STATE ROAD AGENCY OF UKRAINE
(UKRAVTODOR)

M.P. Shulgin State Road Research Institute State Enterprise
(«DerzhdorNDI SE»)

APPROVED
Deputy Director on Scientific Work
_____ V.I. Kaskiv
"06" 10 2020

REPORT

on execution of works under the Agreement dated 19.12.2019 № 797-19

Conducting research on the feasibility of using Nanoalps GmbH in the base layers of road pavement and subgrade.

Head of Ecology
and Subgrade Department _____ N.M. Kharytonova

Kyiv
2020

PERFORMERS

Head of Department		N.M. Kharytonova (Editing the report, drawing conclusions)
Head of Division		O.A. Mykolayenko (Laboratory tests, report writing)
Junior Scientific Researcher		T.M. Lozova (Laboratory tests, report writing)
Junior Scientific Researcher		D.S. Pivtoratskyi (Laboratory tests, report writing)

ЗМІСТ

INTRODUCTION

M.P. Shulgin State Road Research Institute State Enterprise («DerzhdorNDI SE»), in accordance with the Agreement dated 19.12.2019 № 797-19 on the order of Nanoalps GmbH conducted the studis to determine the impact of additive Nanoalps System SOIL on the physical and mechanical properties of mixtures manufactured by technology of cold recycling, and of soils stabilized with its use.

As part of the Agreement, laboratory tests were performed on the material and a report was issued.

Laboratory tests were carried out by the researchers of the Ecology and Subgrade Department of «DerzhdorNDI SE» in the laboratory accredited by the National Accreditation Agency of Ukraine (Certificate of Accreditation NAAU № 2T493 of 24.05.2018).

1 REGULATORY REFERENCES

1. DSTU B V.2.7-309: 2016 Soils stabilized with binders. Test methods

2. DSTU 8801: 2018 Highways. Guidance on the construction of road pavement layers made of stabilized soils

3. DSTU B V.2.1-2-96 Soils. Classification.

4. DSTU B V.2.1-17: 2009 Soils. Methods of laboratory determination of physical properties

5. VBN V.2.3-218-541: 2010 Transport facilities. Construction of road pavement layers made of soils stabilized with binders.

6. DSTU-N B V.2.3-39: 2016 Guidance on the arrangement of road pavement layers made of stone materials

7. DSTU B V.2.7-46: 2010 Cement for general construction purposes

8. DSTU B V.2.7-273: 2011 Water for concretes and solutions. Technical specifications

9.SOU 45.2-00018112-061: 2011.Construction materials. Organic-mineral mixtures of road milled materials of road pavements made by the method of cold recycling. Technical specifications

10. GOST 166-89 Calipers. Technical specifications

2 SOIL COMPOSITION DESIGN

2.1 General information

Nanoalps GmbH is a company engaged in research and development in the field of applied geotechnics. The company Nanoalps GmbH is based on Alpenbau's long-term xpertise in all technical matters..

Nanoalps System SOIL is a silicon polymer additive which finds its main application as an additive to building materials. It interacts with hydraulic binders and significantly expands their field of application. The polymer in a binder form is neutral to the environment, improves many technical properties and at the same time reduces construction costs. It is also able to interact with salt water.

Nanoalps has obtained a patent for three innovative systems that have already been successfully used in various construction projects abroad and have thus won high recognition among customers.

Nanoalps System SOIL is an environmentally neutral and non-toxic polymer additive that improves the physical and mechanical properties of building materials. The water-soluble substance stabilizes the soil in combination with inorganic binders.

Nanoalps System SOIL is suitable for the following applications:

- subgrade stabilization;
- transition type coverage for lower category roads;
- parking lots, bicycle and pedestrian paths;
- forest roads and roads on ski resorts;
- access roads to construction sites.

2.2 Laboratory research of source material

Tests were performed to determine the physical and mechanical properties of the soil samples provided. For soil identification in accordance with DSTU B V.2.1-17 the following indicators were determined: moisture, yield strength, rolling limit, plasticity value, organic residue content, etc.

2.2.1 Procedure of the study to determine the natural soil humidity

Soil moisture is defined as the ratio of the weight of water removed from the soil by drying to reaching a constant weight to the weight of dried soil.

A soil sample for determining the moisture is taken by weight from 15 g to 50 g, placed in a pre-dried, weighted and numbered cup and closed tightly with a cap. The soil sample in a closed cup is weighed.

The cup is opened and together with the cap is placed in a heated drying chamber. The soil is dried to a constant weight at a temperature of (105 ± 2) ° C. Plastered soils are dried at a temperature of (80 ± 2) ° C.

Dry sandy soils are dried for 3 hours and the rest soils - for 5 hours. Subsquent drying of sandy soils is performed for 1 hour, of others - for 2 hours.

After each drying, the soil in a cup is cooled in an exciter with calcium chloride to the ambient temperature and weighed. Drying is carried out until the difference between the weightes of soil and the cup is obtained with the next two weighings not more than 0.02 g.

If at repeated weighing of the soil containing organic substances there is an increase in weight, the result of weighing is taken as the smallest weight.

Soil moisture *W* in percent is calculated by the formula:

$$W = \frac{100 \cdot (m_1 - m_0)}{m_0 - m}$$

where m – is the weight of an empty cup with a cap, g;

m_1 – weight of wet soil with the cup and the cap, g;

m_0 – weight of dried soil with the cup and the cap, g.

It is allowed to indicate soil moisture in separate units.

2.2.2 Procedure of the study to determine the yield strength

The yield strength is defined as the moisture content of a paste prepared from the soil under study when the balance cone is submerged by its own weight in 5 seconds to a depth of 10 mm.

To determine the yield strength, monoliths or soil samples of the disturbed structure are used, which require the preservation of natural humidity.

The sample of soil of natural humidity is crushed with a spatula in a porcelain cup or cut with a knife in the form of thin chips (with the addition of distilled water, if necessary), having removed plant residues large than 1 mm from it, taken from the

crushed soil by quarting a sample weighing about 300 g and rubbed through a sieve with a mesh number 1.

The sample should be kept in a closed glass vessel for at least 2 hours. It is not allowed to add dry soil to the soil paste.

Prepared soil paste is thoroughly stirred with a spatula and small portions tightly (without air voids) placed in a cylindrical cup of the balance cone. The surface of the paste is smoothed with a spatula flush with the edges of the cup.

The balance cone, lubricated with a thin layer of petroleum jelly, is brought to the surface of the soil paste so that its tip touches the paste. The cone is then gently released, allowing it to dive into the paste under its own weight.

Immersion of the cone in the paste for 5 seconds at a depth of 10 mm shows that the soil has humidity which corresponds to the yield strength.

When the cone is submerged for 5 s at a depth less than 10 mm, the soil paste is removed from the cup, added to the rest of the paste, some distilled water is added, thoroughly stirred and the procedure is repeated again. When immersing the cone for 5 s at a depth of more than 10 mm, the soil paste from the cup is transferred into a porcelain cup, lightly dried in the air, continuously stirred with a spatula and the above procedure is repeated again.

When the yield strength of the paste is reached, the samples weighing from 15 g to 20 g are taken to determine humidity.

The customer provided the soil samples from which three samples were selected for further studies and the laboratory numbers were assigned: 2Б – loamy sand; 6Б – loamy sand; 7Б – loamy sand, soil samples are shown in Figure 2.1.

Figure 2.1 — View of soil samples

According to the Sampling Acts: 2Б (Levandivka microdistrict − Lviv, 0.55 m deep) 6Б (Levandivka microdistrict − Lviv, Zelena Street) 7Б (Levandivka microdistrict − Lviv, Zelena Street) are related to loamy sands.

Table 2.1 — Results of determination of natural soil humidity of 2Б sample

Weighing bottle№	Weight of empty weighing bottle+ cap,*m*, g	Weight of wet material with weigning bottle, m_1, g	Weight of dried material, m_0, g	Individual sample humidity, %	Medium humidity, %
088	22,46	38,37	36,22	15,63	15,67
343	21,82	43,74	40,75	15,80	
280	21,61	39,40	37,00	15,59	

Table 2.2 — Results of soil plasticity index determination of 2Б sample

Plasticity indicators	Weighing bottle number	Weight of empty weigning bottle, g	Weighing bottleweight with wet soil, g	Weighing bottleweight with dried soil, g	Average value *W*, %
Humidity at yield point, W_L	197	22,98	37,92	35,35	20,90
	158	23,39	42,83	39,50	
	218	22,36	40,05	36,95	
Humidity at the rolling limit, *Wp*	034	22,79	33,20	31,66	17,39
	013	23,18	39,03	36,68	
Plasticity index *Ip*	3,51				

Table 2.3 - Results of soil weight loss at calcination of sample 2Б

Crucible number	1	2	3
Output dry weight of sample plus crucible weight $m_d + m_B$, g	52,42	58,39	51,65
Weight of sample and crucible after calcination $m_{gl} + m_B$, g	52,13	58,09	51,34
Crucible weight m_B, g	37,03	42,85	35,13
Weight of soil losses $\Delta m_{gl} = (m_d + m_B) - (m_{gl} + m_B)$, g	0,29	0,30	0,31
Output dry weight of sample $m_d = (m_d + m_B) - m_B$, g	15,39	15,54	16,52
Average value of losses at calcination V_{gl}, %	1,88	1,93	1,88
Average value for the sample	1,90		

Table 2.4 - Results of determining the natural soil humidity of sample 6Б

Weighing bottle №	Weight of empty weighing bottle+ cap,m, g	Weight of wet material with weigning bottle, m_1, g	Weight of dried material, m_0, g	Humidity, %	Medium humidity, %
008	23,19	42,70	40,09	15,44	15,27
013	23,18	41,28	38,89	15,21	
011	22,75	39,02	36,88	15,15	

Table 2.5 - Results of determining the soil plasticity index of sample 6Б

Plasticity indicators	Weighing bottle number	Weight of empty weighing bottle, g	Weighing bottle weight with wet soil, g	Weighing bottle weight with dried soil, g	Average value W, %
Humidity at yield point, W_L	130	21,14	38,12	34,74	24,86
	379	22,02	38,73	35,38	
	326	23,13	38,81	35,71	
Humidity at the rolling limit, Wp	359	23,19	33,32	31,60	20,87
	351	20,53	32,10	30,07	
Plasticity index Ip	3,99				

Table 2.6 - Results of soil weight loss at calcination of sample 6Б

Crucible number	1	2	3
Output dry weight of sample plus crucible weight $m_d + m_B$, g	62,31	46,63	46,33
Weight of sample and crucible after fying $m_{gl} + m_B$, g	61,76	46,06	45,77
Crucible weight m_B, g	47,24	31,01	30,75
Weight of soil losses $\Delta m_{gl} = (m_d + m_B) - (m_{gl} + m_B)$, g	0,55	0,57	0,56
Output dry weight of sample $m_d = (m_d + m_B) - m_B$, g	15,07	15,62	15,58
Average value of losses at calcination V_{gl}, %	3,65	3,65	3,59
Average value for the sample	3,63		

Table 2.7 - Results of determining natural soil humidity of sample 7Б

Weighing bottle №	Weight of empty weighing bottle+ cap,*m*, g	Weight of wet material with weiging bottle, m_1, g	Weight of dried material, m_0, g	Humidity, %	Average value %
122	22,02	42,26	39,33	16,93	16,82
343	21,81	39,95	37,33	16,88	
302	22,81	38,65	36,39	16,64	

Table 2.8 - Results of soil plasticity index determination of sample 7Б

Plasticity indicators	Weighing bottle number	Weight of empty weiging bottle, g	Weighing bottle weight with wet soil, g	Weighing bottle weight with dried soil, g	Average value *W*, %
Humidity at yield point, W_L	088	22,46	42,90	39,35	21,29
	014	22,46	41,81	38,41	
	280	21,60	42,66	38,93	
Humidity at the rolling limit, *Wp*	218	22,35	32,78	31,14	18,54
	197	22,99	33,54	31,90	
Plasticity index *Ip*	2,75				

Table 2.9 - Results of soil weight loss at calcination of sample 7 Б

Crucible number	1	2	3
Output dry weight of sample plus crucible weight $m_d + m_B$, g	78,09	81,73	76,28
Weight of sample and crucible after calcination $m_{gl} + m_B$, g	77,73	81,37	75,94
Crucible weight m_B, g	62,65	66,31	61,39
Weight of soil losses $\Delta m_{gl} = (m_d + m_B) - (m_{gl} + m_B)$, g	0,36	0,36	0,34
Output dry weight of sample $m_d = (m_d + m_B) - m_B$, g	15,44	15,42	14,89
Average value of losses at calcination V_{gl}, %	2,33	2,33	2,28
Average value for the sample	2,31		

Based on the results of analysis of these studies it was found that by their characteristics soil samples belong to loamy sands.

Test reports for determining physical and mechanical characteristics of the soils under study are given in Appendix A.

2.3 Laboratory studies of the soil with addition of cement and Nanoalps System SOIL

Soil stabilization was carried out according to DSTU 8801. In order to further study and establish the possibility of using NanoalpsSystem SOIL (Nanoalps) in road

construction, in particular in the layers of the road foundation of the pavement and in the subgrade, the calculations were performed and the proportions of mineral binder use were established. Three test soil samples (Soil + Cement 5% + Nanoalps 0.5%) were molded for the main tests and 12 reference samples which included 5% of cement as soil stabilization without additives. The amount of water was added in accordance with the value of the optimal humidity of each specific soil sample (Appendix Б).

To prepare soil samples using NanoalpsSystem SOIL and without it the following components were used:

- soil in compliance with DSTU 8801;
- cement in compliance with DSTU B B.2.7-46;
- water in compliance with DSTU B B.2.7-273.

Basing on the selected mix designs, 48 samples were prepared in the laboratory in compliance with DSTU-N B B.2.3-39.

View of the samples after their molding with the binder is shown in Figure 2.2.

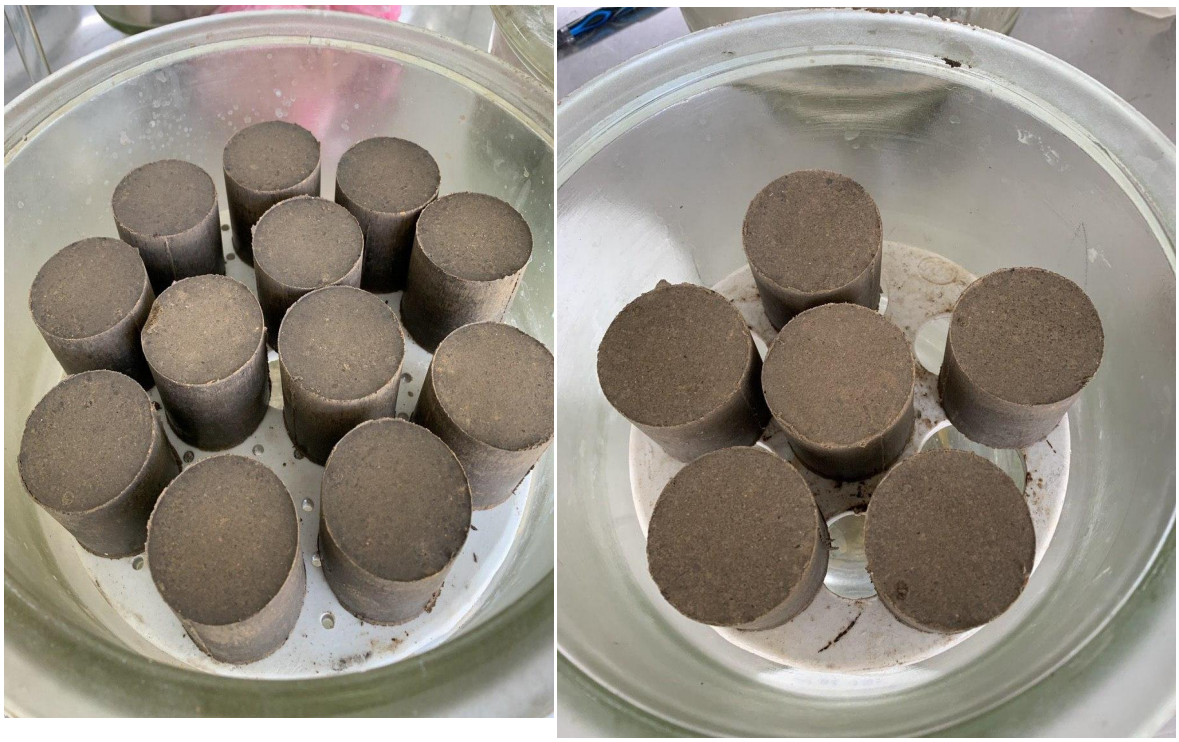

Figure 2.2— View of molded samples

According to the research program, the samples were tested on the 7th day after hardening, with the determination of the compressive strength according to DSTU B B.2.7-309.

Figure 2.3— View of samples on the 7th day

The essence of the method is to determine limit compressive strength which leads to the destruction of the sample under given test conditions.

Determination of limit compressive strength is performed on the samples produced in accordance with the requirements of regulations, and they are cylinders or

cubes. Three samples are tested at each given temperature. Samples of the same age are used for testing.

Before the test, the samples are thermostated in a container of water for (60 ± 5) minutes at the temperatures: (20 ± 1) ° C.

To determine the limit compressive strength of the samples in the water-saturated state the samples are used that are tested in accordance with the value of water saturation. Water-saturated samples, after weighing in the air and in the water, are again placed in the water with a temperature of (20 ± 1) ° C for 10 - 15 minutes, and before the test they are wiped with a soft damp cloth.

The limit compressive strength is determined on mechanical presses at a speed of the press plate (3.0±0.1) mm/min.

To reduce temperature losses of the samples during their contact with the metal plates of the test machine or press, dry cardboard is placed on the upper and lower planes of the sample.

The test must be completed within (1.5 ± 0.5) minutes after the sample has been removed from the thermostat.

The sample removed from the vessel for thermostating is placed on a dry cardboard in the center of the lower plate of the press and the upper plane of the sample is covered by it, then lower the upper plate is lowered at a distance from the surface of the sample in the range from 1.5 mm to 2 mm. This can be achieved by appropriate lifting of the lower plate of the press. After that, the press is turned on and the loading of the sample begins.

The maximum value of the power meter is taken as the destructive load. The limit compressive strength was calculated by the formula:

$$R_p = \frac{2 \cdot P}{\pi \cdot d \cdot l} \cdot 10^{-2}$$

where P - the destructive load, H;

d - the diameter of the sample, cm;

l - height of the sample, cm;

10^{-2} - conversion factor in megapascals.

Figure 2.4 shows a test sample before and after the completion of a prototype test.

Figure 2.4 — View of the sample before and after the test

Test results of the samples and the data obtained during the study are given in Annex B.

3 LABORATORY TESTS OF MIXTURES PRODUCED BY COLD RECYCLING TECHNOLOGY WITH THE ADDITION OF NANOALPS ADDITIVE

Stabilization of mixtures was carried out in accordance with DSTU-N B V.2.3-39. For further research of the use of the Nanoalps System SOIL in road construction, the calculations were performed and proportions were established of the use of inorganic binder. 12 samples were molded (Granular asphalt (GA (АСГ-ukr.) 65% + Crushed stone-sand mix C(ЩПС – ukr.) 9 35% + Cement 5% + Nanoalps 0.5%) for the main tests and 12 control samples (GA 65% + Crushed stone-sand mix C 9 35% + Cement 5%).

3.1 Producing the samples from mixtures

When preparing the mixtures, pre-dried materials in quantities specified in the composition are weighed into a container, the required amount of water is added, mineral and organic or complex binder is added in accordance with SOU 45.2-00018112-061 and is mixed thoroughly.

Mixtures of aggregates with mineral, organic or complex binder are finally mixed at a temperature of (20 ± 2) ° C in a laboratory mixer until complete and uniform combination of all components is reached. In the absence of a mixer it is allowed mixing manually. The time required for mixing is set experimentally. Mixing is considered complete if all mineral grains are evenly covered with binder.

Cylindrical specimens for the determination of physical and mechanical properties of mixtures are produced by compaction of mixtures prepared in the laboratory as well as with combined mixture samples selected according to the requirements of Annex A at mixing plants or on work sites.

Compaction of samples is performed in cylindrical forms. Before filling the forms with mixtures, they are pre-lubricated with an aqueous emulsion. The sizes of forms are chosen depending on the largest size of grains of the offered mix design.

Compaction of samples is performed by pressing under pressure (15.0 ± 0.2) MPa on hydraulic presses. During compaction, a two-way application of the load achieved by transmitting the pressure to the compacting mixture through two liners which are freely mixed in the form towards each other must be ensured.

To produce a test sample, a form with an inserted lower liner which is filled with an approximate amount of mixture is used.

The mixture is evenly distributed in the form by stabbing with a knife or spatula, insert the upper liner and, pressing the mixture with it, the form with the mixture is set on the bottom plate of the press for compaction. The lower liner should protrude from the form by (1.5 - 2.0) cm. The upper plate of the press should touch the upper liner and the electric motor of the press is turned on.

The pressure on the compacted mixture is adjusted to 15 MPa for (5 - 10) s. After (3.0 ± 0.1) min, the load is relieved and the sample is removed from the form with a

squeezing device and its height is measured with a caliper in accordance with GOST 166 with an error of 0.1 mm

Figure 3.1 – Preparing the mixture

Figure 3.2 – Preparing the mixture, adding additive Nanoalps System SOIL

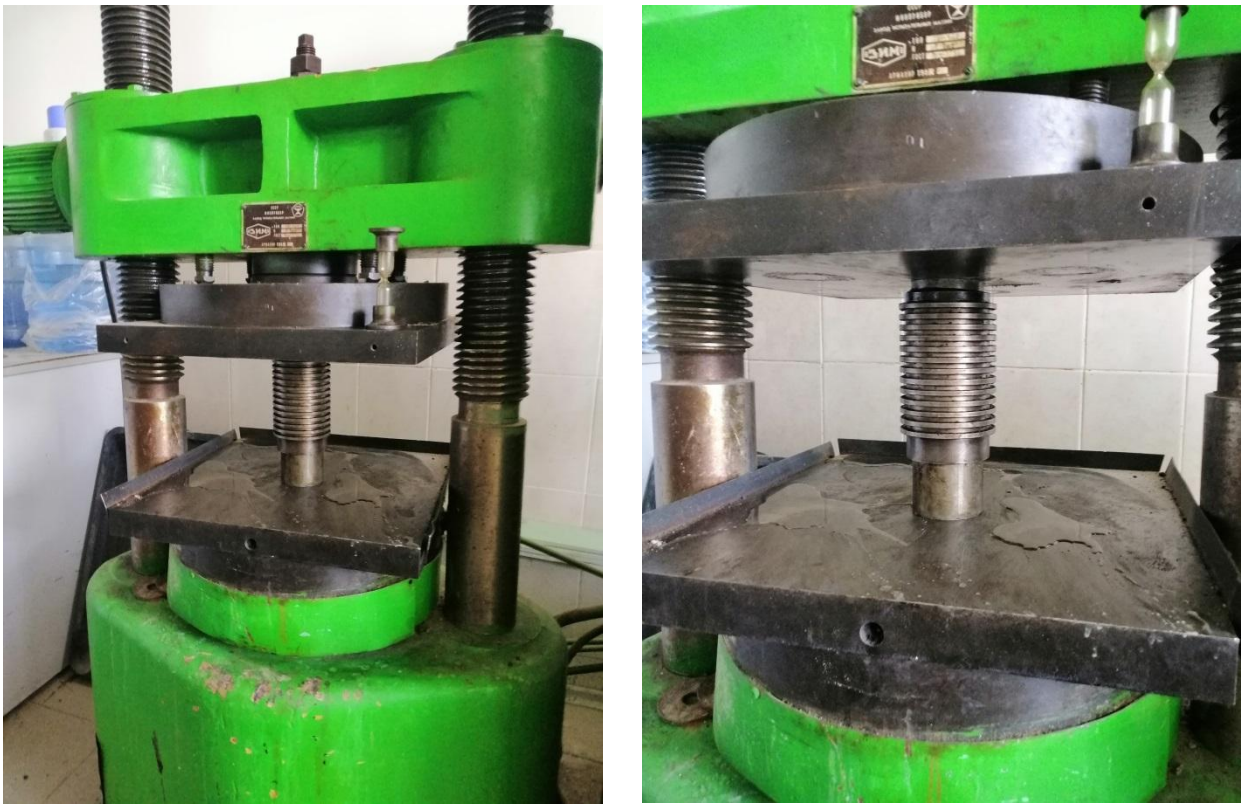

Figure 3.3 – Molding of samples

Figure 3.4 – Molded samples

3.2 Determination of compressive strength limit

The essence of the method is to determine the load required to destroy the sample under given conditions.

To determine the compressive strength of the samples in the water-saturated state, they are immersed in water for 24 h for water saturation.

Before the test, the samples are thermostated at a given temperature.

The compressive strength of the samples is determined on the presses at a speed of the press plate (3.0 ± 0.3) mm / min.

When using hydraulic presses, this speed should be set when the piston is idling before the test.

The sample removed from the vessel for thermostating is installed in the center of the lower plate of the press, then the upper plate is pull down and stopped above the surface level of the sample from 2 mm to 3 mm. It can be achieved by appropriate lifting of the lower plate of the press. After that, the electric motor of the press is turned on and the sample loading is begun. To increase the accuracy of determining the compressive strength limit, it is recommended to use a hinged device.

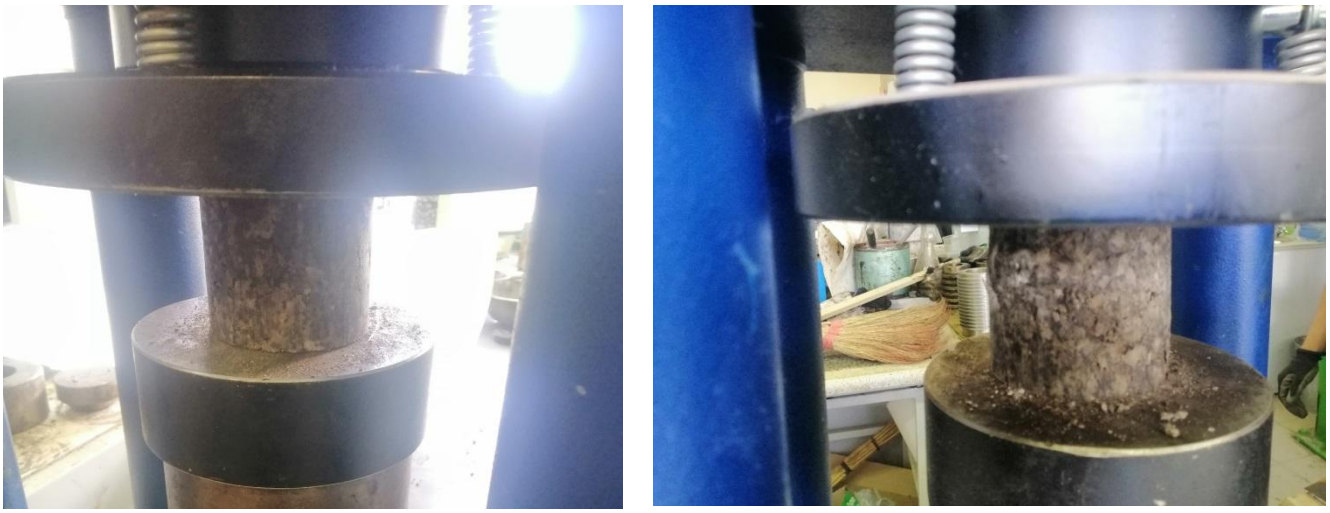

Figure 3.5 – Determination of the compressive strength

The results of determining the compressive strength limit of the mixture with the addition of the additive Nanoalps System SOIL (Nanoalps) are shown in Table 3.1, of reference samples - in Table 3.2.

Table 3.1 – The results of determining the compressive strength limit

Laboratory number of the sample	Granular asphalt (GA (АСГ-ukr.) 65 % + Crushed stone-sand mix C 9 35% + Cement 5 % + Nanoalps 0,5 %				Average calculated value of compressive strength limit
	Compressive strength limit, the 7th day	Compressive strength limit, the 14th day	Compressive strength limit, the 21st day	Compressive strength limit, the 28th day	
	MPa	MPa	MPa		MPa
1	4,3	4,3	5,0	5,5	5,5
2	5,1	4,2	5,3	5,4	
3	4,4	4,2	4,9	5,5	

Table 3.2 – The results of determining the compressive strength limit of reference samples

Laboratory number of the sample	Granular asphalt (GA (АСГ-ukr.) 65 % + Crushed stone-sand mix C 9 35% + Cement 5 % (reference samples)				Average calculated value of compressive strength limit
	Compressive strength limit, the 7th day	Compressive strength limit, the 14th day	Compressive strength limit, the 21st day	Compressive strength limit, the 28th day	
	MPa	MPa	MPa		MPa
1	3,6	3,8	4,9	4,9	4,9
2	4,0	3,9	5,0	4,9	
3	3.8	3,9	4,8	4,9	

CONCLUSIONS

According to the Agreement dated 19.12.2019 № 797-19 commissioned by Nanoalps GmbH (the company is registered in Italy), works to study and establish the impact of the additive Nanoalps System SOIL on the physical and mechanical properties of soils stabilized with its use were carried out.

During the laboratory tests, the moisture, yield strength, rolling limit, the index of soil plasticity and the content of organic residues were determined. Based on the analysis of the obtained data, it can be stated that soil samples: 2Б (Levandivka microdistrict − Lviv, 0.55 m deep); 6В (Levandivka microdistrict − Lviv, Zelena Street); 7Б (Levandivka microdistrict − Lviv, Zelena Street) belong to loamy sands.

According to the research program, the percentage of Portland cement grade M 500 for sample molding was calculated and established. After their hardening on the 7th, the 14th and th 28th day, tests to determine the compressive strength limit and frost resistance were carried out.

According to DSTU 8801 the grade by strength of materials corresponds to M 20.

It was experimentally proved that when adding Nanoalps System SOIL to the soil-cement mixture, the average calculated value of the compressive strength limit of the samples increased by 0.6 MPa compared to reference samples (mixture without adding Nanoalps System SOIL).

The average value of compressive strength limit of compacted crushed stone-sand mixtures with cement and Nanoalps System SOIL additive is 5.5 MPa, which roughly corresponds to the material strength grade - M 40.

In each case, the required content of the additive Nanoalps System SOIL must be determined in the laboratory by testing the samples.

Annex A

STATE ROAD AGENCY OF UKRAINE
(UKRAVTODOR)

M.P. Shulgin State road research institute State Enterprise
("DerzhdorNDI" SE)

APPROVED
Deputy Director
On Scientific Work
_____ V.I. Kaskiv
"12" 05 2020

RESULTS OF MATERIALS TESTING

Laboratory of Ecology and Subgrade Department of "DerzhdorNDI" SE
(location of tests)

20 kg of soil
(name and indication of product)

DSTU B. V . 2.1-17:2009 "Soils. Methods of laboratory determination of physical properties"
(name and designation of the document, standard of product is specified)

Performed : determination of natural humidity; humidity at the yield strength; moisture at the rolling limit, the content of organic matters in the soil
(type of tests)

Customer: Nanoalps GmbH

Agreement No.797-19 dated 19.12.2019

1. Characteristics of the tested products:

1.1 Type and grade of material : subgrade soil
According to DSTU B.V.2.1-2-96 "Soils .Classification" DSTU B.V..2.1-17:2009 Soils. Methods of laboratory determination of physical properties.
(the designation of the standard or specifications is indicated)

Date of sampling _____ - _____ **Delivered to the Customer** May 14 2020

1.2 Sample delivered May 14, 2020

«DerzhdorNDI» SE
(name of organization that delivered the sample)

2. Compliance of the sample with the sampling procedure

2.1 Sampled at: Levadnivka mikrodistrict - Lviv, 0,55 m depth
(location of sampling, type and vehicles numbers)

2.2 Date of sampling: 28.03.2020 **Act No** -

2.3 Type and state of package: polyethylene bag , non-damaged

2.4 Conclusions: sampling according to the requirements of DSTU B.V.2.1-8:2001

2.5 Reg. No. of sample: 22/10

3. Description of the tests

3.1 Tested according to: DSTU B.V.2.1-17:2009

(names of standards, specifications and certified test methods)

3.2 Test start date May 18 2020

Test end date May 29 2020

4. Tests conditions:

Ambient temperature from 9,0 °C to 22,0 °C;
Humidity of ambient air from 49 % to 53 %;
Atmospheric pressure from 745 mmHg to 759 mmHg.

5. Actual values of indicators:

Indicated in tables

Table 1 – Results of determined natural humidity of the soil sample 2Б

No. of weighing bottle	Weight of empty weighing bottle + cover, m, g	Weight of wet material with weighing bottle, m_1, g	Weight of dried material, m_0, g	Humidity %	Sample average humidity %
088	22,46	38,37	36,22	15,63	15,67
343	21,82	43,74	40,75	15,80	
280	21,61	39,40	37,00	15,59	

Table 2 – Results of determined soil plasticity index of sample 2Б

Plasticity indicators	No. of weighing bottle	Weight of empty weighing bottle, g	Weight of weighing bottle with wet soil, g	Weight of weighing bottle with dried soil, g	Average value W, %
Humidity at the yield strength, W_L	197	22,98	37,92	35,35	20,90
	158	23,39	42,83	39,50	
	218	22,36	40,05	36,95	
Humidity at the rolling limit, Wp	034	22,79	33,20	31,66	17,39
	013	23,18	39,03	36,68	
Plasticity index Ip	3,51				

Table 3 – The results of determination of the soil weight loss during calcination of sample 2B

Crucible No.	1	2	3
Output dry weight of sample + weight of crucible $m_d + m_B$, g	52,42	58,39	51,65
Weight of sample and crucible after calcination $m_{gl} + m_B$, g	52,13	58,09	51,34
Weight of crucible m_B, g	37,03	42,85	35,13
Weight of soil loss $\Delta mgl = (m_d + m_B) - (m_{gl} + m_B)$, g	0,29	0,30	0,31
Output dry weight of sample $m_d = (m_d + m_B) - m_B$, g	15,39	15,54	16,52
The average value of losses during calcination V_{gl}, %	1,88	1,93	1,88
The average value for the sample	1,90		

6. Indicators of accuracy of the tests: DSTU B V.2.1.-17: 2009 "Soils. Method of laboratory determination of physical properties "for yield strength and rolling limit error $\Delta = \pm 2\%$

Conclusion *: according to the data obtained during laboratory tests, the soil sample 2 Б has a natural humidity $W = 15.67\%$; humidity at the yield strength $W_L = 20.90\%$; humidity at the rolling limit $W_P = 17.39\%$; plasticity index $I_P = 3.51$ refers to loamy sands, the yield strength indicator $I_L = -1.49$ and is identified as strong loamy sand, the content of organic residues in the soil $V_{gl} = 1.94\%$.

* Test results apply only to the samples tested.

Performers:

(signature) O.A. Mykolayenko (name)

(signature) D. S. Pivtoratskyi (name)

(names of persons responsible for test performance)

04.05.2020

STATE ROAD AGENCY OF UKRAINE

(UKRAVTODOR)

M.P. Shulgin State Road Research Institute Stat Enterprise

(«DerzhdorNDI» SE)

APPROVED
Deputy Director
On Scientific Work
_____ V.I. Kaskiv
«04» 05 2020

RESULTS OF MATERIALS TESTS

Laboratory of Ecology and Subgrade Department of "DerzhdorNDI" SE
(location of tests)

20 kg of soil
(name and designation of products)

DSTU B.V.2.1-17:2009 "Soils. Methods of laboratory determination of physical properties"
(name and designation of regulations, product standard)

Performed: determination of natural humidity; humidity at the yield strength; moisture at the rolling limit, the content of organic matters in the soil
(type of tests)

Customer: Nanoalps GmbH

Agreement No. 797-19 dated 19.12.2019

1. Characteristics of tested products :

1.1 Type and grade of material : subgrade soil

According to DSTU B.V.2.1-2-96 "Soils. Classification", DSTU B.V.2.1-17:2009 Soils. Methods of laboratory determination of physical properties"
(the designation of the standard or specifications is indicated)

Date of sampling _____ - _____ **delivered to the Customer** May 14 2020

1.2 Sample delivered May 14 2020

«DerzhdorNDI» SE
(name of organization that delivered the sample)

2. Compliance of the sample with the sampling procedure

2.1 Sampling location : Levandivka microdistrict − Lviv, Zelena Street
(location of sampling, type and vehicles numbers)

2.2 Date of sampling 31.03.2020 **Act No.** -

2.3 Type and state of package: polyethylene bag, non-damaged

2.4 Conclusions: sampling according to requirements of DSTU B.V.2.1-8:2001

2.5 Sample Reg.No.: 23/10

3. Test description

3.1 Tested according to: DSTU B.V.2.1-17:2009
(names of standards, specifications and certified test methods)

3.2 Test start date May 18 2020

Test end date May 29 2020

4. Test conditions:

Ambient temperature from 19,0 °C to 22,0 °C;
Ambient air humidity from 49 % to 53 %;
Atmospheric pressure from 745 Hg mm to 759 Hg mm

5. Actual values indicators:

Indicated in tables

Table 1 – The results of determination of the natural soil humidity of the sample 6Б

No.of weighing bottle	Weight of empty weighing bottle + cover, m, g	Weight of wet soil with weighing bottle, m_1, g	Weight of dried soil, m_0, g	Humidity of individual specimen sample, %	Average humidity of sample, %
008	23,19	42,70	40,09	15,44	15,27
013	23,18	41,28	38,89	15,21	
011	22,75	39,02	36,88	15,15	

Table 2 – The results of determination of the soil plasticity index of the sample 6Б

Indicators of plasticity	Weighing bottle No.	Weight of empty weighing bottle, m, g	Weight of weighing bottle with wet soil , m_1, g	Weight of weighing bottle with dried soil m_0, g	Average value W, %
Humidity at the yield strength, W_L	130	21,14	38,12	34,74	24,86
	379	22,02	38,73	35,38	
	326	23,13	38,81	35,71	
Humidity on the rolling limit, Wp	359	23,19	33,32	31,60	20,87
	351	20,53	32,10	30,07	
Plasticity index Ip	3,99				

Table 3 – Results of determination of soil weigh loss during calcination of the sample 6B

Crucible No	1	2	3
Output dry weight of sample + weight of crucible $m_d + m_B$, g	62,31	46,63	46,33
Weight of sample and crucible after calcination $m_{gl} + m_B$, g	61,76	46,06	45,77
Weight of crucible m_B, g	47,24	31,01	30,75
Weight of soil loss $\Delta mgl = (m_d + m_B) - (m_{gl} + m_B)$, g	0,55	0,57	0,56
Output dry weight of sample $m_d = (m_d + m_B) - m_B$, g	15,07	15,62	15,58
The average value of losses during calcination V_{gl}, %	3,65	3,65	3,59
The average value for the sample	3,63		

6. Indicators of accuracy of the test: DSTU B V.2.1.-17: 2009 "Soils. Method of laboratory determination of physical properties "for yield strength and rolling limit error $\Delta = \pm 2\%$

Conclusion*: according to the data obtained during laboratory tests, the soil sample 6Б has a natural humidity $W = 15.27\%$; humidity at the yield strength $W_L = 24.86\%$; humidity at the rolling limit $W_P = 20.87\%$; the plasticity index $I_P = 3.99$ refers to loamy sands, the yield strength indicator $I_L = -2.40$ and is identified as a strong loamy sand, the content of organic residues in the soil $V_{gl} = 3.63\%$.

*Test results apply only to the samples tested.

Performers:

(signature) O.A. Mykolayenko (name)

(signature) D.S. Pivtoratskyi (name)

(names of persons responsible for test performance)

04.05.2020

STATE ROAD AGENCY OF UKRAINE

(UKRAVTODOR)

M.P. Shulgin State Road Research Institute Stat Enterprise

(«DerzhdorNDI» SE)

APPROVED
Deputy Director
On Scientific Work
_____ V.I. Kaskiv
«04» _____ 2020

RESULTS OF MATERIALS TESTS

Laboratory of Ecology and Subgrade Department of "DerzhdorNDI" SE
(location of tests)

20 kg of soil
(name and designation of products)

DSTU B.V.2.1-17:2009 "Soils. Methods of laboratory determination of physical properties"
(name and designation of regulations, product standard)

Performed: determination of natural humidity; humidity at the yield strength; moisture at the rolling limit, the content of organic matters in the soil
(type of tests)

Customer: Nanoalps GmbH

Agreement No. 797-19 dated 19.12.2019

1. Characteristics of tested products :

1.1 Type and grade of material : subgrade soil

According to DSTU B.V.2.1-2-96 "Soils. Classification", DSTU B.V.2.1-17:2009 Soils. Methods of laboratory determination of physical properties"
(the designation of the standard or specifications is indicated)

Date of sampling _____ - _____ **delivered to the Customer** May 14 2020

1.2 Sample delivered May 14 2020

«DerzhdorNDI» SE
(name of organization that delivered the sample)

1.2 Sample delivered May 14, 2020
«DerzhdorNDI» SE
(name of organization that delivered the sample)

2. Compliance of the sample with the sampling procedure

2.1 Sampled at: Levandivka microdistrict − Lviv, Zelena Street
(location of sampling, type and vehicles numbers)

2.2 Date of sampling 31.03.2020 **Act No** -

2.3 Type and state of package: polyethylene bag, non-damaged

2.4 Conclusions: sampling performed according to DSTU B.V.2.1-8:2001

2.5 Sample Reg. No. : 24/10

3. Description of tests

3.1 Tested according to : DSTU B.V.2.1-17:2009
(names of standards, technical conditions and certified test methods)

3.2 Test start date May 18 2020

Test end date May 29 2020

4. Test conditions:

Ambient temperature from 19,0 °C to 22,0 °C;
Ambient air humidity from 49 % to 53 %;
Atmospheric pressure from 745 Hg mm to 759 Hg mm

5. Actual values of indicators:

Indicated in tables

Table 1 – The results of determining the natural soil humidity of the sample 7Б

Weighing bottle No.	Weight of empty weighing bottle + cover, *m*, g	Weight of wet soil with weighing bottle , m_1, g	Weight of dried soil, m_0, g	Humidity of individual specimen sample, %	Average humidity of the sample %
122	22,02	42,26	39,33	16,93	16,82
343	21,81	39,95	37,33	16,88	
302	22,81	38,65	36,39	16,64	

Table 2 – The results of determination of the soil plasticity indicators of the sample 7Б

Indicators of plasticity	No. of weighing bottle	Weight of empty weighing bottle, *m*, g	Weight of weighing bottle with wet soil, m_1,g	Weight of weighing bottle with dried soil, m_0,g	Average value *W*, %
Humidity at the yield strength, W_L	088	22,46	42,90	39,35	21,29
	014	22,46	41,81	38,41	
	280	21,60	42,66	38,93	
Humidity at the rolling limit, *Wp*	218	22,35	32,78	31,14	18,54
	197	22,99	33,54	31,90	
Plasticity index *Ip*	2,75				

Table 3 – The results of determination of the soil weight loss during calcination of the sample 7B

Crucible No	1	2	3
Output dry weight of sample + weight of crucible md + mB, g	78,09	81,73	76,28
Output dry weight of sample + weight of crucible $m_d + m_B$, g	77,73	81,37	75,94
Weight of sample and crucible after calcination $m_{gl} + m_B$, g	62,65	66,31	61,39
Weight of crucible m_B, g	0,36	0,36	0,34
Weight of soil loss Δmgl = $(m_d + m_B)$ - $(m_{gl} + m_B)$, g	15,44	15,42	14,89
Output dry weight of sample $m_d = (m_d + m_B) - m_B$, g	2,33	2,33	2,28
The average value of losses during calcination V_{gl}, %	2,31		

6. Indicators of accuracy of the test: DSTU B B.2.1.-17: 2009 "Soils. Method of laboratory determination of physical properties "for yield strength and the rolling limit error Δ = ± 2%

Conclusion*: according to the data obtained during laboratory tests, the soil sample 7Б has a natural humidity $W = 16.82\%$; humidity at the yield strength $W_L = 21.29\%$; humidity at the rolling limit $W_P = 18.54\%$; the plasticity index $I_P = 2.75$ refers to loamy sands, the yield strength indicator $I_L = -1.63$ and is identified as strong loamy sand, the content of organic matters in the soil $V_{gl} = 2.31\%$.

*Test results apply only to the samples tested.

Performers:

(signature) O.A. Mykolayenko (name)

(signature) D.S. Pivtoratskyi (name)

(names of persons responsible for test performance)

04.05.2020

Annex Б

STATE ROAD AGENCY OF UKRAINE
(UKRAVTODOR)

M.P. Shulgin State road research institute State Enterprise
("DerzhdorNDI" SE)

APPROVED
Deputy Director
On Scientific Work
_____ V.I. Kaskiv
"04" 05 2020

RESULTS OF MATERIALS TESTING

Laboratory of Ecology and Subgrade Department of "DerzhdorNDI" SE
(location of tests)

20 kg of soil
(name and indication of product)

DSTU B.V..2.1-12:2009 "Method of laboratory determination of maximum density"
(name and designation of documents, product standard)

Performed: determination of optimum humidity; maximum density
(type of tests)

Customer: Nanoalps GmbH

Agreement No.797-19 dated 19.12.2019

1. Tested products characteristics:
1.1 Type of material : subgrade soil

according to DSTU B V.2.1-2-96 "Soils. Classification ", DSTU B V.2.1-17: 2009 Soils. Methods of laboratory determination of physical properties.
(the designation of the standard or specifications is indicated)

Date of sampling _____ - _____ **Delivered to the Customer** May 14 2020.

1.2 Sample delivered May 14 2020.

«DerzhdorNDI» SE
(name of organization that delivered the sample)

2. Compliance of the sample with the sampling procedure

2.1 Sampled at: Levandivka microdistrict − Lviv
(location of sampling, type and vehicles numbers)
2.2 Sampling date 31.03.2020 **Act No.** -
2.3 Type and state of package: polyethylene bag, non-damaged
2.4 Conclusions: sampling performed according to DSTU B.V.2.1-8:2001

2.5 Sample Reg.No.: 22/10; 23/10; 24/10

3. Test description
3.1 Test performed according to: DSTU B.V.2.1-12:2009
(names of standards, specifications and certified test methods)
3.2 Test start date May 18, 2020.
Test end date May 29 2020

4. Test conditions:

Ambient temperature from 19,0 °C to 22,0 °C;
Ambient air humidity from 49 % to 53 %;
Atmospheric pressure from 745 Hg mm to 759 Hg mm

5. Actual values:
Indicated in the tables

Table 1 – Determination of optimum humidity, maximum sample density 2Б

Nr.	Weight, *m*, g	Height, *h*, cm	Volume, *V*, cm3	Humidity *W*, %	Density , ρ, g/cm3	Max. density of skeleton, ρ_{dmax}, g/cm3
1	194,66	4,8	94,20	9,7	2,066	1,88
2	192,05	4,6	90,28	12,01	2,127	1,90
3	190,90	4,5	88,31	13,2	2,162	1,91
4	189,23	4,7	92,24	14	2,052	1,80

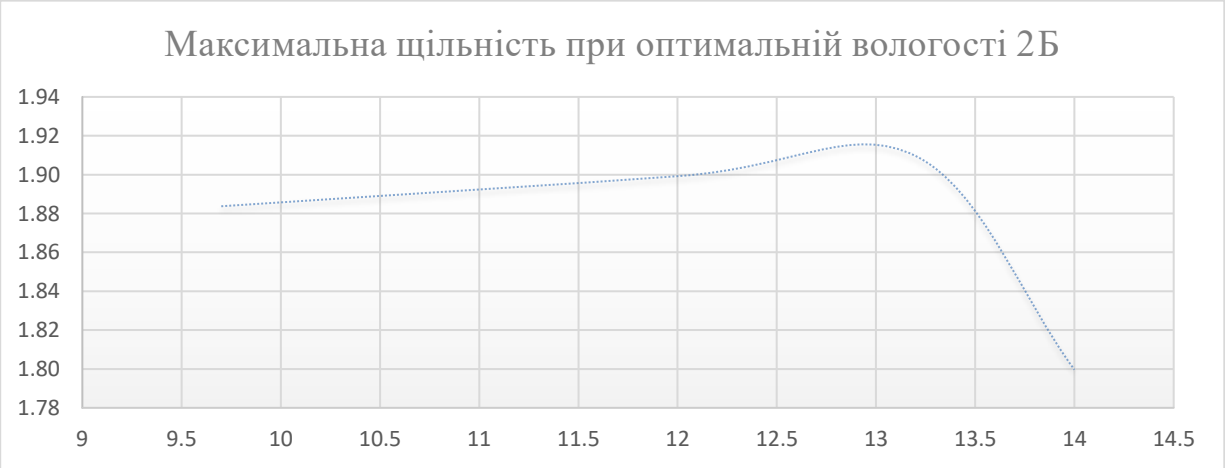

Fig. 1 – Determination of optimal humidity, maximum density of the sample 2Б

Tab. 2 – Determination of optimum humidity, max. density of the sample 6Б

Nr.	Weight, *m*, g	Height, *h*, cm	Volume, *V*, cm3	Humidity *W*, %	Density , ρ, g/cm3	Max. density of skeleton, ρ_{dmax}, g/cm3
1	192,32	4,7	92,24	10,1	2,085	1,89
2	196,15	4,7	92,24	11,9	2,127	1,90
3	192,35	4,7	92,24	14,1	2,085	1,83
4	191,3	4,7	92,24	15,3	2,074	1,80

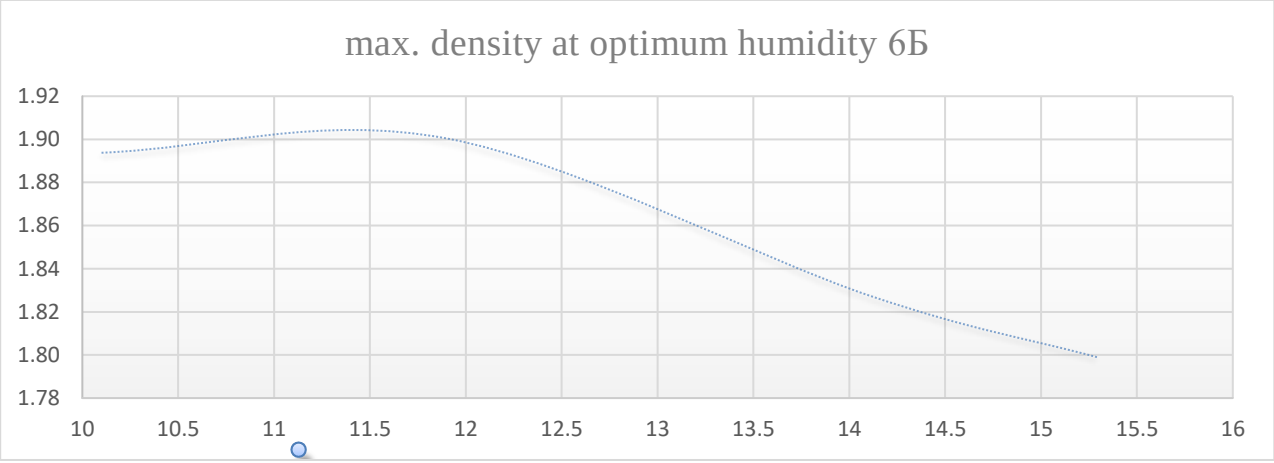

Fig. 2 – Determination of optimum humidity, maximum density of the sample 6Б

Table 3 – Determination of maximum density, optimum humidity of the sample 7Б

Nr.	Weight, *m*, g	Height, *h*, cm	Volume, *V*, cm^3	Humidity *W*, %	Density , ρ, g/cm^3	Max. density of skeleton, ρ_{dmax}, g/cm^3
1	193,03	4,7	92,24	10,5	2,093	1,89
2	194,22	4,6	90,28	12,6	2,151	1,91
3	192,25	4,5	88,31	13,5	2,177	1,92
4	190,03	4,6	90,28	14,8	2,105	1,83

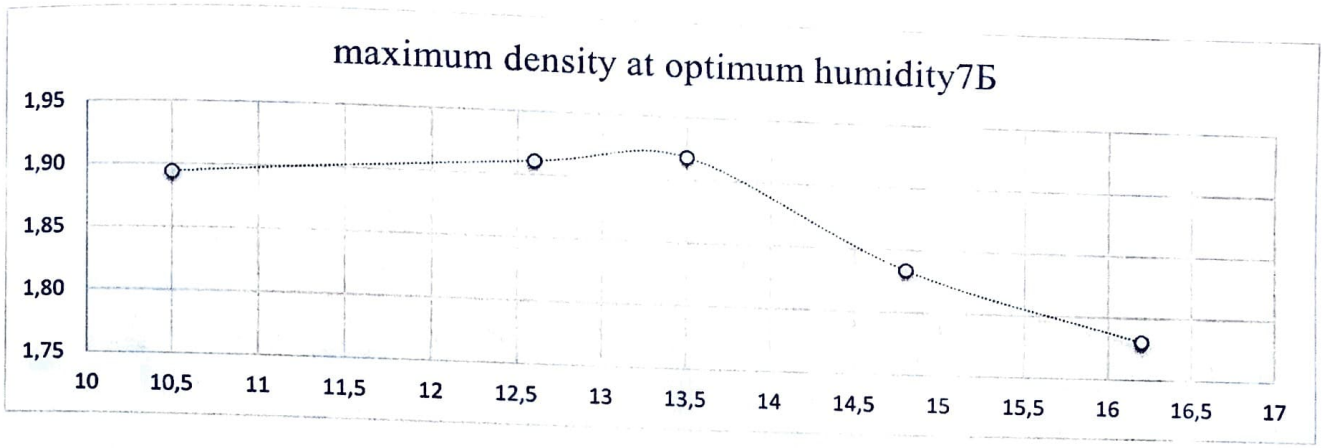

Fig 3 – Determination of optimal humidity, maximum density of the sample 7Б

6. Indicators of accuracy of the test: DSTU B.V.2.1.-17: 2009 "Soils. Method of laboratory determination of physical properties "for yield strength and rolling limit error $\Delta = \pm 2\%$

Conclusion*: according to the data obtained during laboratory tests, soil samples have the following optimum humidity and maximum density: sample 2Б $W_{onm} = 13{,}2\ \%$, $\rho_{dmax} = 1{,}91\ g/cm^3$; sample 6Б $W_{onm} = 11{,}9\ \%$, $\rho_{dmax} = 1{,}90\ g/cm^3$; sample 7Б $W_{onm} = 13{,}5\ \%$, $\rho_{dmax} = 1{,}92\ g/cm^3$.

*Test results apply only to the samples tested.

Performers:

(signature) O.A. Mykolaienko (name)

(signature) D.S. Pivtoratskyi (name)

(names of persons responsible for test performance)

04.05.2020

Annex B

STATE ROAD AGENCY OF UKRAINE
(UKRAVTODOR)

M.P. Shulgin State road research institute State Enterprise
("DerzhdorNDI" SE)

APPROVED
Deputy Director
On Scientific Work
_____ V.I. Kaskiv
«26» 06 2020

RESULTS OF MATERIALS TESTING

Laboratory of Ecology and Subgrade Department of "DerzhdorNDI" SE
(location of tests)

20 kg of soil
(name and designation of the product)

DSTU 8801:2018 Roads. Guidelines for the arrangement of pavement layers from stabilized soils
(name and indication of regulations, the standard for the product)

Performed : method of determination of the compressive strength of soil samples stabilized with inorganic binder and Nanoalps System SOIL additive
(type of tests)

Customer: Nanoalps GmbH

Agreement No.797-19 dated 19.12.2019

1. Tested products characteristics:

1.1 Type and grade of material : subgrade soil

According to DSTU B.V.2.7-309:2016 "Soils stabilized with binder. Test methods"
(designation of the standard or specifications is ndicated)

Date 0f sampling _____-_____ **Delivered to the Customer** May 14, 2020

1.2 Sample delivered May 14, 2020

«DerzhdorNDI» SE
(name of organization that delivered the sample)

2. Compliance of the sample with the sampling procedure

2.1 Sampled at: Levandivka microdistrict − Lviv
(location of sampling, type and vehicles numbers)

2.2 Date of sampling 28.03.2020 **Act of identification No.** -

2.3 Type and state of package: polyethylene bag, non-damaged

2.4 Conclusions : the material is suitable for testing

2.5 Sample Reg. No.: 22/10; 23/10; 24/10

3. Test description

3.1 Tested according to: DSTU B.V.2.7-309:2016 "Soil stabilized with binder. Test methods"
(names of standards, specifications and certified test methods)

3.2 Test start date May 22, 2020

Test end date June 21, 2020

4. Tests conditions :

Ambient temperature from 19,0 °C to 22,0 °C;
Ambient air humidity from 49 % to 53 %;
Atmospheric pressure from 745 Hg mm to 759 Hg mm

5. Actual values:

Indicated in tables

Table 1 – The results of determination of the tensile strength of samples of material 2Б

Sample laboratory No.	Soil + Concrete 5 % + Nanoalps 0,5 %						The average calculated value of the compressive strength
	Compressive strength, the 7th day		Compressive strength, the 14th day		Compressive strength, the 28th day		
	kN	MPa	kN	MPa	kN	MPa	MPa
1.1	0,79	0,40	0,80	0,40	4,73	2,37	2,34
1.2	0,78	0,39	0,82	0,41	4,67	2,34	
1.3	0,77	0,39	0,84	0,42	4,59	2,30	
Frost resistance coefficient – 0,70							

Table 2 – The results of determination of the tensile strength of samples of material 6Б

Sample laboratory No.	Soil + Concrete 5 % + Nanoalps 0,5 %						The average calculated value of the compressive strength
	Compressive strength, the 7th day		Compressive strength, the 14th day		Compressive strength, the 28th day		
	kN	MPa	kN	MPa	kN	MPa	MPa
1.1	0,93	0,47	1,06	0,53	4,45	2,23	2,23
1.2	0,89	0,46	0,92	0,46	4,52	2,26	
1.3	0,91	0,46	0,98	0,49	4,39	2,20	
Frost resistance coefficient – 0,70							

Table 4 – The results of determining the tensile strength of samples of material 7B

Sample laboratory No.	Soil + Concrete 5 % + Nanoalps 0,5 %						The average calculated value of the compressive strength
	Compressive strength, the 7th day		Compressive strength, the 14th day		Compressive strength, the 28th day		
	kN	MPa	kN	MPa	kN	MPa	MPa
1.1	0,90	0,45	1,14	0,57	4,32	2,16	2,21
1.2	0,96	0,48	1,01	0,51	4,48	2,24	
1.3	0,94	0,47	1,07	0,54	4,45	2,23	
Frost resistance coefficient – 0,70							

6. Test accuracy indicators: ± 0.05 MPa according to DSTU B V.2.7-309: 2016 "Soils stabilized with binder. Test methods"

Conclusion*: Tables 1; 2 and 3 show the compressive strength values obtained on the 7th, 14th and 28th day of the life cycle of the samples, according to DSTU 8801: 2018 "Roads. Guidelines for the arrangement of layers of pavement from stabilized soils", grade by strength of materials corresponds to M20

*Test results apply only to the samples tested.

Performers:

(signature) O.A.Mykolaienko (name)

(signature) D.S. Pivtoratskyi (name)

(signature) N.M. Kharytonova (name)

(names of persons responsible for tests performance)

26.06.2020