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LABORATORY DETERMINATION OF THE MAXIMUM DENSITY AND OPTIMAL HUMIDITY OF LARGE-BLOCK SOILS

ЗЕРТХАНАЛЫҚ ЖАҒДАЙДА ІРІ СЫНЫҚТЫ ГРУНТТАРДЫҢ МАКСИМАЛДЫ ТЫҒЫЗДЫҒЫ МЕН ОҢТАЙЛЫ ЫЛҒАЛДЫЛЫҒЫН АНЫҚТАУ

ЛАБОРАТОРНОЕ ОПРЕДЕЛЕНИЯ МАКСИМАЛЬНОЙ ПЛОТНОСТИ И ОПТИМАЛЬНОЙ ВЛАЖНОСТИ КРУПНООБЛОМОЧНЫХ ГРУНТОВ

Annotation. *The purpose of our field research was to develop and select a method of work on laying and compacting the material of large-block soils, ensuring the receipt and determination of maximum density and optimal soil moisture. On the basis of these studies, technical conditions for the construction of thrust prisms are further drawn up.*

This article presents the results of the work performed with a brief methodology of field and laboratory research. The article provides data characterizing the material intended for installation in the body of the dam.

The currently existing methods for determining the control parameters of laying large-block soils are contradictory and require experimental work. A number of parameters are taken into account: grain composition, humidity, density. Therefore, the article considers a laboratory method for determining the maximum density and optimal humidity of stone material when laying in the body of the dam.

The results of the research carried out on the development of our quarry area, the thickness of the uncompacted layer was determined, the choice of a sealing mechanism, the number of passes along one track, the determination of the density of dry soil in experimental field sites intended for use in filling the body of the dam, graphs of the required densities for full-scale grain composition are presented.

The strength properties of the stone material were determined experimentally for the average grain composition and for the upper curve of the accepted "fish".

Keywords: *coarse-grained soil, maximum density, optimal humidity, natural soil, model mixture.*

Аңдатпа. *Біздің далалық зерттеулеріміздің мақсаты топырақтың максималды тығыздығы мен оңтайлы ылғалдылығын алуды және анықтауды қамтамасыз ететін ірі сынықты топырақ материалын төсеу және тығыздау бойынша жұмыстарды жүргізу әдісін пысықтау және таңдау болды. Осы зерттеулердің негізінде болашақта тіреуіш призмаларды тұрғызудың техникалық шарттары жасалады.*

Осы мақалада далалық және зертханалық зерттеулердің қысқаша әдістемесімен орындалған жұмыстардың нәтижелері келтірілген. Мақалада бөгеттің денесіне салуға (төсеуге) арналған материалды сипаттайтын мәліметтер келтірілген.

Қазіргі уақытта ірі сынықты топырақты төсеудің бақылау параметрлерін анықтаудың қолданыстағы әдістері әр түрлі және тәжірибелік жұмыстарды қажет етеді. Бұл бірқатар параметрлерді ескереді: гранулометриялық құрамы, ылғалдылық және тығыздық. Сондықтан бұл мақалада бөгеттің денесіне топырақты төсеген кезде ірі сынықты тасты материалдың максимал тығыздығы мен оңтайлы ылғалдылығын анықтаудың зертханалық әдісі қарастырылған.

Біздің карьер алаңын әзірлеу бойынша жүргізілген зерттеулердің нәтижесінде тығыздалмаған қабаттың қалыңдығы, тығыздау механизмін таңдау, бір із бойынша өту саны, бөгет денесін төгу кезінде пайдалану үшін шамалау тәжірибелік-далалық учаскелердегі құрғақ грунттың тығыздығы анықталады, натурал гранулометриялық құрамы үшін қажетті тығыздықтардың графиктері ұсынылды.

Тас материалының беріктік қасиеттері орташа гранулометриялық құрам үшін және қабылданған жоғарғы гранулометриялық қисық үшін эксперименталды түрде анықталды.

Түйін сөздер: *ірі сынықты топырақ, максималды тығыздық, оңтайлы ылғалдылық, табиғи грунт, аралас қоспа.*

Аннотация*. Целью наших полевых исследований являлось отработка и выбор способа производства работ по укладке и уплотнению материала крупнообломочных грунтов, обеспечивающих получение и определение максимальной плотности и оптимальной влажности грунта. На основе этих исследований в дальнейшем составляются технические условия по возведению упорных призм.*

В настоящем статье приводятся результаты выполненных работ с краткой методикой полевых и лабораторных исследований. В статье приводятся данные, характеризующие материал, предназначенный для укладки в тело плотины.

Существующие в настоящее время методы определения контрольных параметров укладки крупнообломочных грунтов разноречивы и требуют проведения экспериментальных работ. При этом учитывается ряд параметров: зерновой состав, влажность, плотность. Поэтому в статье рассмотрен лабораторный метод определения максимальной плотности и оптимальной влажности каменного материала при укладки в тело плотины.

В результате проведенных исследований по разработке нашей площади карьеры были опеределены толщины неуплотненного слоя, выбор уплотняющего механизма, количество проходов по одному следу, плотность сухого грунта на опытно-полевых участках, предполагаемых для использования при отсыпке тела плотины, представлены графики требуемых плотностей для натурно зернового состава.

Прочностные свойства каменного материала определялись экспериментально для среднего зернового состава и для верхней кривой принятой "рыбки".

Ключевые слова: *крупнообломочный грунт, максимальная плотность, оптимальной влажность, натурный грунт, модельная смесь.*

Introduction. A wide variety of types of coarse-grained soils are widely used in the construction of high ground dams. In general, the quality of materials in any zones of rock-earth dams is determined by their strength, deformability and filtration characteristics. To meet these requirements, it is necessary to specify the grain compositions of the rock mass and the density of their laying at the construction stage.

Density is one of the main physical and mechanical properties of the soil. It should be noted that it largely depends on the granulometric composition. Therefore, the accuracy of determining the granulometric composition of coarse-grained soils is of great importance.

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) began to 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 in a special work. At the end of the XIX century. 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 back to the same time.

Thus, by the beginning of the XX century. The methods of granulometric analysis of granular materials were laid down and sufficiently justified. It should be noted the wide application and scientific development of the basic provisions of granulometric analysis in the mining industry, where, based on numerous studies, the theory of crushing, grinding and screening of minerals was created, the main provisions of which are used by other industries.

Various methods are used to study the granulometric composition of coarse-grained soils, of which the most commonly used are the standard sieving method on sieves with round holes and the linear measurement method. The linear method for determining the granumetric composition is 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 to which the entire section belongs [1].

In the practice of construction production, it may be necessary to determine the granulometric composition of various coarse-grained materials when the size of individual pieces reaches 500, 1000 mm or more. In this case, in order to determine the mechanical characteristics of coarse-grained soils in laboratory conditions, they resort to modeling the grain composition of natural soil.

Based on the study and analysis of numerous experiments and the obtained dependencies, we have developed a method for composing model mixtures that more objectively characterize the composition and condition of the soils under consideration [2].

Using the modeling method, in coarse-grained soil, the percentage of fractions less than 5 mm should be the same in model and full-scale soil. The size of the maximum fraction is determined by the minimum size of the container used. Thus, two points are fixed on the graph of the grain composition of the model mixture: the content of fine earth and the maximum fraction. In our case, a modeling method is used that eliminates the arbitrariness of assigning fractions from 5 to 60 mm. The intermediate points on the graph are obtained by a proportional decrease in the fractions in the natural soil, which are calculated using the formula:

$$P^{м}_{d_i} = \frac{P_{d_i} - P_{<5}}{P^{н}_{i} - P_{<5}} \cdot (100 - P_{<5}) + P_{<5} \qquad (1)$$

where $P^{м}_{d_i}$ – the percentage of fractions in the model mixture; $P_{<5}$ – the percentage of fractions is less than 5mm; $P^{н}_{i}$ – the percentage of the fraction in the natural soil (Figure 1, Table 1). This method of soil modeling is the simplest and most objective [3].

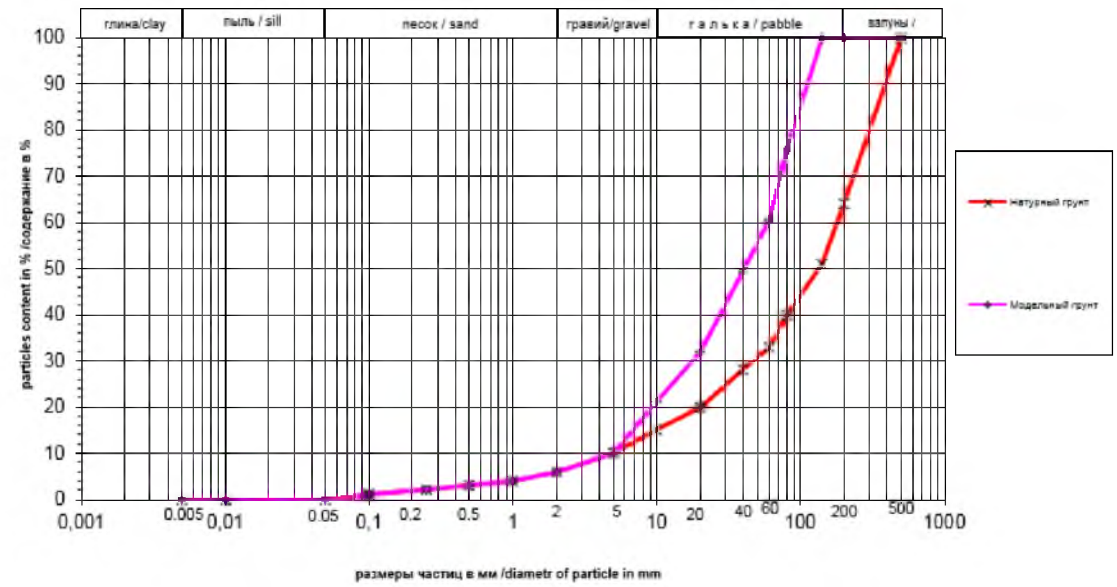

Figure 1. Percentage of fraction in natural soil

Table 1. Calculation table of the granulometric composition of the model soil

Natural soil					Model soil			
					140	The maximum size of fractions in the model soil (mm)		
% fraction content	% of the content of each fraction	weight of fractions in grams	fraction size in mm	fraction size in mm	% fraction content	% of the content of each fraction	weight of fractions in grams	
100,0	0,00	0	>500	500	100,00	0,00	0	
100,0	36,00	1800	200-500	500	100,00	0,00	0	
64,0	13,00	650	140-200	200	100,00	0,00	0	
51,0	11,00	550	80-140	140	100,0	24,15	120732	
40,0	7,00	350	60-80	80	75,85	15,37	76829	
33,0	5,00	250	40-60	60	60,49	10,98	54878	
28,0	8,00	400	20-40	40	49,51	17,56	87805	
20,0	5,00	250	10-20	20	31,95	10,98	54878	
15,0	5,00	250	5-10	10	20,98	10,98	54878	
10,0	4,00	200	2-5	5	10,00	4,00	20000	
6,0	2,00	100	1-2	2	6,00	2,00	10000	
4,0	1,00	50	0,5-1	1	4,00	1,00	5000	
3,0	1,00	50	0,25-0,5	0,5	3,00	1,00	5000	
2,0	1,00	50	0,1-0,25	0,25	2,00	1,00	5000	
1,0	1,00	50	0,05-0,1	0,1	1,00	1,00	5000	
0,0	0,00	0	0,01-0,05	0,05	0,00	0,00	0	
0,0	0,00	0	0,005-0,01	0,01	0,00	0,00	0	
0,0	0,00	0	<0,005	0,005	0,00	0,00	0	
	100,0	5000				100,0	500000	the total weight of the sample in grams
					5	the size of fractions less than which the volume of natural soil does not change		

Therefore, the physical and mechanical properties of the material can be represented as an unambiguous function of two parameters: the content of fine earth m and density ρd, which are determined experimentally based on studies of characteristic differences covering the entire set of quarry soil [5].

A preliminary assessment of the compaction of coarse-grained soil is performed by the standard compaction method in accordance with regulatory requirements on a standard vibration seal device. For each type of material, the maximum densities of soil composition are determined (ρ_d^{min} ; ρ_d^{max}).

The boundary parameters of the total grain compositions adopted by the technical conditions for each variety will have different limiting curves. At the same time, the size of individual fractions reaches up to 700-1000 mm, which forces us to switch to modeling grain compositions of natural soil and performing experimental studies on model mixtures [6].

Results and their discussions. The task of modeling the grain composition of natural soil is performed in such a way that model mixtures can be used in laboratory devices of acceptable sizes. At the same time, the characteristics of the model mixtures should best match the characteristics of the natural soil. The size of the sample tested in the device determines the size of the maximum fraction allowed to be included in the soil mixture. Generalization of the research experience of large-block soils allows us to conclude that the ratio of the sample diameter to the size of the maximum fraction should not be less than five, i.e. $d_{np} \geq 5d_{max}$. So, for a standard device with a diameter of d = 300 mm, the maximum size of fractions should not exceed 60 mm.

When assigning grain composition in model mixtures, it is recommended to keep the percentage of fractions in them less than 5 mm or 10 mm. Thus, two points are fixed on the graph of the grain composition of the model mixture - the content of fine earth and the maximum fraction. In our case, a modeling method is used that excludes the arbitrariness of fractions from 10 to 60 mm [7].

Model mixtures are made for each type of material, which are tested on the installation of a standard seal. Full-scale and model compositions are shown in Figure 2.

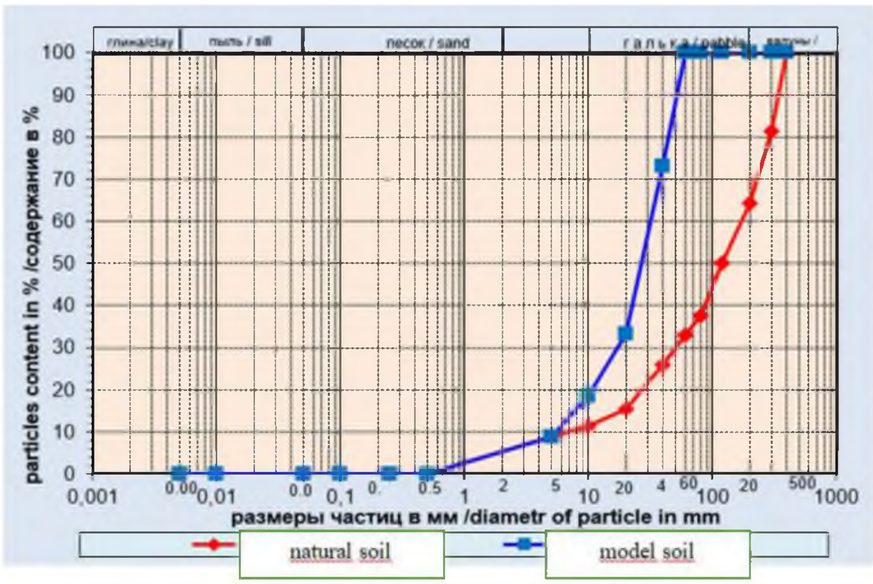

Figure 2. Graph of the grain composition of the rock mass and the model mixture

Before compaction, the mixture is moistened so that the moisture content of the fine earth included in the mixture is at least 5-6%. Then the mixture is loaded into the container of the vibration installation, the distance between the ground surface and the top of the device is leveled and measured with a measuring ruler at five points. The bar of the measuring ruler is rotated by 90 degrees and five more points of the ground surface are measured. The average value of 10 points determines the position of the sample surface from the top of the device, and the difference between the position of the bottom and the ground surface determines the height of the sample.

Knowing the diameter and height of the container, the volume is 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 is calculated.

Dividing the weight of the sample by the volume, we get the bulk density ρ_d^{min}. In this case, humidity is not taken into account, 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 the same time, the loading discs, taking into account the diameter of the shock absorption rings, should freely pass into the container [8].

After assembly, a vibrator is turned on, fixed to the bottom of the platform, and the container vibrates for 6 minutes. Then the loading bag and the rubber gasket are removed and the surface is measured at ten points from the upper face of the container, according to which the volume of the compacted sample and the maximum density are calculated [9-10]. Determination of the limiting densities of soil addition will allow you to plot the function of two parameters: the content of fine-grained soil in a mixture of a model grain composition *m* and density ρ_d [11-12].

It should be noted that the best compaction of the rock mass can be achieved only on the basis of experimental rolling on special filling maps. A preliminary assessment of the compaction of coarse-grained soil is performed by the standard compaction method in accordance with GOST-34-72-646-83 on a standard device, 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 2. The maximum densities of addition of model mixtures, as well as the maximum density of natural soil and the required laying density are equal 0,95 ρ_d^{max} [13-15].

Table 2. Results of standard compaction of stone material

Zones	Densities of model mixtures		Natural soil	Required densities
	ρ_d^{min}	ρ_d^{max}	ρ_d^{max}	ρ_d^{mp}
WE	1.52	1.98	2.14	2.03
WN	1.49	1.87	2.12	2.01

Conclusions. 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.

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.

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 take into account all the spatial variability of soil properties in quarries.

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REVIEW OF RUBBER RECYCLING PRACTICAL STUDIES AND TECHNOLOGICAL DEVELOPMENTS IN USING ASPHALTCONCRETE PAVEMENTS

АСФАЛЬТТЫ ЖОЛ ЖҮЙЕЛЕРІНДЕГІ РЕЗЕҢКЕНІҢ ҚАЙТА ӨҢДЕЛУІ: ҚОЛДАНБАЛЫ ЗЕРТТЕУЛЕР МЕН ТЕХНОЛОГИЯДАҒЫ ЖЕТІСТІКТЕРГЕ ШОЛУ

ОБЗОР ПРАКТИЧЕСКИХ ИССЛЕДОВАНИЙ ПО ПЕРЕРАБОТКЕ РЕЗИНЫ И ТЕХНОЛОГИЧЕСКИХ РАЗРАБОТОК ПРИ ИСПОЛЬЗОВАНИИ АСФАЛЬТОБЕТОННЫХ ПОКРЫТИЙ

Abstract. *This review paper examines the global situation of modifying asphalt binder using crumb rubber, offering a thorough summary of the progress achieved in this area till now. Utilizing a broad range of international experiences, the study explores the various procedures, strategies, and formulations used by researchers and practitioners throughout the globe. The examination covers significant advancements in the manufacture of crumb rubber, the modification procedures of binders, and the subsequent improvements in the performance of asphalt.*

The article analyzes case studies and research results from different nations, highlighting the intricate strategies used to enhance the integration of crumb rubber into asphalt binders. Moreover, the study examines the economic, environmental, and performance-related consequences linked to these alterations, emphasizing the sustainable and cost-efficient elements that have gained growing recognition within the global asphalt community.

This paper seeks to provide significant insights into the current practices, problems, and possible future prospects in the field of modifying asphalt binder using crumb rubber by synthesizing and comparing data from various locations. This resource is very beneficial for academics, engineers, and politicians who want to use worldwide experiences to improve sustainable and resilient asphalt infrastructure.

Keywords: *asphalt modification, bitumen, pavement, crumb rubber, asphalt concrete.*

Аңдатпа. *Бұл жетістіктерге шолу мақалада резеңке ұнтақтарды қолдана отырып, асфальтбетон тұтқыр модификациясының жаһандық жағдайы қарастырылады, осы салада бүгінгі күнге дейін қол жеткізілген прогреске егжей-тегжейлі шолу жасалады. Халықаралық тәжірибенің кең ауқымын пайдалана отырып, зерттеу бүкіл әлем бойынша зерттеушілер мен тәжірибешілер қолданатын әртүрлі технологияларды, әдістер және тұжырымдамаларды*