows the granulometric composition of the full-scale mixture, there are two points: the content of fine-grained soil and a large fraction. The modeling approach used here excludes the arbitrariness of allocating fractions of at least 5 or 60 mm. The middle point on the graph is obtained by proportionally reducing the fraction in the natural soil and is calculated using the formula:

$$P\frac{m}{d}=\frac{Pi-P<5}{p\frac{H}{I}-P<5}(100\text{- }p<5)+p<5$$

$P\frac{m}{d}$ - the percentage of sizes in the full-scale mixture

$p<5$- grid sizes < 5mm;

$p\frac{H}{I}$ - the percentage of soil

For each type of material, model mixtures are prepared, which are tested by laying for soil compaction. On each layer of the laying, the mixture is moistened so that the moisture content of the fine-grained soil in the mixture is from 5 to 6%. After that, the vibration units are placed in a container (Fig. 4), leveled and measured between the surface of the soil and the top of the installation at five points using a measuring ruler. And it defines five points on the ground surface and can rotate 90° (Huang et al., 2016).

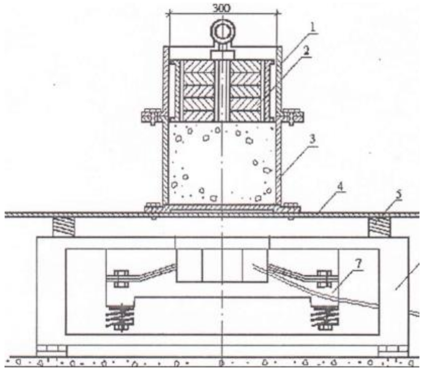

Figure 4 – Vibration installation for soil compaction: 1-cylinder direction, 2-soil loads, 3-boxes, 4-metal plate, 5-spring hole, 6-frame, 7-vibrator.

The position of the bottom and the ground can be determined as a sample. After that a vibrator, which is fixed to the bottom of the platform can be connected, and the vibration lasts 8 minutes. Then the additional packaging material and the rubber gasket are removed, the surface in ten points of the container is measured, according to which the maximum density of the compressed sample is calculated (Liu et al., 2020).

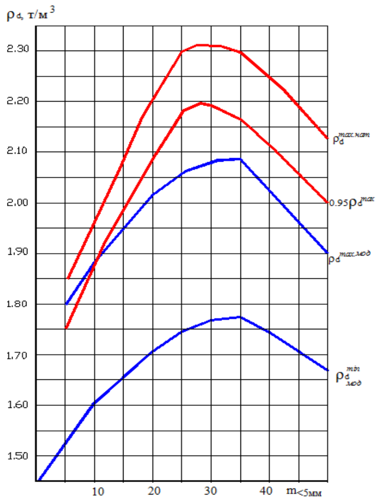

Figure 5 – Graph of the maximum density of additives from the composition of the soil for d<5 mm fractions

The value of the limiting density of the additive allows to make a graph from two points: the content of small grains 'm' and density “p_d”. in a mixture of a model granulometric composition. The graph shows the extreme density values at a certain content of fine grains in the composition and the mixture under study. By testing mixtures with different fine grain contents, it is possible to determine the optimal fine grain content (Fig. 5). From the results of compaction of the model mixture, its maximum additional density and the maximum density of natural soil, it follows that the required coating density is $0.95p^{max}_{d}$

Table 1 - Compaction of model mixtures

N	The content of fr. <5mm, in %	The content of fr. <20mm, in %	Density of model mixtures, t/m³		Nature ground ρ_d^{max}, t/m³ t/m³	Required densities ρ_d^{mp}, t/m³
			ρ_d^{mix}	ρ_d^{max}		
1	24	34	1,57	2,01	2,15	2,22
2	17	46	1,70	1,89	2,03	2,12
3	9	32	1,76	2,04	2,14	2,24

The results shown in Table 1 are used to determine the relative density of quarry stones for a granulometric composition containing 10–25 % fine fractions.

Table 2 - Experimentally proven data

Experimental data	Composition, %	Soil density , t/m³			
		I_d=0,65	I_d=0,70	I_d=0,75	I_d=0,80
	24	1,83	1,85	1,89	1,97
	17	1,79	1,82	1,84	1,89
	9	1,75	1,83	1,85	1,87

We have determined on an experimental site the results of dense soil with persistent prisms, in which it depends on the layers in which the skating rink went and different thicknesses, which you can see in the following figures. (Fig. 6,7 and 8).

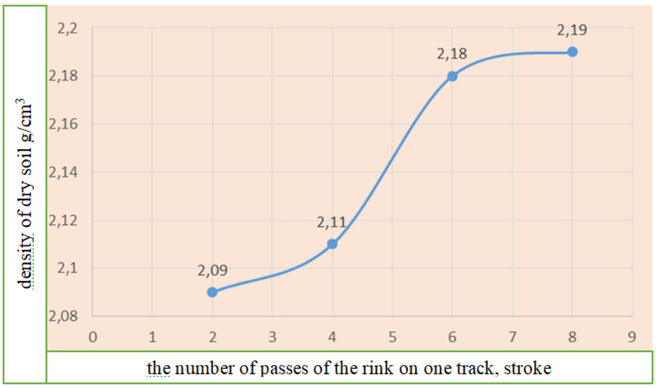

Figure 6 – The density is determined in each 50cm layer with the vibrator turned on

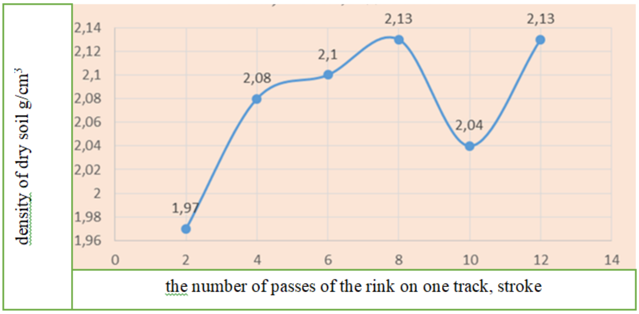

Figure 7 – The density is determined in each 80 cm, in which water is displaced 160 liters per m^3 layer, with the vibrator turned on

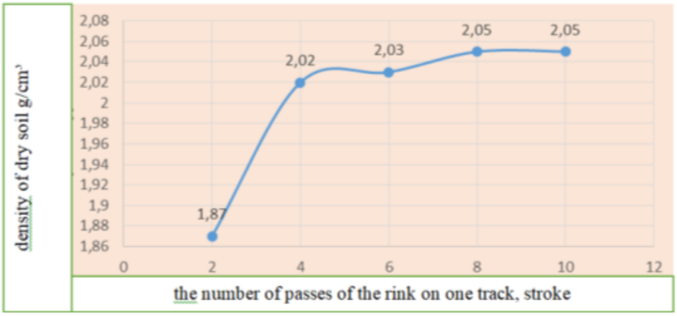

Figure 8 – The density is determined in each 70 cm layer, in which water is displaced 160,1 liters per m^3, with the vibrator turned on

Thrust prisms (stones) from bedrock were laid in layers of 50 cm, 70 cm, and 80 cm, rehydrated from a water carrier and pressed with a 27-ton roller for 6–8 revolutions. We obtained all the above data on an experimental site, with a granulometric composition of up to two hundred mm. In a quarry with the application of blasting, an experimental curve can be used to estimate the granulometric composition of the resulting stone. At the same time, it is possible to determine the effectiveness of the method in maintaining the required granulometric composition of the stone (Peng, 2022). To complete the results on the granulometric composition of the stone, we needed to make a processing experiment in order to determine the method of shot blasting to obtain the required fraction (Rassulov et al., 2020). By an expedient method, we calculated how to make it to a ground degree.

An expedient way to obtain a high density is the distribution of stones of one meter, forced wetting with water with a flow rate of 150–300 l/m3 and sealing with a vibrating mechanism with a large radius of action. To prevent the scattering of stones, it is recommended to distribute them evenly over the surface of the layer with heavy-duty dump trucks, and then level them with a bulldozer (Rasulov et al., 2023).

As can be seen from the granulometric composition and density of stones laid in the experimental embankment, the relative sediment of stone layers in the embankment decreases with an increase in the content of fine-grained (<5 mm) soil in the composition of the embankment; when loading 4.0 MPa, the sediment also decreases from 8.6 mm to 6.2 mm, becoming significantly larger with an increase in the fine grain of the rock and the deformation of the material increases. The most optimal value of the content of fine-grained rock in the composition of the soil is 18–25 %, at which the amount of subsidence does not exceed 6 mm (Shabayev et al., 2020).

Results

The simulated task of the granulometric composition of the soil was performed in this case in laboratory situations using fraction sizes. The content of natural soils and modeling should always be consistent with each other. The size of the fractions depends on the granulometric composition of the soil. The large-block soils diameter must not exceed five, i.e. $d_{np} \geq 5d_{\max}$. So, for a standard we used the diameter of the installed equipment d = 300 mm, a great value does not exceed 60 mm (Internet, 2022).

When assigning grain composition in full-scale conditions, for determining the size of the sieves, the size is from 5 to 10 mm. Since the graph can be used to determine the granulometric composition of the soil in which two points are displayed – the first one is the minimum and maximum fraction in the case, a modeling method is used that excludes the arbitrariness of fractions from 10 to 60 mm.

For a standard seal, we made various natural mixtures with each layer. The granulometric composition of the natural mixture can be seen in Figure 9

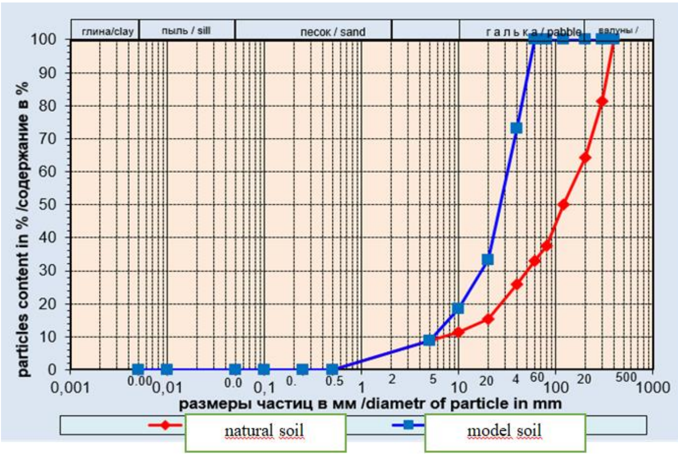

Figure 9. Granulometric composition of the soil

Knowing the diameter and h container, the volume can be calculated. The weight of the model mixture for a container with a diameter of d = 300 mm can be assumed to be 40-45 kg. Based on this weight, the weight of all fractions of the model mixture can be calculated.

Dividing the total volume of the sample is the ratio of its specific gravity, we get the bulk density ρ_d^{min} In this case, humidity is not considered, because the sample was formed in an air-dry state. A 10 mm thick rubber gasket is placed on the soil sample with a minimum density and a sample load is installed, consisting of metal discs assembled into a package with a through rod with a total weight of 100 kg. Rubber rings are put on the bag in the upper and lower parts so that the package does not hit the walls of the device. At this time loading discs, considering the diameter of the shock absorption rings, should freely pass into the container.

It should be noted that the best compaction of the rock mass can be achieved only based on experimental rolling on special filling maps. We compacted the coarse-grained soil with the state standard, where maximum addition densities are obtained for each type of material (ρ_d^{min} ; ρ_d^{max}). The results of the standard seal are shown in Table 3. High density addition of model mixtures, as high density of the natural soil layer soil and the required laying density are equal 0,95 ρ_d^{max} (Tilloev, 2019).

Table 3. Results of standard compaction of stone material

Zones	Densities of model mixtures		Natural soil	Required densities ρ_d^{mp}
	ρ_d^{max}	ρ_d^{max}	ρ_d^{max}	
WE	1,52	1,98	2,14	2,03
WN	1,49	1,87	2,12	2,01

Conclusion

When developing stone quarries with the help of explosions, it is possible to evaluate the grain composition of the resulting stone material using experimental optimal curves. At the same time, it is possible to judge the effectiveness of the applied method of conducting drilling and blasting operations in a quarry, which ensures the production of stone material of the required grain composition. To obtain complete information on the grain composition of the stone material, experimental blasting operations should be conducted, in which the method of explosions to obtain the required fractions will be determined.

According to the data obtained, the most rational, providing a high density, is the method of laying stone material in layers no more than 1.0 meters thick with mandatory wetting with water at a flow rate of 150–300 l/m3 and sealing with a vibrating mechanism of a large radius of action. To prevent layering, it is recommended to lay stone material with large-capacity dump trucks with a uniform distribution over the surface of the layer, followed by leveling with bulldozers.

The “fish” of the stone curve for a thrust prism reaches up to 1000 mm in fraction, and according to the results of experiments at the test site 200 mm, i.e., the curve shown on the graph is the upper curve. To obtain the data of the lower curve, it is necessary to conduct research during the filling process at the construction site of the Pskov dam.

As can be seen from the granulometric compositions and densities of the stone material laid in the experimental embankment, the relative precipitation of the layer of stone material in the embankment decreases with an increase in fine-grained fractions in the soil composition (fr.<5 mm). At loads of 4.0 MPa, they also decrease from 8.6 mm to 6.2 mm with an increase in fine earth from 5 % to 18 %. With an insufficient amount of fine-grained rock, the porosity of the rock mass is high enough and the deformations of the material are significant. The most optimal value of fine-grained soil is 18–25 %, at which precipitation will not exceed 6 mm.

Domestic and foreign experience in the construction of pressure-bearing soil structures shows that at different stages of design, no matter how the indicators of the properties of soil materials are established, their uncertainty is inevitable, since they must correspond to the actual density of the laid soil in the structure, the exact value of which becomes known only during construction. Even experienced rolling operations, which establish not only the technological parameters of soil laying, but also the geotechnical properties after its compaction, do not show sufficiently accurate values of soil properties, since they are carried out in conditions different from the main construction in terms of the scale of excavation, they cannot consider all the spatial variability of soil properties in quarries.

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