Scan to know paper details and author's profile

Experimental Determination of Suction Pressure using the filter Paper Method for Unsaturated Clay Soils in the Moscow Region

M.A. Novgorodova & D.N. Gorobtsov

University for Geological Prospecting

ABSTRACT

Introduction: In the world, practice of soil research there is ASTM Standard Test Method for Measurement of Soil Potential (Suction) Using Filter Paper D 5298-16. However, unfortunately, in Russia there are no defining documents related to negative pore pressure, or matrix suction, or SWCC, yet.

Materials and methods. In this study, as a practical example of the effect of suction pressure on slope stability, the authors considered an object located in Zelenograd. Because of the experiment, SWCC was obtained and a geomechanical model was created.

Results. Thus, for cover loams, the value of the initial suction pressure is 17 kPa. The value of matrix suction is 199 kPa. For fluvioglacial loams, the value of the initial suction pressure is 14 kPa. The value of matrix suction according to the graph is 207 kPa.

Discussion and conclusion: Subsequently, calculations were performed in the Plaxis software without taking into account the suction pressure and with taking into account the suction pressure, while all other model parameters remained unchanged.

Keywords: matric suction; suction pressure; unsaturated soils; filter paper method; SWCC.

Classification: LCC Code: TA710, TA703

Language: English

Great Britain Journals Press

LJP Copyright ID: 925625
Print ISSN: 2631-8490
Online ISSN: 2631-8504

London Journal of Research in Science: Natural & Formal

Volume 25 | Issue 3 | Compilation 1.0

© 2025. M.A. Novgorodova & D.N. Gorobtsov. This is a research/review paper, distributed under the terms of the Creative Commons Attribution-Noncom-mercial 4.0 Unported License http://creativecommons.org/ licenses/by-nc/4.0/), permitting all noncommercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Experimental Determination of Suction Pressure using the filter Paper Method for Unsaturated Clay Soils in the Moscow Region

M.A. Novgorodova[α] & D.N. Gorobtsov[σ]

ABSTRACT

Introduction: In the world, practice of soil research there is ASTM Standard Test Method for Measurement of Soil Potential (Suction) Using Filter Paper D 5298-16. However, unfortunately, in Russia there are no defining documents related to negative pore pressure, or matrix suction, or SWCC, yet.

Materials and methods. In this study, as a practical example of the effect of suction pressure on slope stability, the authors considered an object located in Zelenograd. Because of the experiment, SWCC was obtained and a geomechanical model was created.

Results. Thus, for cover loams, the value of the initial suction pressure is 17 kPa. The value of matrix suction is 199 kPa. For fluvioglacial loams, the value of the initial suction pressure is 14 kPa. The value of matrix suction according to the graph is 207 kPa.

Discussion and conclusion: Subsequently, calculations were performed in the Plaxis software without taking into account the suction pressure and with taking into account the suction pressure, while all other model parameters remained unchanged.

Keywords: matric suction; suction pressure; unsaturated soils; filter paper method; SWCC.

Author α σ: Sergo Ordzhonikidze Russian State University for Geological Prospecting, Russia, Moscow.

I. FOR CITATION

In Russian engineering practice, the classical concept of soil mechanics assumes solving problems involving either fully saturated or fully dry soil, which are actually two limiting states of soil. In most cases, soils used as foundations for buildings and structures are in an unsaturated state and their degree of water saturation can vary from 0% to 100%. In this case, designers use the Van Genuchten-Mualem equation in their models, which is intended for unsaturated soils. Unsaturated soils are commonly found in many parts of the world, at a shallow depth (from 2-3 m to 10-15 m) from the surface, as well as in arid regions, where the natural groundwater level is usually at a greater depth. Common to all these soils is their negative pore water pressure, which plays an important role in assessing mechanical properties and also complicates their studies in the laboratory. The presence of air and water in the pore spaces between soil particles causes capillary action, which creates suction.

The relationship between soil suction pressure and water content is determined by SWCC and is an important tool for predicting and interpreting the behavior of unsaturated soils, including under load. SWCC is the relationship between matric suction (chemical potential) and water content (gravimetric or volumetric) or degree of saturation. As the soil passes from a saturated state to an unsaturated state, the distribution of mineral, water and air phases changes as the stress state changes. The relationships between these phases take different forms and affect the engineering properties of unsaturated soils.

In the world practice of soil research, there is ASTM Standard Test Method for Measurement of Soil Potential (Suction) Using Filter Paper D 5298-16. But, unfortunately, in Russia there are no defining documents related to negative pore pressure, or matrix suction, or SWCC.

The advantages of the filter paper method are the ability to measure total suction, which is the sum of osmotic and structural suction, as well as technical simplicity, low cost and sufficient accuracy.

Based on ASTM D 5298, we conducted experimental studies to determine the characteristic curve. The tests were carried out using the filter paper method with the Whatman No. 42.

As a practical example of the effect of suction pressure on slope stability, we will consider an object located in Zelenograd.

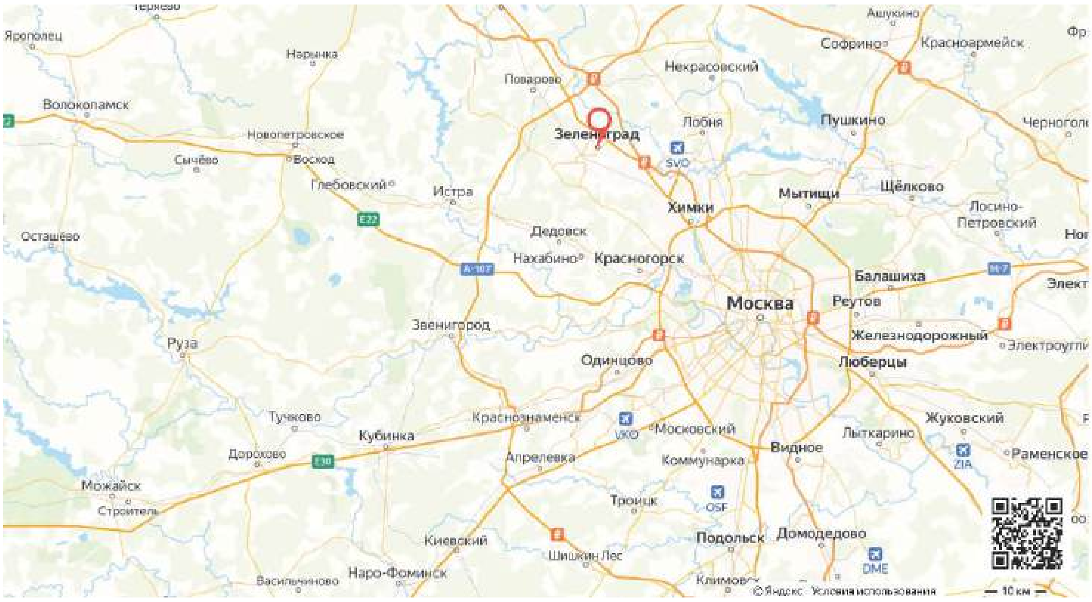

Figure 1: The city of Zelenograd (marked with a red dot).

The engineering-geological section is represented by:

- Modern technogenic (fill) accumulations (tQIV), represented by refractory loams; fine sands of medium density;
- Upper Quaternary cover deposits (prQIII) represented by gray-brown, heavy, semi-hard loams with ferrugination interlayers;
- Middle Quaternary fluvioglacial water-glacial and lacustrine-glacial deposits of the Moscow horizon (f,lgQIIms), represented by soft- and refractory loams, rarely peaty.

As a result of the experiment, the characteristic soil-water curves presented in Figures 2 and 3 were obtained. Thus, for the mantle loams, the value of the initial suction pressure, or air entry value (AEV), is 17 kPa. Before this point, there is a boundary effect zone. The value of matrix suction according to the graph is 199 kPa, and after it, there is a residual zone. Between the points of air entry and matrix suction values, there is a transition zone. For fluvioglacial deposits, the value of the initial suction pressure, or air entry value (AEV), is 14 kPa. Before this point, there is a boundary effect zone. The value of matrix suction according to the graph is 207 kPa, and after it, there is a residual zone.

©2025 Great Britain Journals Press

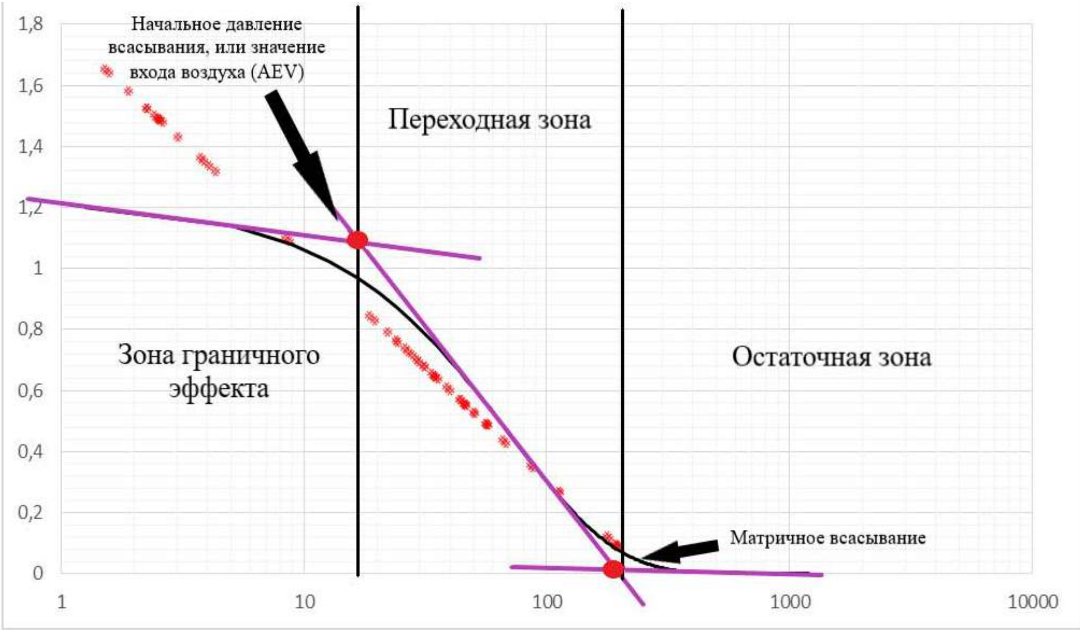

Figure 2: Results of constructing SWCC for cover loams

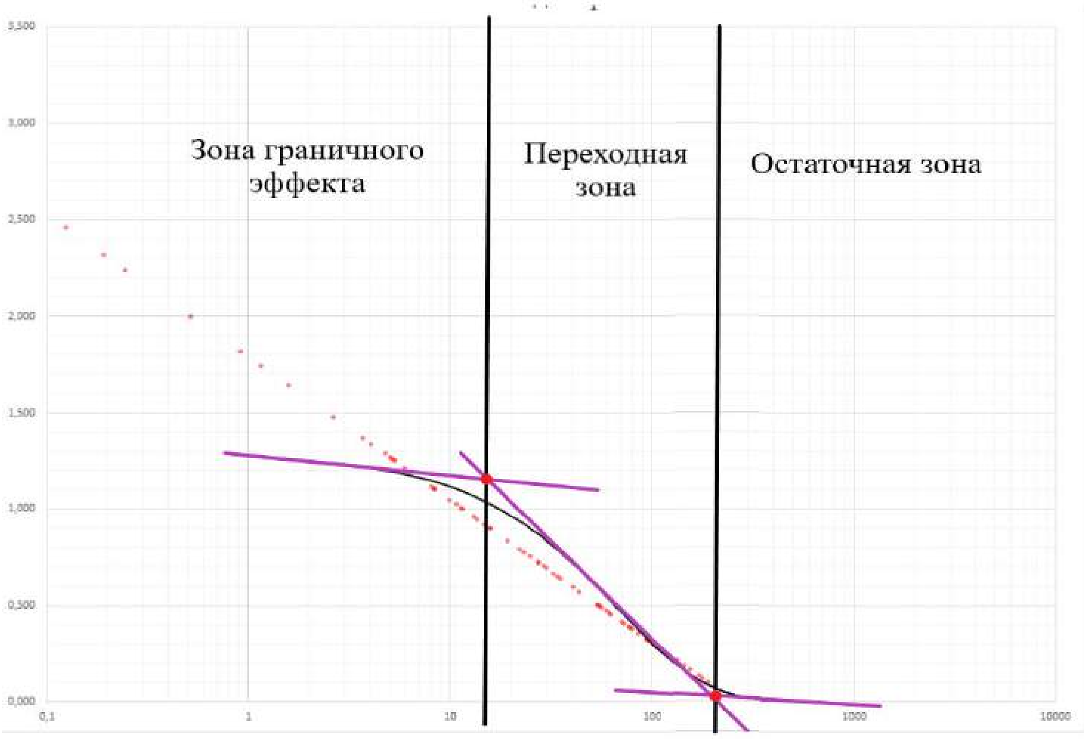

Figure 3: Results of SWCC construction for fluvioglacial loams

In addition, X-ray diffraction quantitative analysis was performed for qualitative assessment. The results of mineral analysis are presented in Table 2:

©2025 Great Britain Journals Press

Sample	smectite *	illite	chlorite	kaolinite	palygorskite	quartz	calcite	Actinolite	Aragonite	dolomite	potassium feldspar (микроклин)	plagioclase (альбит)	Gypsum	Pyrite	Anatase
Sheet	8,7	23,8	10,7	4,0	-	17,2	2,2	-	-	20,1	8,7	4,6	-	-	-
Glacial	13,6	5,1	2,1	3,3	2,0	45,2	11,6	-	-	7,5	7,6	2,0	-	-	-

**smectite and mixed-layer illite-smectite minerals*

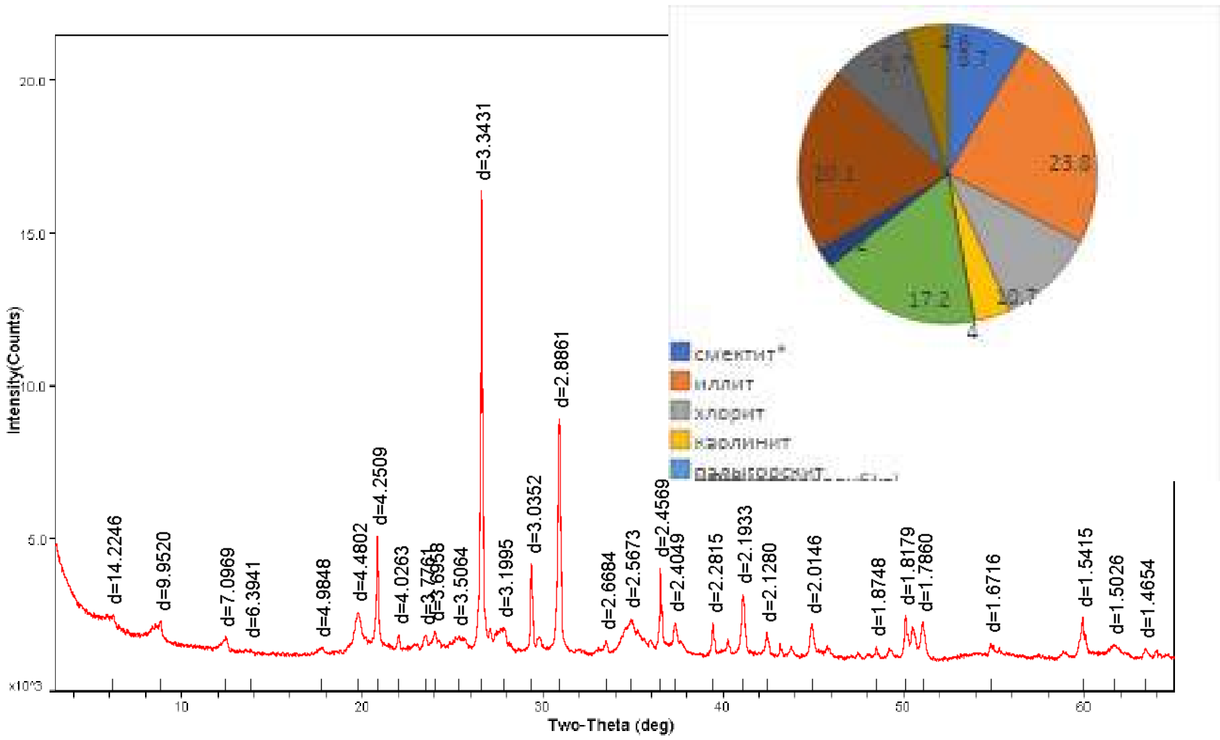

Figure 4: Results of mineral analysis for cover loams

©2025 Great Britain Journals Press

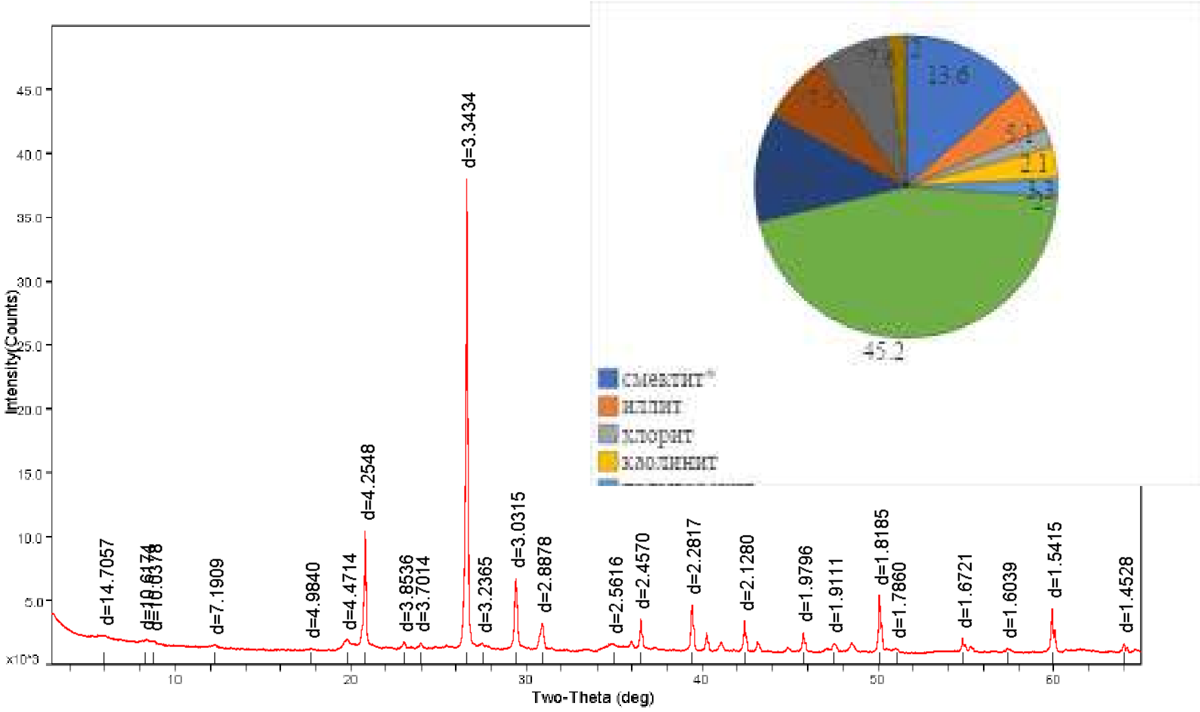

Figure 5: Results of mineral analysis for fluvioglacial loams

As mentioned above, suction pressure and capillarity can affect the physical and mechanical properties of soils, which in turn affect the value of the slope stability coefficient.

The solution of the Mualem-Van Genuchten model is presented in the Plaxis software for geotechnical calculations, but it is necessary to use the SWCC soil-water characteristic curve, constructed on the basis of laboratory tests or adopted according to recommendations for different types of soils.

Subsequently, calculations were performed in the Plaxis software without taking into account the suction pressure and with it, while all other parameters of the model remained unchanged.

The modeling results are presented in Figures 6-10.

The first calculation was performed for a preliminary assessment of the effect of suction pressure. For this purpose, a stability calculation was performed for a slope composed of one type of soil. The calculation results are shown in Figures 6 and 7. The modeling analysis showed that even if the slope is formed by one type of soil, there is a difference between the values of the stability coefficient without taking into account suction and with it. Without suction and capillarity, the stability coefficient was 1.21. With suction and capillarity, the stability coefficient was 1.38.

The analysis of the figures showed that the slope stability coefficient without taking into account suction and capillarity of the soil is 1.46 (Figure 8). With suction and capillarity, the stability coefficient increases to 1.67 (Figure 9). If only the suction pressure is taken into account in the modeling process without taking capillarity into account (Figure 10), the stability coefficient is 1.66.

In addition, the pore pressure was calculated, including the negative one. The maximum value was 39.94 kPa, and the negative value was -50 kPa according to the boundary condition. The maximum suction pressure was also 39.94 kPa.

©2025 Great Britain Journals Press

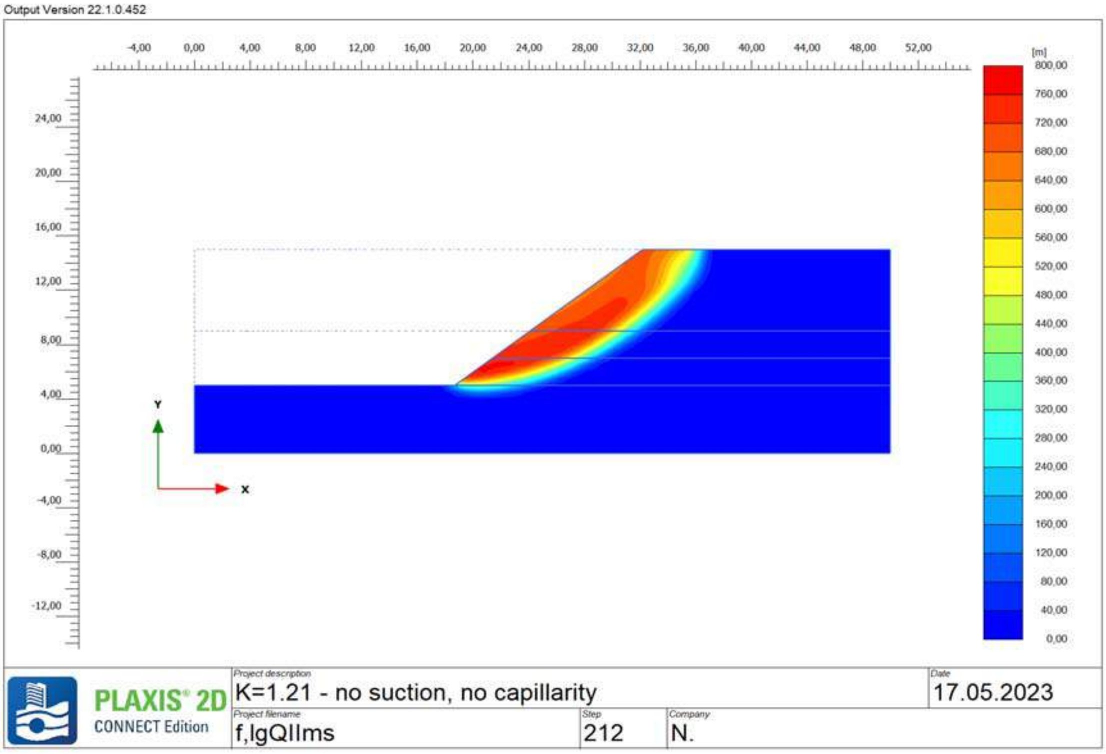

Figure 6

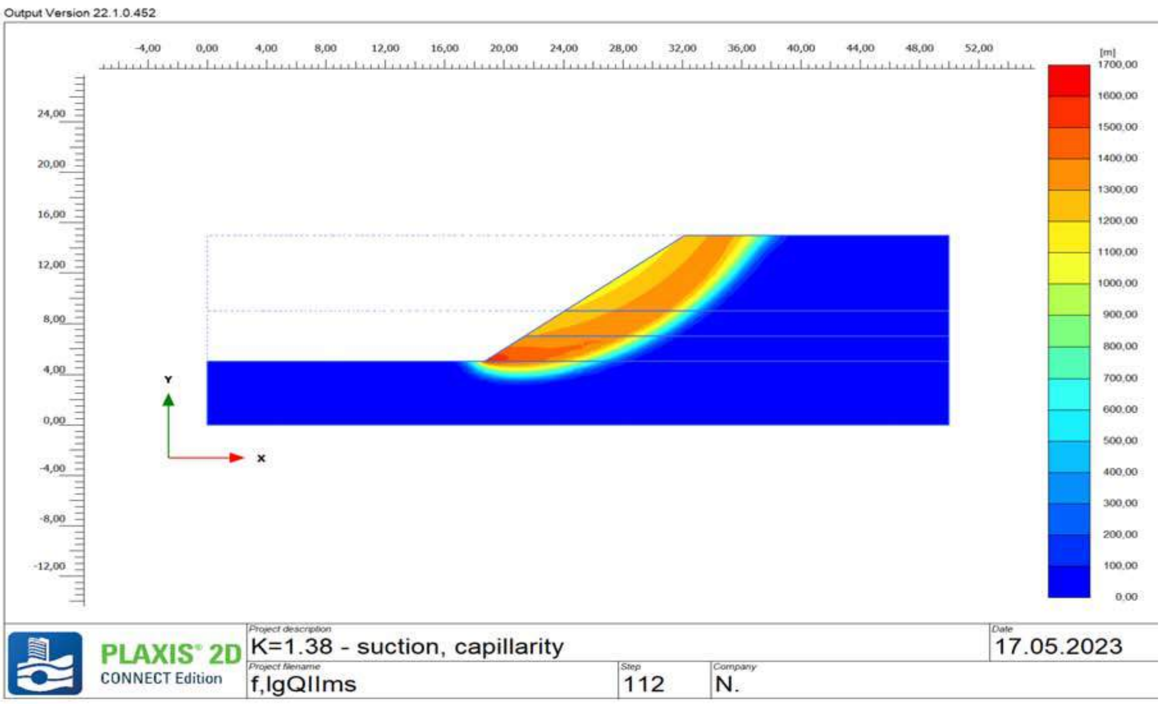

Figure 7

©2025 Great Britain Journals Press

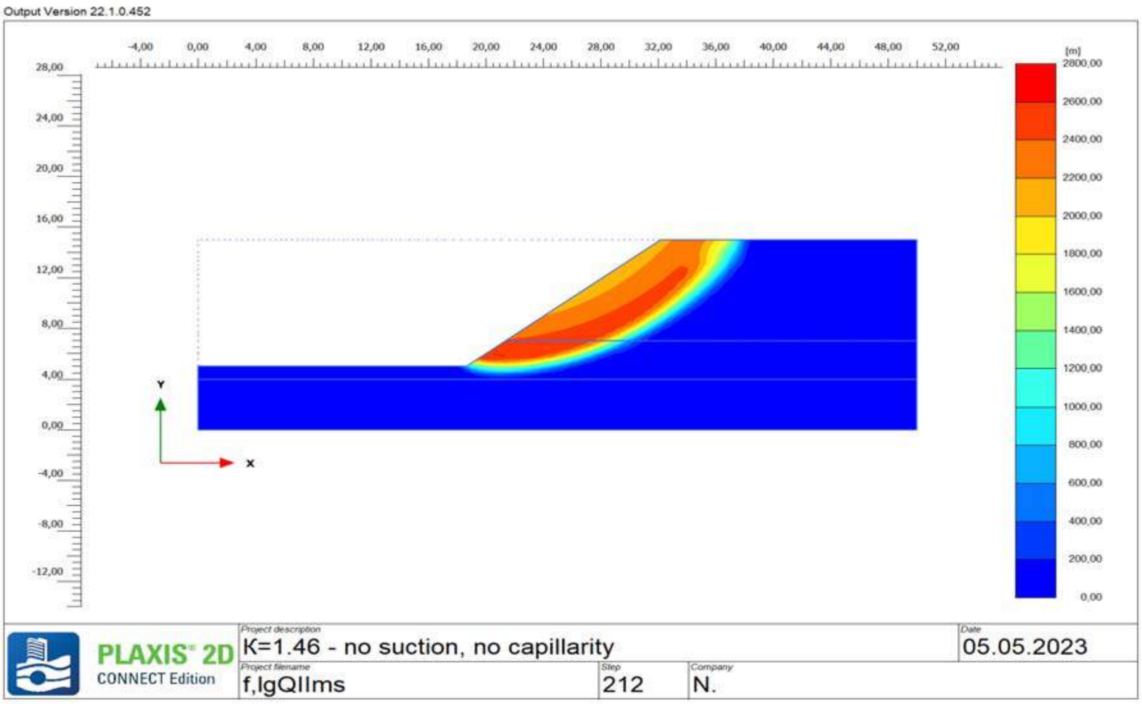

Figure 8

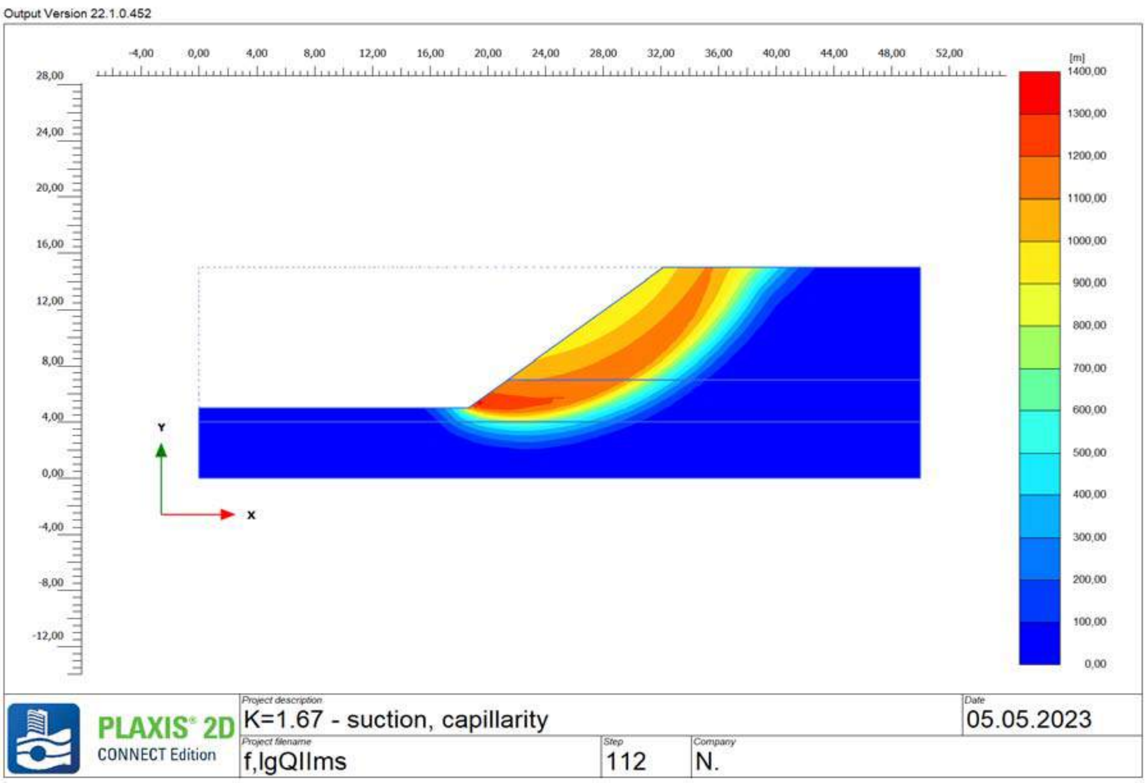

Figure 9

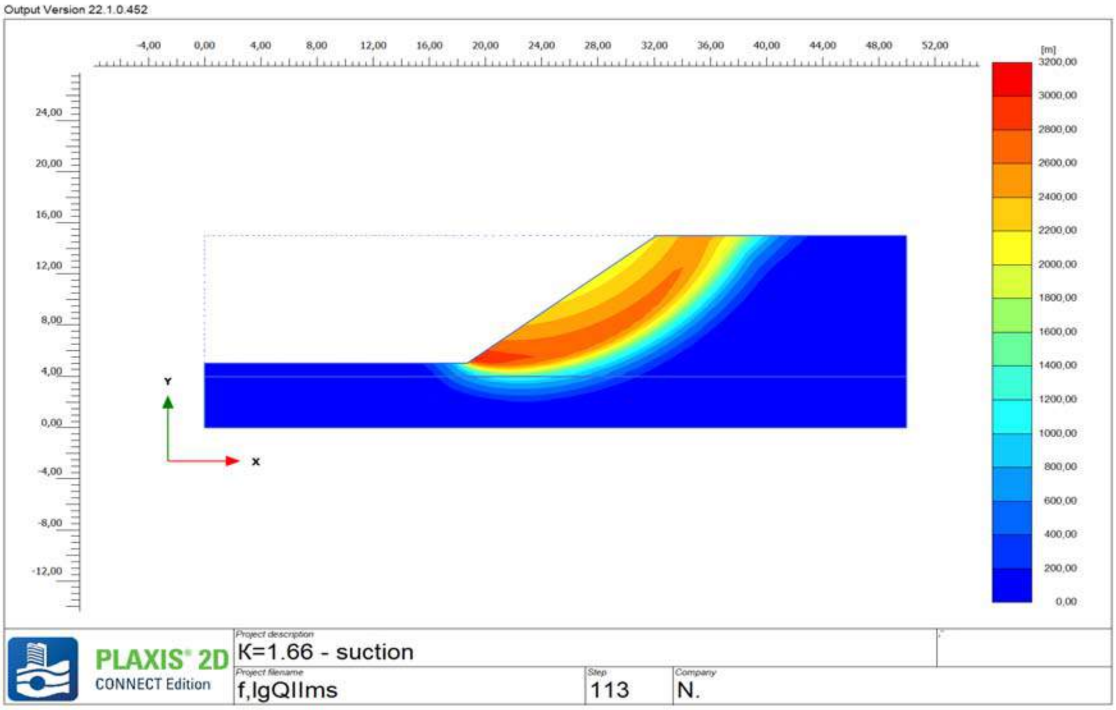

Figure 10

REFERENCES

1. Bishop, A. W. (1959). "The principle of effective stress." Teknisk Ukeblad I Samarbeide Med Teknikk, 106(39), 859–863.
2. Fredlund, D. G., and Rahardjo, H. (1993). Soil mechanics for unsaturated soils, Wiley, New York.
3. Fredlund, D.G., Soil Suction Monitoring for Roads and Air Fields, 1989, In Proceedings of Symposium on the State of the Art of Pavement Response Monitoring Systems for Roads and Airfields, pp.113-121.
4. Greco, Roberto. Rainfall-induced landslides in shallow granular soil covers: hydrological processes controlling slope response to seasonal climatic forcing. iRALL School, October 20, 2021, Chengdu University of Technology. Microsoft PowerPoint Presentation.
5. Houlsby, G. T. (1979). "The work input to a granular material." Geotechnique, 29(3), 354–358.
6. Houlsby, G. T. (1997). "The work input to an unsaturated granular material." Geotechnique, 47(1), 193–196.
7. Khalili, N., and Khabbaz, M. H. (1998). "A unique relationship for *X* for the determination of shear strength of unsaturated soils." Geotechnique, 48(5), 681–688.
8. Lu, N., and Likos, W. J. (2006). "Suction stress characteristic curve for unsaturated soil." J. Geotech. Geoenviron. Eng., 132(2), 131–142.
9. Methodical recommendations for the course "Fundamentals of Hydrogeology" Authors: K.V. Belov, A.B. Lisenkov. MGRI. Moscow, 2019, 47 p.
10. Mitchell, J. K., and Soga, K. (2006). Fundamentals of soil behavior, Wiley, New York.
11. Muraleetharan, K. K., and Wei, C. (1999). "Dynamic behavior of unsaturated porous media: Governing equations using the theory of mixtures with interfaces (TMI)." Int. J. Numer. Analyt. Meth. Geomech., 23, 1579–1608.
12. Murray, E. J. (2002). "An equation of state for unsaturated soils." Can. Geotech. J., 39, 125–140.
13. Ning Lu, F.ASCE. Is Matric Suction a Stress Variable? Journal of Geotechnical and Geoenvironmental Engineering Volume 134, Issue 7 https://doi.org/10.1061/ (ASCE)1090-0241(2008)134:7(899)

©2025 Great Britain Journals Press

14. Novgorodova M.A., Gorobtsov D.N., Ushakov A.S. Effect of suction pressure of clayey partially saturated soils on slope stability. Proceedings of Higher Educational Establishments: Geology and Exploration. 2024;66(2):69-79. https://doi.org/10.32454/0016-7762-2024-66-2-69-79.
15. Skorobogatko K.V. 2022. Soil mechanics of saturated and unsaturated soil regions // Specialized calculation complexes MIDAS URL: https://midasoft.ru/blog/mekhanika-gruntov- nasyshchennoy -i- nevodonasyshchennoy-oblasti-grunta/ (date of access: 02.03.2024).
16. Skorobogatko K.V. Modeling of soil properties in the unsaturated zone above the groundwater level // Specialized calculation complexes MIDAS. URL: https://midasoft.ru/blog/modelirovanie-svoystv-grunta-v-nevodonasyshchennoy-oblasti-vyshe-urovnya-gruntovykh-vod/ (date of access: 08.10.2024).

©2025 Great Britain Journals Press