IRSTI 67.21.29

T. Ono

Hokkai-GakuenUniversity,Sapporo, Japan
E-mail: tono@hgu.jp

A Proposal of Standard Test Method for Frost Susceptibility of Soil

Abstract. A recommendation of a standard test method for frost susceptibility of soil is proposed. The recommendation is required in order to have a design technique of common and equivalent quality not only in domestic but international practice. This topic is one of the essential and current objectives of Technical Committee 216 (ISSMGE) and has been discussing to the present. The purpose of the proposed recommendation test method is defined, different methods from several countries are compared, necessary and common articles are selected and some items are specified to discuss. It is expected that this proposal would take a role to be a draft suggestion to promote discussion and achieve a final recommendation.
Keywords: Frost susceptibility of soil, Test method, TC216.

DOI: doi.org/10.32523/2616-7263-2021-135-2-49-57

Attempt for standardization of frost heave test

In 1989, there was held an International Symposium on Frost Geotechnical Engineering organized by ISSMFE Technical Committee TC-8 on Frost (the present TC216), Finnish Geotechnical Society (SGY), and Technical Research Center of Finland (VTT) in Finland. The reference testing procedures for the use of laboratory frost heave tests in the determination of frost susceptibility of soil were published in the Work report 1985-1989[1)] by TC-8.

In 1995, comparative laboratory frost heave tests were carried out with common soil material planned by TC-8. Twelve laboratories had reported test results, but a final summary report was not published. A comparison report of the test results by nine Japanese institutes is available[2)].

Definitions of Terms

The terms are defined as follows for one dimensional freezing test with cylindrical cell.

Frost susceptibility -The propensity for a soil to accumulate ice and to heave during freezing

Frost heave - Upward displacement due to volume increase of soil with growing ice layers (ice lens) parallel to 0°C isothermal when soil freezes with water supply.

Amount of frost heave - Change of specimen height during freezing.

Frost heave ratio - Ratio of volume increase to initial volume of the specimen.

Frost heave rate - Increase of frost heave divided by length of time.

Freezing rate - Speed of advancement of freezing line into the unfrozen soil.

Existing Test Methods

Figures 1 to 4 show test devices which are publicized in literature or currently available by the author. Tables 1 to 3 summarize their dimension and procedure. The classification by frost susceptibility index used in those methods are shown in Tables 4 to 6. These devices and procedures have been set up and used for different purpose of freezing test.

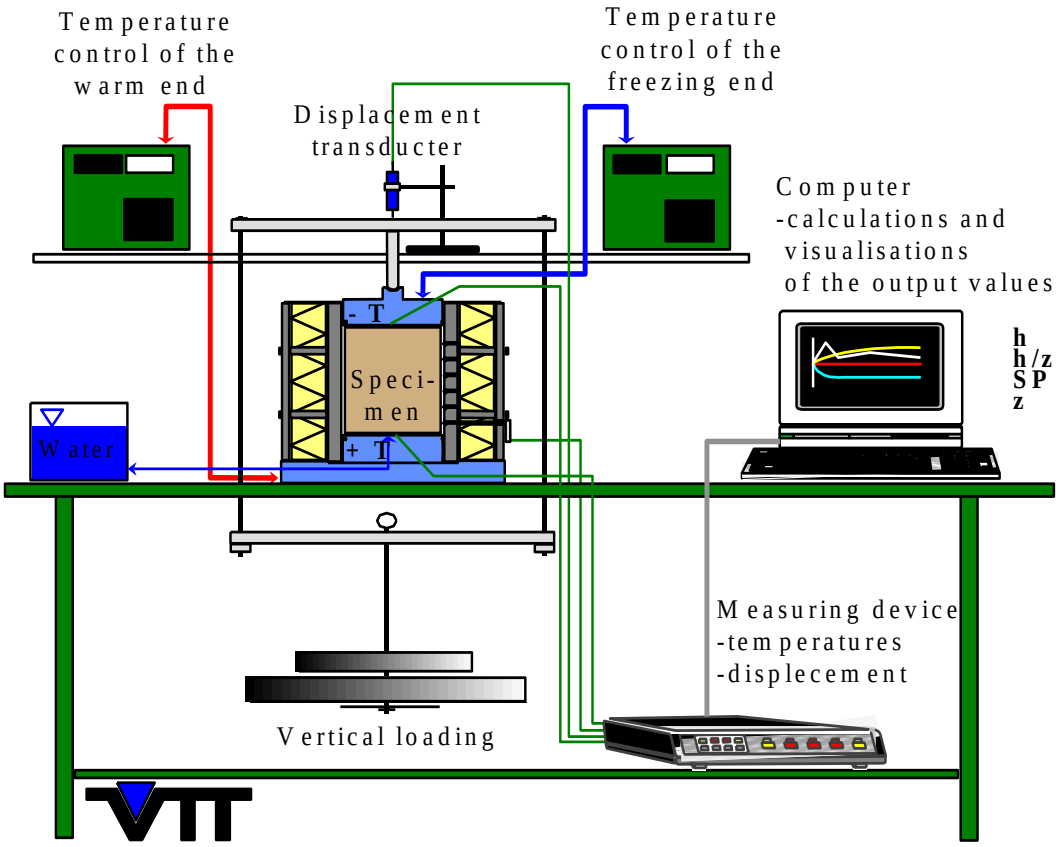

Figure 1. Test device used in Sweden

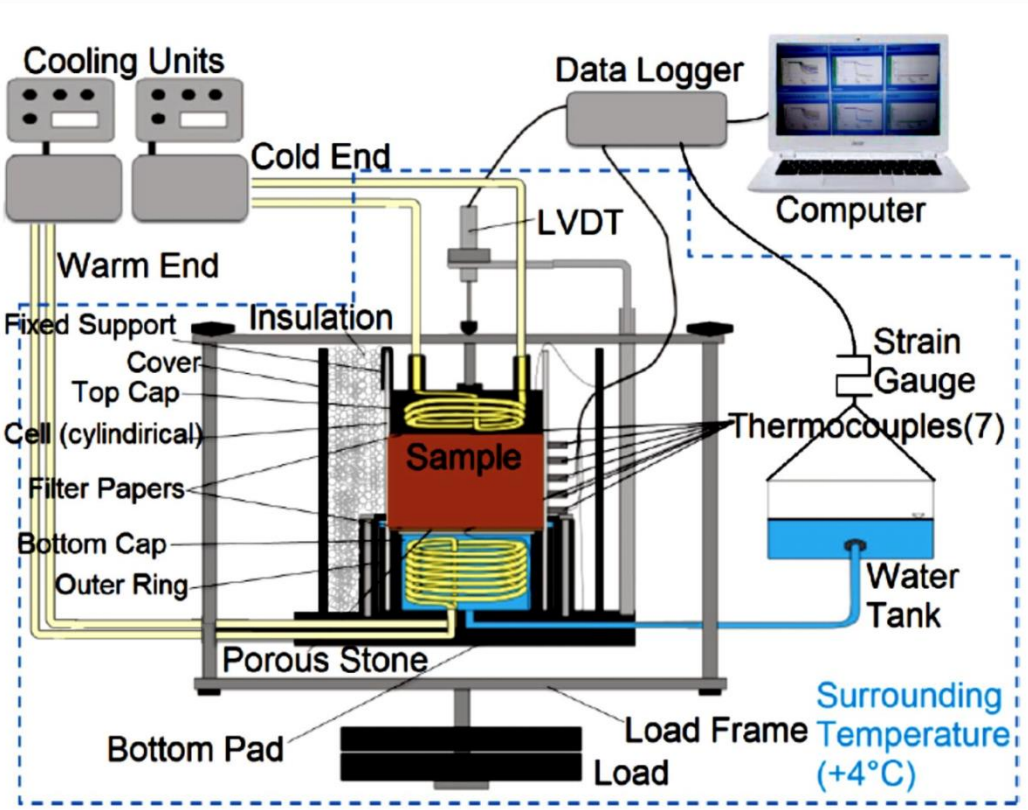

Figure 2. Test device used in Finland[3)]

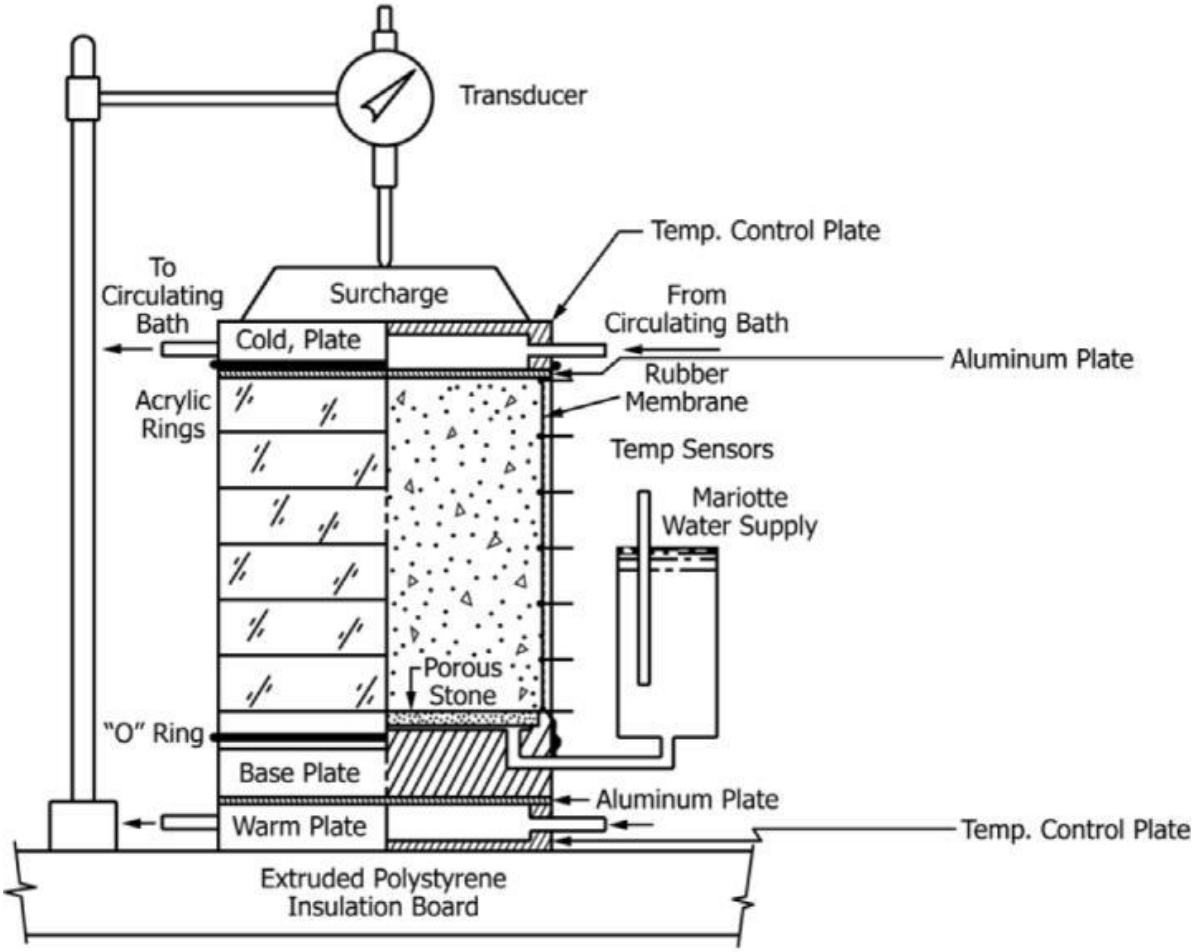

Figure 3. Test device written in ASTM (USA)[4] US

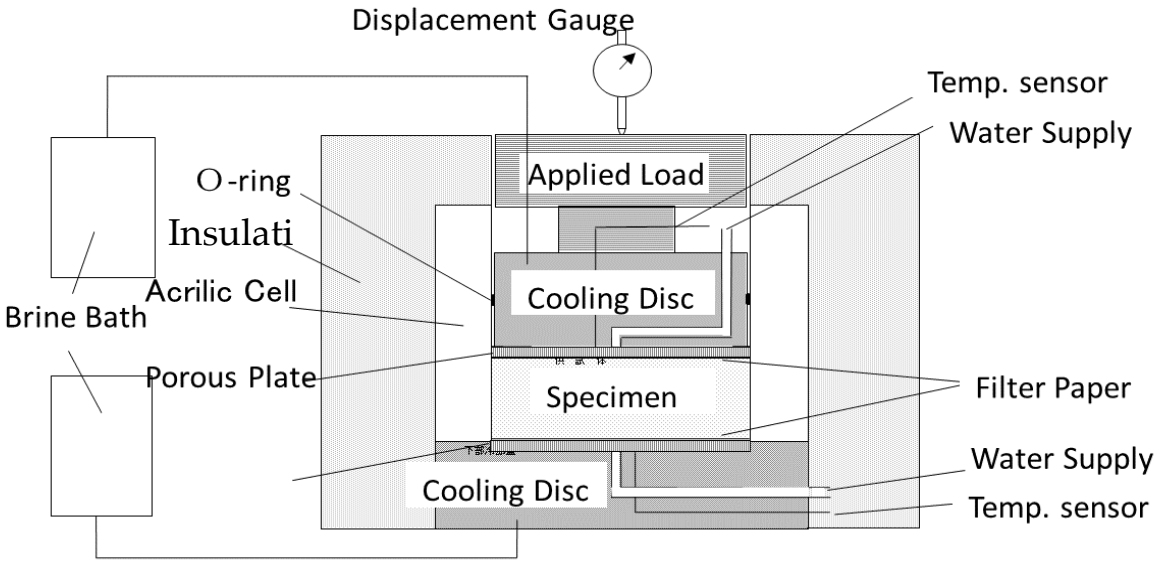

Figure 4. Test device used in Japan[5] US

Table 1

Dimension and Procedure

	Sweden	Finland
Purpose	frost heave	frost heave, thaw compression, frost susceptibility
Parameters obtained	segregational heave, heat extraction rate	frost heave ratio, SP
Specimen	compacted	undisturbed/compacted
Applied loads	-	2,20,40 kPa
Water supply	bottom	bottom
Temp. of top/bottom	cold / warm fixed	-3 ^{o}C / +1 ^{o}C fixed
Temp. sensors	7 thermocouples	8 thermistors
Freezing direction	top to bottom	top to bottom
Test duration	4 days	24 hours
Friction control	-	rubber membrane
Specimen size D/H	100/100 mm	80-150/70-200
Freezing and thawing	can be performed	two cycles
Chamber/Insulation	+4 ^{o}C/70 mm	0±1 ^{o}C/split barrel

Table 2

Dimension and Procedure

	USA(ASTM-D5918)	Japan (JGS-0171)
Purpose	frost susceptibility, thaw weakening	frost susceptibility
Parameters obtained	heave rate, bearing ratio	heave rate
Specimen	compacted	compacted/undisturbed
Applied loads	3.5 kPa	10 kPa
Penetration rate	3.6 mm/hour	1-2 mm/hour
Water supply	from bottom	from top

Temp. of top/bottom	cold / warm fixed	+0 °C / -0.1 °C/hour
Temp. sensors	7 thermocouples	2 pt100 sensors(top and bottom)
Freezing direction	top to bottom	bottom to top
Test duration	5 days	until penetrated top
Friction control	rubber membrane, multi-ring cell	slight space, greased wall, freezing direction
Specimen size D/H	150/150	100/50
Freezing and thawing	two cycles and CBR	no thawing process
Classification	average frost heave rate	maximum heave rate

Table 3

Dimension and Procedure (for artificial freezing)[6)]

	JAPAN(JGS-0172)
Purpose	frost heave for artificial freezing
Parameters obtained	frost heave ratio, thaw settlement ratio and design parameters
Specimen	undisturbed
Applied loads	field over burden stress
Water supply	from top
Temp. of top/bottom	+0 °C / cooling rate required to obtain parameters
Temp. sensors	2 pt100 sensors(top and bottom)
Freezing direction	from bottom to top
Test duration	until penetrated top
Friction control	slight space, greased wall

Specimen size D/H	60/20-40
Freezing and thawing	one cycle
Model	$\xi = \xi 0 + (\sigma 0/\sigma)(1+ (U0/U)^{1/2})$, ξ : frost heave rate, U: penetration rate, σ : confining stress

Table 4

Classification by Frost Susceptibility Index, SP[7)]

	Segregation Potential SP mm^2/Kh
Negligible	< 0.5
Low	0.5 – 1.5
Medium	1.5 – 3.0
Strong	>3.0

Table 5

Classification by Frost Susceptibility Index, ASTM(USA)[8)]

	Symbol	8-H Heave Rate *mm/day*
Negligible	NFS	<1
Very low	VL	1 to 2
Low	L	2 to4
Medium	M	4 to8
High	H	8 to16
Very high	VH	>16

Table 6

Classification by Frost Susceptibility Index, JGS(Japan)[5)]

	Frost Heave Rate U_h *mm/h*, Freezing Rate 1-2 *mm/h*
Low	< 0.1
Medium	0.1– 0.3
High	≧ 0.3

Recommendation of Test Method for Frost Susceptibility of Soil

First of all, it is proposed that the index of frost susceptibility of soil is categorized in the physical property of soil such as Atterberg index, because most of engineering purposes to carry out frost susceptibility test would be to investigate not to obtain "how much it heaves", but to know "it is frost susceptible or not as a material" for the initial judgement of necessary frost protection in the field. A proper frost heave test, as a model test with field conditions, will be then selected to obtain required data for the detailed practical design.

Frost susceptibility test of soil as a physical index test should have clear output to show the susceptibility and classification of soil making use of certain reliable parameter obtained from the test. However, it is not a practical idea to indicate single parameter index as a common recommendation method as we know several index parameters already working in different countries or areas shown above. Our task is to show a practical guideline which works well for the engineering purpose with an acceptable concept.

Followings are basically referred to the Work report 1985-1989 by TC-8[1)], and modified by considering the existing methods for proposal of essential testing elements to obtain a frost susceptibility index and classify the frost susceptibility of material.

This recommendation does not restrict any optional procedure and dimension as far as the frost susceptibility index is practically reliable and works well, and the method provides value which is not relying on material and tester.

Test device

Test device consists of cylindrical test cell, temperature and displacement measurement sensors, measurement system for supplied water volume, loading device, temperature control unit and data acquisition equipment. The cell should be constructed of a material with low thermal conductivity and insulated with proper insulation material to keep a horizontal freezing front line in the sample during test. The friction between the sample and the cell wall should be minimized with appropriate manner. Temperatures should be controlled with the precision of 0.1 degree at least.

Sample preparation

Saturated compacted sample with appropriate density is used to ensure a stable physical test results as possible.

Test and Test results

Temperatures, displacement and supplied water volume should be recorded during freezing with suitable intervals for the purpose.

It is recommended to confirm to start freezing without delay of frost heave by means of avoiding the super cooling of sample surface at the beginning of freezing process, and to check the amount of frost heave coinciding with the calculated value from the supplied water volume.

Test results should give an index parameter to determine and classify the frost susceptibility of the material.

Determination of frost susceptibility

The index parameter to determine and classify the frost susceptibility should have good corresponding relation with the field observation to ensure its certainty.

Discussion

Test Device

The insulation around the cell and the precision of temperature sensors are shown as essential items especially for a testing under low temperature to obtain proper data, but other details for device are not indicated because several testing devices with different dimensions and styles are already used and working now.

Test

The recommendation of avoiding supercooling and checking frost heave by water volume is one of the reasonable methods to increase the accuracy of test results. Typical techniques to break supercooling are "tapping" and "thermal shock".

Frost Susceptibility Index

Frost susceptibility index should have a basis which is connected well to field observation as a practical physical index. It is expected to clarify correlation between the index and the field data in the explanation of test method.

References

1. ISSMFE Technical Committee on Frost, TC-8The use of laboratory frost heave tests in the determination of frost susceptibility: International Symposium on Frost Geotechnical Engineering, VTT Symposium 94. Saariselkä, Finland, 1989. -P. 37-42.

2. Ono T., Fukuda M. and Mitachi T. Comparative Frost Heave Test Results in Japan: Proceeding of Ninth International Conference on Cold Regions Engineering, ASCE. Duluth, USA,-1998. -P. 624-635.

3. VTT Method Description Frost heave test Thaw compression test, TPPT-R07, -1999.

4. ASTM Standard Test Methods for Frost Heave and Thaw Weakening Susceptibility of Soils, ASTM D 5918- 96, -P. 3, -1996.

5. JGS (Japanese Geotechnical Society) Test method for frost susceptibility of soils, JGS 0172, -2009.

6. JGS (Japanese Geotechnical Society) Test method for frost heave prediction of soils, JGS 0171, -2009.

7. ISSMFE Technical Committee on Frost, TC-8Work Report 1985-1989: International Symposium on Frost Geotechnical Engineering, VTT Symposium 94, Saariselkä , Finland, -1989, -P. 21.

8. ASTM Standard Test Methods for Frost Heave and Thaw Weakening Susceptibility of Soils, ASTM D 5918- 96, -P. 8, -1996.

Т. Оно

Хоккай-Гакуен университеті, Саппоро, Жапония

Топырақтың аязға төзімділігін сынау әдісінің стандарт ретінде ұсынысы

Аңдатпа. Топырақтың аязға бейімділігі бойынша стандартты сынау әдісі ұсынылады. Ұсыныс тек отандық қана емес, халықаралық тәжірибеде де ортақ және баламалы сапаны жобалау техникасына ие болу үшін қажет. Бұл тақырып 216 Техникалық Комитетінің (ISSMGE) маңызды әрі ағымдағы мақсаттарының бірі болып табылады. Осы уақытқа дейін талқыланып келеді. Ұсынылатын тестілеу әдісінің мақсаты айқындалды, бірнеше елдердің әртүрлі әдістері салыстырылды, қажет әрі жалпы мақалалар таңдалды, кейбір тармақтар талқылауға ұсынылды. Бұл ұсыныс талқылауға ықпал етіп, соңғы ұсынысқа қол жеткізу үшін ұсыныстың жобасы бола алады деп күтілуде.

Түйін сөздер: топырақтың аязға бейімділігі, тест әдісі, TC216.

T.Оно

Университет Хоккай-Гакуэн, Саппоро, Япония

Проект метода определения морозостойкости грунтов в качестве общепринятого стандарта

Аннотация. Предложена рекомендация по стандартному методу испытаний на морозостойкость грунтов, которая необходима для того, чтобы методика проектирования общего и равноценного качества была не только в отечественной, но и в международной практике. Данная тема является одной из основных и текущих задач Технического комитета 216 (ISSMGE) и обсуждается до сих пор. Определяется цель предлагаемого рекомендательного метода тестирования, сравниваются различные методы из нескольких стран, выбираются необходимые и общие статьи, а также указываются некоторые вопросы для обсуждения. Ожидается, что это предложение сыграет роль проекта предложения, способствующего обсуждению и выработке окончательной рекомендации.

Ключевые слова: морозостойкость почвы, метод испытания, ТС216.

References

1. ISSMFE Technical Committee on Frost, TC-8The use of laboratory frost heave tests in the determination of frost susceptibility: International Symposium on Frost Geotechnical Engineering, VTT Symposium 94. Saariselkä, Finland, 1989. P. 37-42.

2. Ono T., Fukuda M. and Mitachi T. Comparative Frost Heave Test Results in Japan: Proceeding of Ninth International Conference on Cold Regions Engineering, ASCE. Duluth, USA, 1998. P. 624-635.

3. VTT Method Description Frost heave test Thaw compression test, TPPT-R07, 1999.

4. ASTM Standard Test Methods for Frost Heave and Thaw Weakening Susceptibility of Soils, ASTM D. 5918 – 96, P. 3, 1996.

5. JGS (Japanese Geotechnical Society) Test method for frost susceptibility of soils, JGS 0172, 2009.

6. JGS (Japanese Geotechnical Society) Test method for frost heave prediction of soils, JGS 0171, 2009.

7. ISSMFE Technical Committee on Frost, TC-8Work Report 1985-1989: International Symposium on Frost Geotechnical Engineering, VTT Symposium 94, Saariselkä , Finland, 1989, P. 21.

8. ASTM Standard Test Methods for Frost Heave and Thaw Weakening Susceptibility of Soils, ASTM D 5918- 96, P. 8, 1996.

Information about author:

T. Ono - ТС21 төрағасы, Хоккай - Гакуену ниверситеті, Саппоро, Жапония.

T. Ono - Chair of TC21, Hokkai - Gakuen University, Sapporo, Japan.