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The Temperature Control Technology of Bridge Foundation in Permafrost Regions

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Abstract

The stability of engineering structure are threatened in the permafrost regions by the global warming. Therefore, it is necessary to further the study on the temperature field of the pile foundation in the frozen soil area. In the paper, six different forms (pile arrangement within two, three, four; pile arrangement outside two, three, four) were studied for temperature effect in the next 50 years. Date from these numerical simulation indicates that the thermal pile has a active cooling effect in the bridge and the stability of bridge pile foundation were promoted. The same number arrangement of the the thermal pile is better outside the pile foundation than that inside the pile foundation.

Keywords: climate warming;permafrost; bridge foundation; thermal pile

1. Introduction

In recent years, due to the impact of global warming, there is a significant degradation of permafrost in permafrost regions. The degradation is manifested as the significant increase of soil temperature, the decrease of maximum frozen soil depth, the decrease of permafrost area, the increase of seasonal frozen soil area, and the lower bound of the frozen soil. Permafrost presents a general trend of degradation[1-3]. In order to ensure the overall stability of the bridge foundation engineering, the treatment measures are adopted by thermal pile. Thermal pile uses

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natural energy of foundation, the vapor liquid two phase convection circulate under the action of temperature difference. Through the evaporation section, the temperature of the surrounding soil is decreased, the cold storage of the frozen soil is increased, the thermal stability is enhanced, and the permafrost is protected. Thermal pile technology is a new technology with broad application prospects, especially in the global temperature increase in the environment, its role is more obvious. Practice has proved that the thermal pile can be prevented in permafrost thaw and frost heaving. It has achieved significant results in the Qinghai Tibet railway and highway subgrade test section of permafrost regions. In the future, thermal pile will be gradually applied in the construction of permafrost regions.

2. Thermal pile thermosyphon

Thermal pile is an airtight vacuum cavity infused with low boilling point liquid such as ammonia, freon, etc. The upside of thermal pile(condensation part) has a radiator, and the downside (evaporation part) is embedded into a permafrost layer. The middle part is thermal-insulating with the special liquid inside. In cold season,the liquid absorbs heat from the permafrost and vaporize. Then, the steam will go upwards to condensation part along thermosyphon depending on press difference. Then, the steam becomes liquid and release evaporation latent, and the liquid flows to evaporation part, thus, the whole device will take heat in the permafrost away [4-8].

3. Numerical analysis model and boundary conditions

3.1. Numerical analysis model

Thermal pile effective influence range is a three-dimensional heat transfer problems. The mathematical model is strongly nonlinear problem, which can't use a general method to solve it. Therefore, in this paper, the three-dimensional numerical analysis was used by finite element software ANSYS. Six dirfferent forms (pile arrangement within two, three, four; pile arrangement outside two, three, four) were studied for temperature effect. The coefficient of thermal conductivity of thermal probes is 10.0.

The bridge pile foundation is modeled by Solid70. The thickness of snow layer is 10cm and it is assumed to be above the ground surface. The heat capacity of the snow is 2100, coefficient of thermal conductivity is 0.09. Birth and death element method is adopted in calculation process control snow every year only applied in the winter (from November to March), the snow layer is killed in other months.

The variation of soil parameters with temperature is discontinuous. The new variable enthalpy H is used, which is the function to be solved. Enthalpy is the integral of the product of density and specific heat to the temperature, which is given by the following formula(1).

$$H = \int \rho c(T) dT \tag{1}$$

$$Q = L\rho_d \left(w - w_u\right) \tag{2}$$

- Q =phase change thermal
- L =crystallization or melting latent heat of water
- w =total moisture content
- ρ_d =dry density of soil