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Determination of frost-susceptibility of soils

Determination du potentiel du gel du sol

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ABSTRACT
The ISSMFE/ISSMGE Technical Committee on Frost (TC 8) has dealt with the determination of frost-susceptibility of soils and given proposals for recommended methods and procedures. This presentation is a short summary of the work.

RÉSUMÉ
Le comité technique de ISSMFE/ISSMGE du gel (TC 8) s`est occupé de la détermination de la gélivité des sols et a proposé des procédures et méthodes. Cette présentation est un bref résumé de ce travail.

1 INTRODUCTION

The frost-susceptibility (FS) of a soil has to be treated firstly as a soil property and secondly as the frost-susceptibility of a soil in situ. The first treatment is meant for comparing the properties describing the frost-susceptibility of various soils with each other. The second one takes into account the influence of geological profile and boundary conditions on the frost heave in a soil layer in situ, e.g. the effects of freezing index, the depth to the ground water level and the stress state.

Frost action causes in a frost-susceptible soil frost heaving, thaw settlement and thaw weakening. The frost heaving is considered as an important design factor in many countries. A structure's technical design for frost action is firstly based on frost heaving. After that the bearing capacity of the super structure during thawing also has to be controlled, e.g. when concerning road structures.

In the conditions, where the effects of thaw-settlement or thaw-weakening are more important than frost heaving, other criteria have to be used e.g. the thaw CBR or the resilient modulus (Cole & al. 1986) but those criteria are not considered here.

2 FROST-SUSCEPTIBILITY OF A SOIL TYPE

It is recommended that the criteria for the determination of the frost-susceptibility of a soil be grouped on three (I – III) levels as proposed by Chamberlain (1981). The frost-susceptibility of a soil type may be evaluated on the basis of grain size distribution only (level I), if the structure in question tolerates frost heave to a certain extent and/or the work in question concerns big soil masses. In those cases the classification of soils into frost-susceptible or non-frost-susceptible materials is enough. The criterion proposed by the ISSMFE Technical Committee on Frost (1989) provides a good basis for that purpose (Fig 1). The Finnish Road Administration has used nearly the same method successfully during several decades.

1. If the grain size curve lies completely within the region 1, the soil is allways frost-susceptible (FS); in the region 1L the FS is low.
2. If the grain size curve falls completely inside the regions 2,3 or 4, the soil is non-FS.
3. If the lower part of the grain size curve permanently passes the boundary of the next region on the finer side, the soil is FS.
4. Borderline cases have to be controlled with more exact methods.

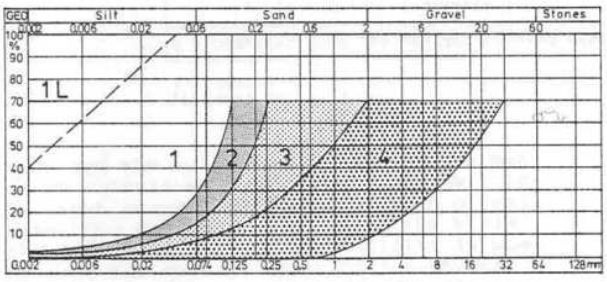

Figure 1. Determination of frost-susceptibility of a soil on the basis of a grain size curve (ISSMFE-TC 8, 1989).

In connection with more qualified structures the determination of frost-susceptibility has to be improved by other criteria based on the index properties and/or on the hydraulic properties of soils (level II) or by using frost heave model tests (level III) (ISSMFE-TC8 1989 and Slunga & Saarelainen 1989).

When checking the border between frost-susceptible and non-frost-susceptible soils, suitable criteria are e.g. the height of capillary rise (Beskow 1949) and the fines factor (Vinson & al. 1987). The water content of soil corresponding to a certain pF-value (Jones & al. 1984) seems possibly also to provide a reliable frost-susceptibility criterion, but a practical criterion on this basis is not yet established.

A comparison of the criteria for improved frost-susceptibility determination is shown in Table 1. The basic and most reliable parameters are the segregation potential (Konrad 1980) and the rate of frost heave (Chamberlain 1981). It is proposed that these parameters be determined from the results of standardized frost heave model tests. Using these parameters it is also possible to determine the degree of frost-susceptibility. The parameters are determined using in situ samples or samples, which have been compacted into the density corresponding to the in situ density of a soil at a depth of one meter. It is proposed that the specimen be consolidated by a load of 20 kPa. The recommended

type of freezing test is a constant-temperature test, during which the vertical load is very low, 3 kPa. A frost heave test may also be conducted with a constant rate of frost penetration.

Table 1. Determination of frost-susceptibility of a soil type /6/.

FROST SUSCEPTIBILITY CLASS	CAPILLARY RISE /1/ m	FINES FACTOR /3,4/	SEGREGATION POTENTIAL /5/ SP_0 mm^2/Kh	FROST HEAVE RATE /2/ mm/d
NEGLIGIBLE	< 1,0	< 2,5	< 0,5	< 0,5
LOW	1,0 – 1,5	2,5 – 5,0	0,5 – 1,5	0,5 – 2,0
MEDIUM	1,5 – 2,0	5,0 – 10	1,5 – 3,0	2,0 – 4,0
STRONG	> 2	> 10	> 3	> 4

/1/ Beskow (1949) /3/ Rieke & al. (1983)/5/ Konrad (1980) /2/ Chamberlain (1981) /4/ Vinson & al. (1987) /6/ ISSMFE-TC 8 (1989)

The comparison of frost-susceptibility criteria in Table 1 is mainly done on the basis of literature and partly on the basis of series of laboratory tests and field observations conducted in Finland 1986-87. The basic material is, however, limited and therefore a calibration in local conditions is necessary.

3 FROST-SUSCEPTIBILITY OF A SOIL IN SITU

The frost-susceptibility of a soil in situ may be determined by

- investigating
  - if the soil type is frost-susceptible assuming that all other requirements for frost heaving exist (level I) or
  - if there is available water enough for frost heaving in addition to all other requirements for frost heaving (level II) or
- conducting
  - frost heave model tests for the determination of segregation potential/ frost heave rate or
  - in situ observations of frost heaving, frost depth, temperature and water content in the soil (level III).

The frost susceptibility of a soil in situ should be considered on the basis of in situ observations or on the basis of parameters from laboratory tests, taking into account the real soil conditions and the relationship between the measured and calculated frost heave and the tolerable frost heave. The classifying criterion is then the tolerable frost heave assuming that the bearing capacity during thawing is satisfied. The frost heave has to be calculated according to accepted design conditions.

4 SUMMARY

The frost action in a frost-susceptible soil occurs as frost heaving, thaw settlement and thaw weakening. Which of these processes is the determining factor for the design depends on the local climate and soil conditions as well as on the sensitivity of the structure in question to the effects of frost action. The concept of frost-susceptibility (FS) is usually based on frost heaving. In the conditions, where the effects of thaw weakening (or settlement) are more important, criteria other than frost heaving shall be used.

The frost-susceptibility of a soil type may be determined by several laboratory methods (e.g. grain size distribution, capillarity, fines factor and frost heave model test) or by in situ observations. It is reasonable to group the methods on various levels depending on the reliability of them.

The most important criterion in a frost-susceptibility classification is to separate the FS-soils and the non-FS-soils from each other. For the FS-soils it is also important to determine the degree of the frost-susceptibility. A successful international FS-classification would provide an unanimous base for the determination of the FS of a soil type. The ISSMGE Committee on Frost (TC 8) has produced a recommendation to improve unification in the determination of the FS of soils.

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