Study on Frost Heave Evaluation System of Large Canal Foundation Soil in Cold Area

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Abstract. Frost heave of canal foundation soil is the main factor of destroying canal system engineering in the cold area. Restricted by technical and economic conditions, further evaluation of the frost heaving index and system of the large channel in cold areas where needed. Based on the field investigation and relevant evaluation methods, several evaluation indexes such as water content, compaction coefficient, fine grain content, and cumulative negative surface gas temperature, the direction of canal slope are selected. Combined with the observation results of the prototype test field for many years, the frost heave degree of large channel foundation soil was comprehensively evaluated. The purpose of this paper is to standardize the evaluation method of frost heave characteristics of canal foundation soil in cold region, which has important guiding significance for the prevention and control of road frost damage in the cold region.

1 Introduction

The frost heave degree of large channel foundation soil in cold areas is influenced by the water content, compaction coefficient, fine grain content, cumulative negative surface gas temperature, the direction of canal slope, and many other factors [1-5]. When carrying out the prevention and control work of canal frost damage according to the influence factors of frost heave, in addition to carrying out necessary investigation and monitoring of canal frost heave in a cold area, the possibility of frost heaving of canal foundation soil should be studied in advance. With the development of related subjects and the deepening of problem cognition, many evaluation techniques have been formed in the field of engineering, including fuzzy analysis, operation analysis, artificial neural network, etc.

Large channel project in the cold area of northern China, the project line is long, the climate and geological conditions along the line are different. Therefore, the frost heave degree of foundation soil in different channel sections is different, and the measures to deal with the frost damage are different for different frost heaving conditions. To evaluate the frost heave degree of the canal foundation soil, to grade the quantity of frost heaving, and to implement different measures by sections is helpful for the management to optimize the resources and improve the efficiency of frost damage treatment. It is the concrete embodiment of improving the scientific management level of engineering and is also the objective need for the development of related subjects and technologies.

2 Evaluation index

The determination of evaluation standards is not only related to the characteristics of indexes but also closely related to the requirements of evaluation methods. By the principle of easy access to the indexes, and try to make every index in the system can be described quantitatively, there is a need to understand the range of changes in each index so that the quantification of the indicators can be achieved. For the index grade division, refer to the "Code for design of hydraulic structures against ice and freezing action" (GB/T50662), the soil frost heaving grade is divided into 5 grades (Table 1). According to the long-term practice and a large number of research conclusions, the water content, compaction coefficient, fine grain content, the cumulative negative surface gas temperature, and the direction of canal slope are selected as five indexes. These indexes are divided into five levels according to the standard values by five influence descriptions: "very weak", "weaker", "stronger", "strong" and "very strong".

Table 1. Level of frost heaving of soil

Level of frost heaving of soil	I	II	III	IV	V
	No-frost heaving	Weak frost heaving	Frost heaving	Strong frost heaving	Extra-heavy frost heaving
GB/T50662 Frostheaving quantity h(cm)	$h \leq 2$	$2 < h \leq 5$	$5 < h \leq 12$	$12 < h \leq 22$	$h < 22$

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Evaluation target of frost heaving	Very weak	Weaker	Stronger	Strong	Very strong

2.1 Water content

The influence index of the water content of large canal foundation soil mainly includes the minimum distance between the groundwater level and the frozen surface during freezing, according to the classification of the level of frost heaving in G.0.1 Appendix G of GB50007, the index can be divided into 5 grades.

2.2 Compaction coefficient

The results show that the frost heaving rate increases with the increase of compaction coefficient under the same conditions. The evaluation grade of the compaction coefficient is shown in Table 2.

Table 2 Evaluation grade of compaction coefficient

Evaluation grade	I	II	III	IV	V
Compaction coefficient	>0.99	0.99~0.97	0.97~0.94	0.94~0.91	≤0.91

2.3 Compaction coefficient

For the influence of fine grain content, it is generally considered that the soil with the content ≤0.075 mm and less than 10% is no-frost heaving soil, and the frost heaving rate increases with the increase of fine grain content, but decreases when the fine grain content exceeds a certain proportion. According to the quality ratio of the fine grain content less than 0.075 mm in the canal foundation soil, the standard value interval is divided, and the evaluation grade of the fine grain content index accords with the stipulation of Table 3.

Table 3 Evaluation grade of fine grain content

Evaluation grade	I	II	III	IV	V
Fine grain content (Particle size<0.075mm)	<5 or>60	5~10 or 40~60	10~15	15~30	30~40

2.4 Cumulative negative surface gas temperature

For the interval setting of the cumulative negative surface gas temperature, according to the observation data of many years, when the cumulative negative surface gas temperature is -40°C or lower, the depth of freezing and the thickness of freezing are close to or reach the maximum value when the impact on the canal is the most serious; The initial temperature of an average month is more than -5°C when the frost depth and frost heaving amount are small. Besides, according to the basic characteristics of the monthly average negative

temperature, the cumulative negative surface gas temperature decreases linearly from-5°C to-40°C, as shown in Fig 1, the temperature range is divided into three intervals. The evaluation grades of the cumulative negative surface gas temperature are shown in Table 4.
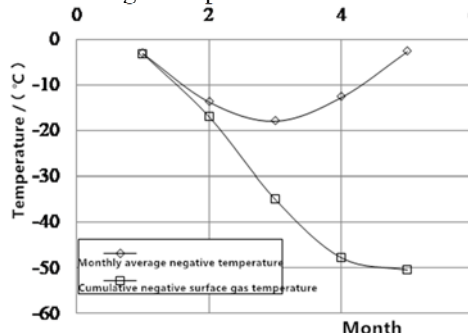

Fig.1 Basic characteristics of the monthly average negative temperature

Table 4 Evaluation grade of cumulative negative surface gas temperature

Evaluation grade	I	II	III	IV	V
Cumulative negative surface gas temperature	>-5.0	-5~-17	-17~-29	-29~-40	<-40

2.5 The direction of canal slope

The direction of large canal slope is shown in Fig.2. According to the observation results of in-situ frost heave test of large canal, the frost depth or the quantity of frost heaving of large canal shady slope is greater than that of sunny slope, and the ratio is 1.3 or even greater. According to this, the evaluation grade of the direction index of canal slope is given in Table 5.
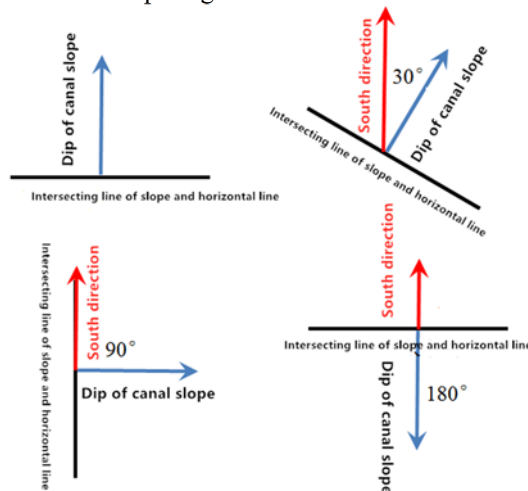

Fig.2 Schematic diagram of the direction of large canal slope

Table 5 Evaluation grade of the direction of canal slope

Evaluation grade	I	II	III	IV	V
The direction of canal slopeIntersection	0~36	36~72	72~108	108~144	144~180

angle of dip of slope and south direction (°)		

3 Evaluation system and evaluation procedure

By using analytic hierarchy process (AHP), the frost heave evaluation system of large canal in cold area is established, which is composed of target layer A, criterion layer B and index layer C. The characteristics of canal foundation soil in the criterion layer B1 include three index layer parameters: water content, compaction coefficient and fine grain content, and the characteristics of the external environment in the criterion layer B2 include two index layer parameters: cumulative negative surface gas temperature and the direction of canal slope. The frost heave evaluation system of foundation soil is shown in Table 6.

Table 6 Evaluation index system of the level of frost heaving

Targetla 4yer A	Criterion layer B	Index layer C
Frost heavings ituation of large canal in cold area	B1Characteristics of canal foundation soil	C1Water content
		C2Compaction coefficient
		C3Fine grain content
	B2Characteristics of the external environment	C4Cumulative negative surface gas temperature
		C5The direction of canal slope

The pre-determined objective of frost heave evaluation of foundation soil is described as "very weak", "weaker", "stronger", "strong", and "very strong", which correspond to five evaluation grades of Grade I, II, III, IV and V respectively (Table 1).

4 Application of evaluation system

4.1 Weight of each parameter in index layer

The weighting factors for each parameter are determined as shown in Table 7:

Table 7 Weight score of each parameter

Weight of criterion layer		Weight of index layer	
B1 Characteristics of canal foundation soil	0.53	C1 Water content	0.29
		C2 Compaction coefficient	0.15
		C3 Fine grain content	0.26
	0.47	C4 Cumulative negative surface gas temperature	0.21

B2 Characteristics of the external environment	C5 The direction of canal slope	0.09

The subordinate scores of each index are determined according to "technical code for monitoring canal safety of cold area", and the comprehensive scores of frost heave of foundation soil are calculated according to the formula (1):

Table 8 Subordinate scores of each index

Evaluation grade of each parameters	I	II	III	IV	V
Subordinate scores of each index	1	3	5	7	9

$$s = \sum_{i=1}^{m} b_i \sum_{j=1}^{n} (c_{ij} \times k_{ij}) \qquad (1)$$

where: the $'s'$ is the composite score of evaluation of canal frost heave; b_i is the weight of the i-th characteristic of the criteria layer; c_{ij} is the index weight of the j-th index; k_{ij} is the subordinate value of the j-th selected in the i-th quasi-measure layer; m=1, 2; n=1, 2, 3, 4, 5.

4.2 Evaluation of the level of frost heaving

According to the formula (1), the composite score of evaluation of canal frost heave is calculated and graded according to Table 9. The level of frost heaving increases gradually from grade I to grade V.

Table 9 Classification standard of frost heaving

Comprehensive evaluation grade of frost heave of large canal	I	II	III	IV	V
Composite score	< 2	2~4	4~6	6~8	≥8

4.3 Engineering application

According to the field observation data of the large canal, the canal section with pile number 47km on the shady slope is selected for evaluation. The water content before freezing is 14.8%, the plastic limit water content is 17.33%, the groundwater level is close to the bottom of the canal, the subordinate score of water content is 3; the compaction coefficient is 0.96, the subordinate score of compaction coefficient is 5; the < 0.075 mm particle content is more than 60%, the subordinate score is 1; the subordinate score of cumulative negative surface gas temperature is 7; the subordinate score of the direction of canal slope is 9. According to this, the composite score of

frost heaving is 2.1 and the frost heave comprehensive evaluation grade is grade II.

5 Conclusion

(1). The establishment of frost heave evaluation index system provides convenience for the determination of frost heave level of canal foundation soil in large canals, and the frost heave level of canal foundation can be judged only by the easily observed and obtained index data.

(2). The evaluation index system of frost heaving situation of canal foundation soil in the cold area is established by considering the influence factors of canal frost heaving, is suitable for the grade evaluation of large dam embankment foundation frost heave in a cold area, which makes the prevention of canal frost damage more targeted.

References

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