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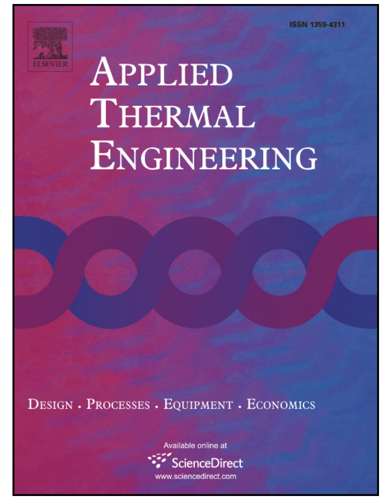

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Formation mechanism of longitudinal cracks in expressway embankments with inclined thermosyphons in warm and ice-rich permafrost regions

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Abstract

Thermosyphon-induced longitudinal cracks affect the embankment stability in permafrost regions, which is a serious concern for the Chinese Qinghai-Tibet Expressway (QTE) to be constructed in the near future. Here, longitudinal cracking on the experimental inclined thermosyphon embankment of the QTE in warm and ice-rich permafrost regions is investigated. The cooling effect of the inclined thermosyphons is found to be concentrated in the embankment center, with uneven ground-temperature fields causing embankment differential deformation. Tensile stress concentration is induced on the embankment top surface, with longitudinal cracks potentially being initiated at the maximum tensile stress point. The temporal and spatial initiation of longitudinal cracks is determined by both the embankment stress state and the asphalt-pavement splitting strength. According to the computation, longitudinal cracking was initiated before May or in October-December in the second year after construction completion, 1.8-2.8 m from the embankment center on the sunny half of the pavement. Without significant climate warming change, the main longitudinal crack width development continues with decreasing annual increments, approaching a stable state eventually. To overcome this cooling effect problem for the inclined thermosyphon embankment, the structure should be improved to add cold energy and decrease heat absorption under the slopes. The inclined-vertical thermosyphon embankment proposed herein decreases the embankment cracking probability.

Key words: longitudinal crack; inclined thermosyphon embankment; Qinghai-Tibet Expressway (QTE); warm and ice-rich permafrost region

1 Introduction

Under the influence of both global warming and anthropogenic engineering, the permafrost degeneration on the Qinghai-Tibet Plateau has been accelerated, causing engineering failure from thaw settlement, especially in warm and ice-rich permafrost regions [1-5]. The “positive cooling roadbed” principle has been used to lower the permafrost temperature, by adjusting the solar radiation, heat convection, and heat conduction [6-8]. Two-phase closed thermosyphons (abbreviated to “thermosyphons”) are widely used in frozen-soil engineering as a heat-convection-adjustment measure, e.g., in the Qinghai-Tibet Highway (QTH), Qinghai-Tibet Railway (QTR) and Qinghai-Tibet Power Transmission Line (QTPTL) [9-13]. A thermosyphon transfers heat in a single direction with a low-boiling-point liquid, driven by the temperature difference between the evaporation and condensation sections and using no external energy [14-17]. Thermosyphon application increases both the heat-release capability of the engineering foundation

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