ISSN NO: 2770-4491
Date of Publication:06-06-2022

Method for determining the maximum density and optimal moisture content of coarse soils

Kayumov A. D.
The Tashkent State Technical University named after Islam Karimov.
Address: University street №2, Tashkent city, Uzbekistan.
Azimova Sh. N.
The Samarkand State Institute of Architecture and
Civil Engineering named after Mirza Ulugbek.
Lolazor street №73, Samarkand city, Uzbekistan

Abstract. This article presents the results of a study to determine the maximum density and optimal moisture content of coarse soils with clay and sand aggregates using large-size SoyuzDorNII device. Values of maximum density and optimum moisture content were recommended depending on the size of the fraction.

Keywords: highways, subgrade, coarse soils, sandy and clay aggregates, standard compaction, maximum density, optimum moisture content, compaction coefficient.

Introduction

The quality of the highway's subgrade construction is ensured by compliance with the requirements of ShNK 2.05.02-07 “Highways” [1] in terms of the coefficient of soil compaction K_{comp}.

The compaction coefficient is understood as the ratio of the actual density of dry soil ρ_d of the subgrade to the maximum density ρ_d^{max}, i.e.:

$K_{comp} = \rho_d / \rho_d^{max}$.

The maximum density of soils up to 20 mm in size is determined by layer-by-layer compaction according to state standards GOST 22733-2002 [2].

For coarse-grained soils, there is no standard for determining their maximum density.

It is known that with an increase in the density of coarse-grained soils, their strength increases significantly, therefore, it is important to determine the maximum density of coarse soils [3].

Methods. Abroad, vibration is used to determine the maximum density of coarse-grained soils and their model mixes. The vibration test method has proved itself in practice and is used worldwide. For example, in the USA, according to the state standard ASTM D2049, the soil sample in a cylindrical mold with a diameter of 152 mm or 279 mm was subjected to vibrations under load on a vibration table under vertically directed oscillation. In this method, due to insufficient freedom of particle motion under vertically directed vibrations, soil repacking is not fully realized.

“Dynapac” company in its own laboratory has developed a method, according to which a top-mounted vibratory rammer compacts the soil in a mold with a diameter of 150 mm. The method was tested and accepted as a Swedish standard. A similar method using a vibratory rammer was developed in England and approved as a British standard.

The disadvantage of these methods for determining the maximum density of coarse soils is the additional crushing of soil samples during testing, which usually leads to an overestimation of the density values and complicates the task of achieving the standard compaction coefficient observed on sites.

Considering the fact that the granulometric composition of coarse-clastic soils can vary in significant ranges (in size and content of fine particles), a special method was developed to study the influence of these parameters on the maximum density and optimal moisture content.

The methods proposed, relate to the construction of roads and airfields, in particular, to the determination of the maximum density and optimal moisture content of the compaction of gravel-crushed stone-sand and other coarse-grained soils with a grain size of more than 20 mm.

When developing a special technique, the following tasks were set for the authors:

ISSN NO: 2770-4491
Date of Publication:06-06-2022

- to develop methods for adapting GOST 23558-94 [4] for testing crushed stone-gravel-sand mixes and other coarse-grained soils that do not contain inorganic binder;
- to increase the maximum grain size of the tested coarse-grained soil to 120 mm;
- the conditions for testing stone material should be as close as possible to the conditions of compaction of coarse-grained materials on sites under the influence of compacting mechanisms;
- to reduce the degree of crushing of coarse-grained soil particles during its testing in laboratory conditions.

Results and Discussion. The task set to determine the maximum density and optimal compaction moisture content of coarse-grained soils with a grain size of up to 120 mm was achieved by the GOST 23558-94 standards with the following additions and changes:

- for testing coarse-grained soils with grain sizes up to 40 mm, it was proposed to use a large-size SoyuzDorNII device;
- for coarse-grained soils with a grain size of 80-120 mm, it was proposed to use a device with a diameter and height 1.5 times greater than the largest size of soil particles;
- the test mix was proposed to pack (to ram) through a rubber pad, which eliminates the crushing of particles during packing and brings the conditions closer to the actual conditions of compaction of coarse-grained soil on sites under the pneumo-wheels of the vibratory rollers.

The proposed method is applicable to coarse-clastic mixes of continuous and discontinuous granulometry, corresponding to the grain composition requirements of GOST 25607-2009 [5], i.e. mixes C3, C4, C5, C6, C7, C8 with continuous granulometry and C9, C10 and C 11 with discontinuous granulometry with upper and lower boundaries.

The maximum density and optimum moisture content of mixes of coarse soils were determined in the following sequence:

- preparation of the device for testing (assembly of the device and its weighing);
-loading the mix to be tested into the cylinder of the device in one step;
- laying a rubber pad 6 mm thick on the surface of the leveled mix;
- for coarse-grained soils with grain sizes up to 40 mm compaction of the mix was conducted by 120 blows of a 2.5 kg kettlebell, falling from a height of 30 cm;
- for coarse-grained soils with grain sizes up to 80 mm compaction of the mix was conducted by 120 blows of a 5 kg kettlebell, falling from a height of 30 cm;
- for coarse-grained soils with grain sizes up to 120 mm compaction of the mix was conducted by 120 blows of a 7.5 kg kettlebell, falling from a height of 30 cm;
- determination of the volume of the compacted mix and soil sampling for moisture content after its loosening;
- repetition of the experiment of the tested mix, with a 0.5% difference in moisture content, until its maximum density is reached.

As a result of the experiment, the bulk density ρ_b, the maximum density ρ_M, the optimal moisture content W, and the compaction coefficient of coarse-clastic mixes , K_{comp}. were determined (see Table 1).

Table 1

Characteristics of coarse-clastic mixes of continuous and discontinuous granulometry

The largest grain size D, mm	Mix number		ρ_b, g/cm^3 or t/m^3		ρ_M, g/cm^3 or t/m^3	Compaction coefficient, K_{comp}.	W, %
1	2	3	4		5	6	7
	Subgrade mixes (continuous granulometry)						
120	C3	upper	1.90		2.36	1.24	3.0
		lower	1.84		2.30	1.25	1.5
80	C4	upper	1.84		2.28	1.24	4.0

ISSN NO: 2770-4491
Date of Publication:06-06-2022

		lower	1.78		2.24	1.26	2.0
40	C5	upper	1.76		2.22	1.26	5.5
		lower	1.70		2.15	1.26	3.3
20	C6	upper	1.71		2.16	1.26	6.2
		lower	1.65		2.06	1.24	5.4
10	C7	upper	1.66		2.12	1.28	6.8
		lower	1.62		2.00	1.23	7.0
5	C8	upper	1.64		2.10	1.28	7.2
		lower	1.60		1.96	1.23	8.0
	Subgrade mixes (discontinuous granulometry)						
80	C9	upper	1.94		2.29	1.18	3.0
		lower	1.86		2.20	1.18	2.2
40	C10	upper	1.84		2.18	1.18	5.1
		lower	1.72		2.07	1.20	4.0
20	C11	upper	1.72		2.09	1.21	7.2
		lower	1.66		1.97	1.19	5.8

Note. *The density of the coarse-grained soil skeleton in the bulk state and under standard compaction can vary depending on their genesis within ± 5%.*

Analysis of the data from Table 1 allows us to state the following:

- bulk density of coarse soils is within 1.60 - 1.90 t/m^3 for mixes with continuous granulometry and within 1.66 - 1.94 t/m^3 for mixes with discontinuous granulometry. Smaller values of density correspond to the lower boundaries; larger values correspond to the upper boundaries of particle size distributions;

- the values of the coefficient of compaction of coarse-clastic soils relative to their bulk density are on average 1.25 for mixes of continuous granulometry and 1.20 for mixes of discontinuous granulometry.

Figures 1 and 2 show the change in the maximum density and optimal moisture content of coarse-clastic soils with pulverescent and clay particles for mixes of continuous and discontinuous granulometry with lower and upper boundaries.

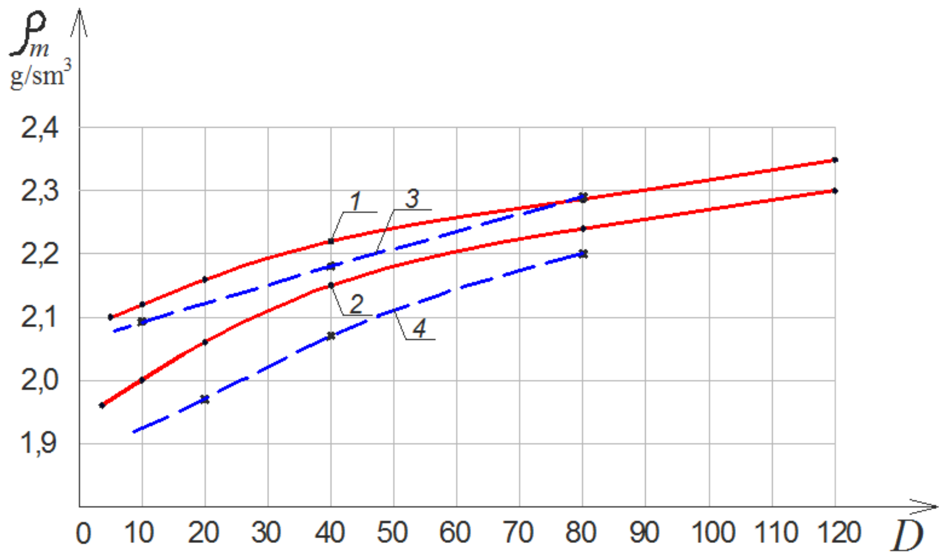

Fig.1. Change in the maximum density of coarse soils with pulverescent and clay particles for mixes of a) continuous granulometry: with 1 upper and 2 lower boundaries; b) discontinuous granulometry: with 3 upper and 4 lower boundaries

ISSN NO: 2770-4491
Date of Publication:06-06-2022

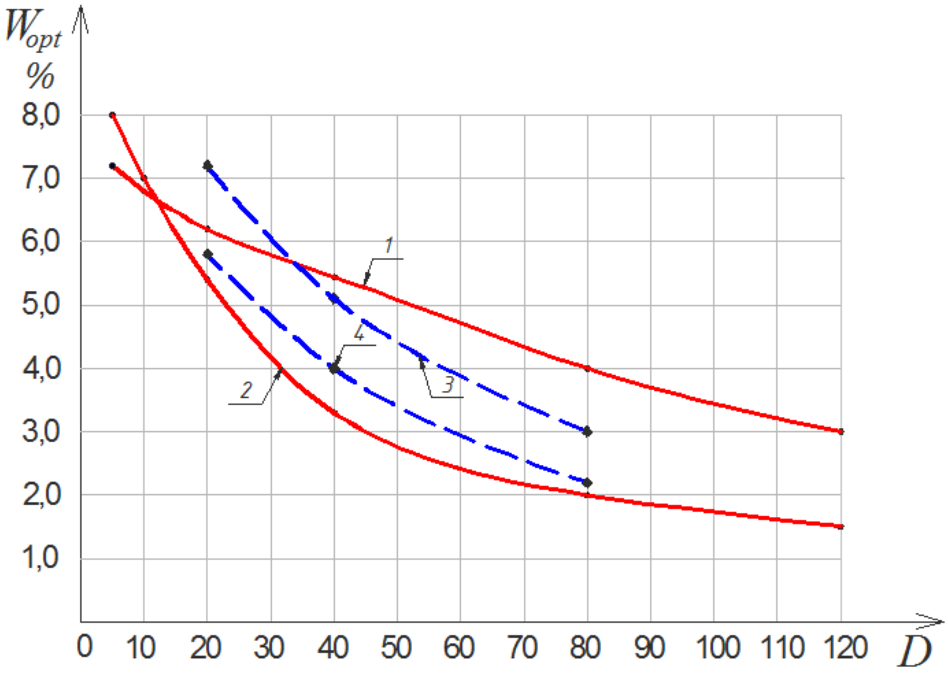

Fig.2. Changes in the optimal moisture content of coarse-grained soils with pulverescent and clay particles for mixtures of a) continuous granulometry: with 1 upper and 2 lower boundaries; b) discontinuous granulometry: with 3 upper and 4 lower boundaries

Analysis of the data from Figs. 1 and 2 allows us to state the following:

- the maximum density of coarse soils is in the range of 1.96 - 2.36 t/m^3 for mixes of continuous granulometry and in the range of 1.97 - 2.29 t/m^3 for mixes of discontinuous granulometry. Here, too, smaller values of the maximum density correspond to the lower boundaries; larger values correspond to the upper boundaries of particle-size distributions;

-optimum compaction moisture content of coarse soils is set within 1.5 - 8.0% for mixes of continuous granulometry and 2.2-7.2% for mixes of discontinuous granulometry. Lower values of moisture content correspond to mixes with a lower content of pulverescent and clay particles, higher values correspond to mixes with a high content of pulverescent and clay particles.

Figure 3 shows the process of compaction of coarse soils during the construction of highways "4N 513 and to Chunkaymish village, 10 km" in Nurabat district of Samarkand region. To achieve the required density K_{comp}.= 0.96, the soils were compacted by eight passes of trailed single-drum vibratory rollers of the XCMG XS163J type at optimal moisture content.

ISSN NO: 2770-4491
Date of Publication:06-06-2022

Fig. 3. Compaction to the maximum density of coarse-grained soils with vibratory rollers at optimal moisture content; Nurabat district, “4N 513 and to Chunkaymish village" highway construction

Conclusions

Thus, knowing from Table 1 and Figs. 1 and 2, the number and dimensions of individual fractions in the composition of coarse-grained soils, it is possible to determine their maximum density and optimal moisture content, which are necessary to achieve the required strength in the construction of highways' subgrades.

References

1. ShNK 2.05.02-07 “Roads”. Goskomarchitektstroy of the Republic of Uzbekistan, Tashkent, 2008. 69 p.
2. GOST 22733-2016. Interstate standard. "Soils. Method for laboratory determination of maximum density. Reissue of GOST 22733-2002. 2019. 20 p.
3. Dobrov E.M. et al. Coarse clastic soils in road construction. -M.: Transport, 1981. 180 p.
4. GOST 23558-94. Interstate standard. Crushed stone-gravel-sand mixes and soils treated with inorganic binders for road and airfield construction. -M.: MNTKS, 2010. 18 p.
5. GOST 25607-2009. Interstate standard. Specifications. Crushed stone-gravel-sand mixes for coatings and bases of roads and airfields. -M.: MNTKS, 2010. 16 p.

Information author's

Prof. Kayumov Abdubaki Jalilovich,
Doctor of Technical Sciences,
Tashkent State Technical University, Tashkent, Uzbekistan
e-mail: abdubakigmg@mail.ru
Azimova Shakhlo Nizomovna
Doctoral Student, Professor's Assistant
Samarkand State Institute of Architecture and Civil Engineering,
Samarkand, Uzbekistan
e-mail: azimovasahlo65@gmail.com