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In situ experimental study on thermal protection effects of the insulation method on warm permafrost

Zhi Wen *, Yu Sheng, Wei Ma, Jilin Qi

State Key Laboratory of Frozen Soil Engineering, CAREERI, CAS, Lanzhou, Gansu 730000, China

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Abstract

To evaluate the thermal protection effects of the insulation treatment, a 307 m long railway test section was constructed on the Qinghai–Tibetan plateau in 2001. Over 5 years observation data were collected and analyzed. The results showed that there was an obvious temperature difference between the top and the bottom of the insulation. The temperature of the deep permafrost rose for both the expanded polystyrene (EPS) and polyurethane foam (PU) sections due to the embankment construction. Because the soil temperature at the depth of 0.5 m below the south facing slope was much higher than that of the north facing slope and was a few degrees higher than that of the embankment surface, the permafrost temperature under the south facing slope rose, and the permafrost temperature under the centre of the embankment remained unchanged, and the permafrost temperature under the north facing slope dropped. Accordingly, the artificial permafrost table under the center of the embankment did not change, while the artificial permafrost table under the northern slope rose, and the artificial permafrost table under the southern slope declined. The experiment indicated that the insulation method was suitable for permafrost regions with low embankment surface temperature and it was not suitable for warm permafrost regions with high embankment surface temperature.

Keywords: Qinghai–Tibetan railway; Permafrost regions; Thermal insulated treatment; Ground temperature

1. Introduction

The Qinghai–Tibetan railway on the Qinghai–Tibetan plateau passes through about 550 kilometers of continuous permafrost regions, in which the warm permafrost regions with mean annual ground temperature higher than −1.0 °C accounts for about 275 km. The construction on permafrost may induce substantial disturbance on the heat and mass balance between the ground surface and atmosphere, which will result in more heat absorption in the embankment. Besides, the mean annual air temperature on the Qinghai–Tibetan plateau has been rising in the past decades with the influence from global warming. Qing's research (2002) showed that the air temperature in the north-west area of china will rise by 1.9–2.3 °C in the following 50 years. As a result, the temperature of permafrost underneath may rise, sufficiently to lead to thawing of the permafrost. Thaw settlement is bound to happen, which results in serious damages to the embankment in the Qinghai–Tibetan plateau (Wu and Tong, 1995; Wen et al., 2003; Liu et al., 2002). Therefore, many countermeasures, such as ventilated embankment, open-graded embankment, heat pipes and sunshine shading have been applied to protect the permafrost (Ma et al., 2002).

* Corresponding author. Tel.: +86 931 4967 262.
E-mail address: wenzhi@lzb.ac.cn (Z. Wen).

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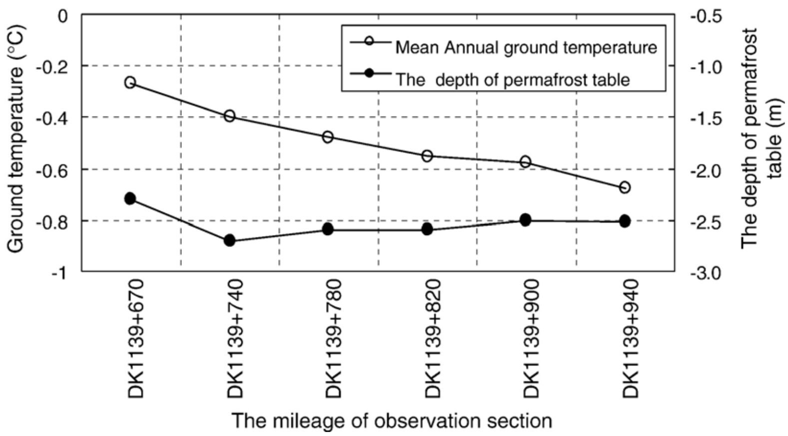

Fig. 1. The mean annual ground temperature and the permafrost table along the test railroad.

The principle of the thermal insulated treatment is to increase the thermal resistance and decrease the heat exchange thus, the permafrost degradation is delayed and the thermal stability of the embankment in a certain period is guaranteed (Wen et al., 2005a). There are two opinions of the permafrost protecting effect of the thermal insulated method. Some researchers think that the thermal insulation may raise or keep the artificial permafrost table under the embankment, and may prevent permafrost degradation, and improves the thermal stability of the embankment (Liu and Tian, 2002; Zang and Wu, 1999; Wen et al., 2005b). Others think that as a passive way to permafrost protection, the thermal insulation may reduce the heat entering into the embankment in warm seasons, but it will also affect the permafrost cooling in cold seasons. It may slow down the degradation of permafrost and protect permafrost under embankment for some period, but it can not change the eventual tendency of degradation. Taking the global warming into consideration, it is not suitable to use it in the permafrost regions, especially in the warm permafrost regions (Cheng et al., 2003; Sun, 2003). However, the thermal insulated method has many advantages, such as construction simplicity and lower

Table 1
Soil properties in the insulation test embankment

Soil type	Moisture content (%)	Density (kg m^{-3})	Thermal conductivity in frozen state (J m^{-1} °C h^{-1})	Thermal conductivity in thawed state (J m^{-1} °C h^{-1})	Thermal capacity in frozen state (J kg^{-1} $°C^{-1}$)	Thermal capacity in thawed state (J kg^{-1} $°C^{-1}$)
Subgrade fill	6–8	2100	5400	5040	830	1060
Sub-clay	15–17	1920	6480	5400	910	1270
Ice-rich soil	30–200	1500	7920	3600	1180	1910

Table 2
The experimental railroad description

Test segments	Location	Length (m)	Insulation thickness (m)	Obversation sections	Paved depth of the insulation
EPS-1	DK1139+618−700	82	0.10	DK1139+670	0.5 m above the ground surface
EPS-2	DK1139+700−750	50	0.08	DK1139+740	0.8 m below the subgrade
PU-1	DK1139+750−800	50	0.04	DK1139+780	0.8 m below the subgrade
EPS-3	DK1139+800−850	50	0.08	DK1139+820	0.5 m above the ground surface
PU-2	DK1139+850−925	75	0.04	DK1139+900	0.5 m above the ground surface
Conventional embankment			No insulation	DK1139+940	