

Effect of chemical additives on the freezing characteristics of clayey soils

A Zhussupbekov¹, G Tleulnova¹, E Serebrennikova²

¹Department of Civil Engineering, L.N. Gumilyov Eurasian National University, 2, Satpayev Street, Astana 010008, Kazakhstan

²South Ural State University, 76, Lenin prospect, Chelyabinsk 454080, Russia

E-mail: astana-geostroi@mail.ru

Abstract. Some regions in Kazakhstan and Russia have a long winter season. On average, the ice freezes in early December and the end of March. In this study, the authors investigate the different type of soil, four specimens of soil with different engineering characteristics and soil classification by a unified classification method. The freezing test was carried out for four sorts of classified samples CL by the Unification Classifications (USCS). The temperature change of the specimens and change condition of the outside freezing temperature, appear the amount of frost heaving. During the experiments the authors used the sample of soils - marine clay, containing chemical additives— ash 4%, 6%, 8% and only clay. The frost test equipment consists of a sample loading part, water supply part and a measuring device for heaving the amount and atmospheric pressure. The measuring part is a load cell for measuring the pressure and holder Linear Variable Differential Transformers (LVDT) for measuring the swelling amount of the same phase. The boundary temperature condition was at -12°C. The temperature of 1 cm deep at the surface of the specimen was 0°C and the inside temperature of the experiment was changed to -3°C. As a results, for the TRRL standard it was found out that the minimum heaving amount is 0,5 mm during 48 h, which has clay with chemical additives ash 8%, and maximum heaving amount is 4 mm during 48 h, which contains clay without chemical additives.

1. Introduction

The question of frozen soils studied by many researchers, both local and foreign. Most experienced in these works are considered scientists from South Korea.

Nevertheless, the problem seasonally freezing soils such as change the mechanical and physical properties of frozen soils are dependent on temperature, etc., is quite complex and poorly understood. The thickness of frozen soils was determined from the temperature regimes. The temperature regime depends on climate. In regions of Kazakhstan has long winter season. On average, the ice freezes in early December and the end of March.

In this study, investigate the different type of soil, 4 kinds of specimen of soil with different engineering characteristics and soil classification by unified classification method. In experiments used sample of soils is marine clay CL for USCS. The object of study is research frozen soils clay with different content chemical additives.



2. Experimental method

The study on geotechnical properties of frozen soil was carried out through indoor and field tests such as the characteristics of heaving amount. However, although ASTM, JGS, and TRRL methods are currently being used for the determination of statistical sensitivity, there is a need to establish an appropriate test method for the domestic environment conditions and establishment of the statistical sensitivity criteria. Therefore, in this research, the frozen soil temperature change, frozen water amount, floating water, and amount ice lens were measured for four kinds of soil samples by using the frozen soil sensitivity test method which is currently applied by using the produced room frozen experiment apparatus(freezing camera) [1-16].

2.1. Geotechnical properties of samples

First, the mechanical characteristics and freezing test were carried out for four kinds of classified samples by the Unification Classification (USCS). The temperature change of the sample depends of the continuous condition of the freezing temperature, the amount of frost heave, moisture of soil. The sensitivity of the images was evaluated by analyzing the characteristics. Specific gravity tests, liquid and plastic tests, sieving tests, and compaction tests were carried out in accordance with the standard test methods to determine the physical properties of each classified soil sample. In particular, the maximum dry unit weight and the optimal water content were calculated with a maximum grain size of 10 mm for the compaction method used in the roadside compaction management [12-17]. Microscopic size of particles or a small amount of fine clay.

In this research use four kinds of samples clay with different chemical additives content was used. And also analyzed the behavior of clay samples during the freezing test

3. Methodology of experiments

All four samples were placed, and the temperature, the amount of swelling, the swelling pressure, and the floating water content were measured. The boundary temperature condition of the room temperature experiment was maintained at -12 ° C until the temperature of 1 cm above the specimen of the specimen reached 0 ° C after the start of the in situ coincidence test. The temperature of 1 cm deep at the surface of the specimen was 0 ° C and the internal temperature of the experiment was changed to -3 ° C, and the experiment was performed for 96 hours after the start of the experiment. In order to maintain the inflow water temperature constant at 4 ° C, the temperature was controlled through the cooling system and the thermal insulation system.

Figure 1 and Figure 3 are presented equipment for monitoring and checked displacement freezing soil in samples.

In addition, as shown on Figure 2 and Figure 4 the freezing method was one-sided warm-tempering method, and the freezing direction of the sample was frozen from the top to the bottom as in the ASTM method and the TRRL method. However, when it is frozen from top to bottom, the top is frozen, and there is a cohesive force between the mold and the sample, and the frost is frozen. In order to overcome this disadvantage, in this experiment, a silicone material pad with elasticity was inserted between the mold and the sample to minimize the adhesion between the mould and the sample.

3.1. Experimental equipment and measurement

Figure 3 shows the attached device and the whole view of the room sampler system, which was constructed to evaluate the characteristics of the frost the soil type. The frost test equipment consists of a sample loading part, a water supply part for supplying water, and a measuring device for measuring the expansion amount and the atmospheric pressure.

A total of four specimens can be inserted into the loading section of the sample, and a porous stone having a thickness of 6 mm and a diameter of 100 mm is placed on the bottom of the loading section.

The measuring part is composed of a holder for mounting a load cell for measuring the in-phase expansion pressure and a holder for mounting LVDT (Linear Variable Differential Transformers) for measuring the swelling amount of the same phase. TRIME-FM, a model of time domain reflectometry

(TDR), was installed inside the specimen. The temperature of each specimen was measured using a thermocouple installed at 1 cm intervals. LVDT (Figure 1) check settlement soil in the samples [18-20].



Figure 1. LVDT for measuring the swelling amount.



Figure 2. Four samples in freezing box.

The sensors of the decal and thermocouple were connected to the data logger automatic measuring equipment. In addition, the TDR probe floating water was measured by connecting to a laptop and measured by a measuring program. All the data were measured at intervals of 1 hour (Figure 4).



Figure 3. Monitor to check displacement freezing soil.



Figure 4. Freezing camera.



Figure 5. Prepare soil in samples for freezing test.

In this experiment, the specimens were weighed at 100% degree of compaction using the maximum drying unit weight and the optimum water content, in the soil compaction test method.

The system is equipped with an open system to generate a phase due to the rise of the capillary tube. In general, the water supply system uses open and closed methods according to the groundwater conditions when testing the field samples. However, in this case, the experiment was carried out in an open method to reproduce the condition of the area vulnerable to frostbite because the groundwater level was low. The specimens were plumbed into 3 layers and the specimens were soaked for 2 days after compaction to induce saturation.

4. Experimental results

The amount of swelling is an important parameter used to estimate the frost heave rate used for the determination of the isosceles sensitivities.

In general, soil properties increase steadily when the supply of sufficient water is maintained at a constant zero temperature. Such a frost heaving characteristic can be obtained by varying the amount of in-phase expansion during a unit time which is used as an index to judge statistical sensitivity.

The figure 6 is shows the amount of in-phase expansion depending on the type of soil.

The temperature of 1 cm deep at the surface of the specimen was 0 °C and the inside temperature of the experiment was changed to -3 °C. As a results, for TRRL standard it was found that the minimum heaving amount is 0.5 mm during 48 hr, which have clay with chemical additives ash 8%, and maximum heaving amount is 0.4 mm during 48 hr, contain clay without chemical additives. In table 1 are presented the results of heaving ratio during 24 hour different types of clay samples. Clay with chemical additives 8% is 0.4 mm, it is less than comparable other type soils.

Table 1. Value heaving rate of different sort of freezing of soil.

Heaving ratio	Clay	Clay+chemical additives 4%	Clay+chemical additives 6%	Clay+chemical additives 8%
mm/day/ 24 hours	2.5	1.0	0.6	0.4

Table 2. Value heaving amount of different sort of freezing of soil.

Discription	Clay	Clay+chemical additives 4%	Clay+chemical additives 6%	Clay+chemical additives 8%
Displacement (mm)	15	2.5	0.7	0.5

In the table 2 are illustrated displacement freezing soil, clay with chemical additives 8% has 0.5 mm.

4.1. Results of Ice Lens Characteristics

When water is present in the bottom soil at a temperature below 0 °C, the water rises along the surface of the soil constantly due to the capillary phenomenon, and flows into the upper part to cause frostbite. In stationary frost heaving, the freezing of pore water gradually increases and the amount of in-phase expansion increases with the increase of ice crystals in the sample. The formation of the pieces was remarkable, and the enlargement of the area of the ice lens portion could be confirmed by the naked eye. However, CL, which are not susceptible to frostbite, are very small in shape and cannot be visually confirmed [2-10]. The figure 6 are illustrated different type of samples. So, much better physical characteristics is clay with chemical additives 8% has piece ice lens.

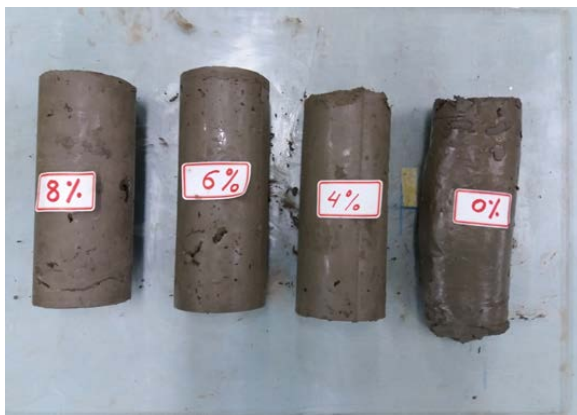


Figure 6. Results freezing test of different type of clay samples.

The figure 7 are presented results heaving amount (mm) and elapsed time (hr). Samples clay with chemical additives 8% has 0.5 mm during 36 hours, and maximum heaving amount is 0.5 mm during 48 hours.

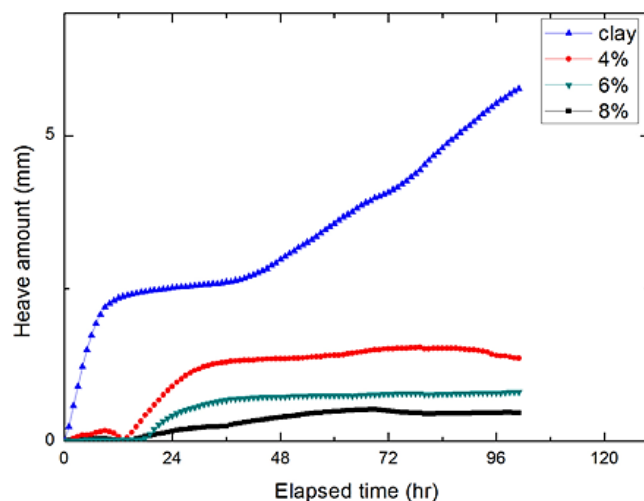


Figure 7. Graphs of samples of freezing test.

5. Conclusion

In this study, the frozen soil temperature change, frozen water amount, floating water, and ice lens were measured for four types of soil samples using the currently used frost susceptibility test method. The main conclusions are as follows CL, which were found to be highly susceptible to the same phase among four samples used in the experiment. When the temperature characteristics, swelling amount,

and floating water characteristics are analyzed, it can be seen that the most important factor affecting the isothermal sensitivity at the same temperature is the rise of the soil capillary. The amount of 200 sieve passing through the soil, the particle size distribution, and the permeability coefficient interact with each other to affect the frost heave characteristics. In other words, clay with chemical additives 8% content, but less clay content, tend to be more susceptible to frostbite.

As a result of comparing ASTM, JGS, and TRRL methods with the method applied in this experiment, different test results were different from each other according to each test standard and same phase sensitivity criterion. Because the different phases are generated according to the experimental condition, the appropriate experiment is applied according to the temperature and moisture characteristics of the region.

The temperature change of the specimens and change condition of the outside freezing temperature, appear the amount of frost heaving. During the experiments used sample of soils is marine clay contain chemical additives – ash 4%, 6%, 8% and only clay. The frost test equipment consists of a sample loading part, water supply part and a measuring device for heaving amount and atmospheric pressure. The measuring part is load cell for measuring the pressure and holder (LVDT) for measuring the swelling amount of the same phase. The boundary temperature condition was at -12°C . The temperature of 1 cm deep at the surface of the specimen was 0°C and the inside temperature of the experiment was changed to -3°C . As a results, for TRRL standard it was found that the minimum heaving amount is 0.5 mm during 48 hr, which have clay with chemical additives ash 8%, and maximum heaving amount is 2.8 mm during 48 hr, contain clay without chemical additives.

References

- [1] Zhussupbekov A, Shakhmov Zh, Lukpanov R, Tleulnova G and Kudryavtsev S 2017 Frost depth monitoring of pavement and evaluation of frost susceptibility at soil ground of Kazakhstan *Proc. 19th Int. Conf. on Soil Mechanics and Geotechnical Engineering* (South Korea) **2** pp 1455–1458
- [2] Shakhmov Zh, Zhussupbekov A 2015 Frost susceptibility of soil and in-situ monitoring of frost depth in construction *Proc. 15th Asian Regional Conf. on Soil Mechanics and Geotechnical Engineering* ARC (Japan) pp 537–540
- [3] Zhussupbekov A, Shakhmov Zh, Tleulnova G 2017 Geotechnical problems on freezing ground soil and experimental investigation in Kazakhstan *Science in cold and arid region* (China) **9** (3) pp 331–334
- [4] Shin E Sh, Ryu B H, Park J J 2013 The Frost Heaving Susceptibility Evaluation of Subgrade Soils Using Laboratory Freezing System *J. Korean Geosynthetic Society* (South Korea) **12** pp 13–23
- [5] Zhussupbekov A, Shakhmov Zh, Yenkebayev S, Lukpanov R 2015 Freezing of the soil ground and experimental investigation in condition of Astana *Proc. 6th Int. Geotechnical Symposium on Disaster Mitigation in Special Geoenvironmental Conditions* (India) pp 427–430
- [6] Tleulnova G 2018 Application TRRL method of frozen soil ground *Proc. XIII Int. Scientific Conf. for Students and Young Scientists Science and Education* (Kazakhstan) pp 6249–6253
- [7] Tsytovich N 1973 *Mechanics of Frozen soil ground* (Moscow) pp 125–148
- [8] Karlov V D 2007 *Soil-based and Foundations on season freezing and swelling soil ground* (Saint-Petersburg) pp 135–170
- [9] Nevzorov A L 2000 *Foundations on seasonally frozen ground* (Moscow) pp 30–47
- [10] Shakhmov Zh 2013 *Influence of the freezing to soil ground of foundation* PhD Thesis (Astana) pp 65–79
- [11] Shakhmov Zh 2014 Assessment of the degree frost heaving soil ground by different methods *Proc. Int. Scientific Conf. of Young Scientists* (Astana) pp 4436–4443
- [12] Zhussupbekov A, Shin E, Shakhmov Zh, Tleulnova G 2018 Estimation of bearing capacity of model pile foundations in seasonally freezing soil ground *Proc. of Int. Conf. on Soil of Mechanics in Geotechnics* (Novocherkassk) pp 83–94

- [13] Shin E Ch 1994 *Shallow strip on geogrid-reinforced clay under static and cyclic loading* PhD Thesis Illinois University (USA) pp 95–124
- [14] Das Braja M 1984 *Principles of Foundation Engineering*, 2nd ed (USA: PWS Publishing Company 20 Park Plaza) pp 85–112
- [15] Dalmatov B I 1981 *Soil mechanics and foundations* (Moscow) pp 266–275
- [16] Tsytovich N A 1983 *Soil mechanics* (Moscow) pp 38–67
- [17] Anderson D M 1989 Frost heave properties of soils *Proc. Int. Symposium Frost in Geotechnical Engineering* (Finland) **1** pp 105–113
- [18] Zhussupbekov A, Omarov A, Moldazhanova A, Tulebekova A, Borgekova K, Tleulenova G 2017 Investigations of the interaction of joint piles with problematical soil ground in Kazakhstan *Proc. of 7th Int. Conf. GEOMATE 2017* (Japan) pp 383–388
- [19] Phukan Arvind 1998 Driving piles in warm permafrost *Proc. 7th Int. Conf. on Permafrost* pp 891–895
- [20] Shin E C, Park J J 2012 Soil freezing characteristics and temperature distribution in In-Ground LNG storage tank *Int. Journal of Offshore and Polar Engineering* (South Korea) **22** (1) pp 53–62