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A Preliminary Study on the Long-Term Structural Stability of Ventilation Ducts in Cold Regions

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Abstract

The construction of roadways in permafrost regions modifies ground-surface conditions and consequently, negatively varies thermal stability of the underlying frozen soils. To avoid the thawing of the permafrost layer under the scenario of global warming, roadways are usually laid on a built-up embankment, which not only disperses the traffic loads to underlying layers but also minimize the thermal disturbance. In the embankment, duct ventilation, or called air duct, can be embedded to further cool the underlying permafrost. While the thermal performance of duct ventilations has been well documented, the long-term structural stability of duct ventilation remains unknown. This study examines the structural stress of ventilation ducts that are placed in harsh weather such as the Qinghai-Tibet Plateau. The ducts are currently buried in the embankment filler, with the wind-outlet and -inlet ends exposed and cantilevered out of the embankment. Field studies found that the exposed parts have plagued cracking and even failures, especially at the fixed end of the cantilevered part. Damages of these concrete ducts are attributed to cyclic freezing-thawing attack, thermally-induced stresses, moisture-induced stresses, and concrete swelling. These physical attacks are caused by the harsh weather in the Qinghai-Tibet plateau. It is recommended to insulate the exposed part of the ducts and to fabricate durable and dense concrete ducts.

Keywords: Concrete; Freezing-Thawing; Thermal Stress; Swelling and Shrinkage; Cracking.

1. Introduction

Air ducts have been applied to cool foundations built in cold regions since 1970s [1-6]. The air ducts are placed parallel to the embankment shoulder (Figure 1-b) to counteract the wintertime insulating effects of the snow cover and to cool the underlying permafrost soils through natural convection inside the ducts. In the last decade, ventilation duct has been applied to cool roadbeds built in cold regions, such as the Qinghai-Tibet Railway (Figure 1) [1-3]. Differently, ducts in the roadbeds of Qinghai-Tibet Railway are a row of concrete pipes inserting through an embankment, with wind-inlet and -outlet parts extending and overhanging out of roadbeds (Figure 1). The duct performs cooling effects because it allows airflow to deposit cold energy in the duct in cold seasons [7]. Although air inflow into the duct also leads to the heat intake in the duct, in the Qinghai-Tibet plateau the duct tends to introduce a negative heat budget to the ground due to the windy weather in winter but the clam weather in summer. To diminish heat intake, temperature-controlled shutters may be installed in wind inlet and outlet to prevent air inflow during summertime [8, 9]. The cooling effect can be further enhanced if the duct is perforated to allow the air contacting directly with the soil and to allow turbulence air flow along the inner ring of the ducts.

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