High-resolution Electrical Resistivity Tomography (ERT) measurements along paved roads in permafrost regions of Mongolia

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Abstract

The purpose of this study was to investigate the settlement and deformations of the embankment constructed in warm permafrost regions of Mongolia. In this investigation, five experimental sites were selected, namely R01, R02, R03, R04, and R05. High-resolution ERT measurements and drilling methods were used in this study. As the results show, frozen ground was identified at boreholes in the R02 (3.4 m), R03 (3.0 m), R05 (3.2 m) sites, while it was absent at the R04 and R01 sites. According to ERT, the upper and lower permafrost limits have resistivity values of 1022 Ω m. These permafrost limits were associated with drilling results of the boreholes. At all sites excluding the R03 site, settlement and deformations of the road surface were found with different rates between 5 cm and 30 cm. High-resolution ERT measurements clearly show the permafrost thawing, especially underneath the embankment in the R01, and R04 sites, where the permafrost thawed down to 11 m.

Keywords: ERT, paved roads, permafrost, Mongolia.

Introduction

The Mongolian road network currently amounts to 12722 km, including 5354 km of paved roads, 6213 km of unpaved roads, and 1153 km of planned roads (Adhikari, 2013). Of this, approximately 1200 km of paved roads were constructed on warm permafrost with a mean annual ground temperature higher than -2.0°C (Jambaljav, 2017). Along paved roads in warm permafrost zones, significant settlement and deformations related to creep were found at many places where the embankments are unusually tin. Therefore, the stabilization of the embankments must be taken into consideration, particularly for those embankments directly underlain by the warm permafrost layer. The purpose of this study was to investigate the settlement and deformation of the embankments constructed in the Mongolia.

Five experimental sites were selected in the continuous to isolated permafrost zones (Fig. 1). These sites are referred to hereafter as R01 (Chuluut), R02 (Terkh), R03 (Khurental), R04 (Tsagaannuur), and R05 (Alag-Erdene). Furthermore, the Mongolian government is planning to construct paved road in the future at the R03 site. Along paved roads, the ice contents change significantly over short distances at the sites.

Methods

In this survey, we measured high-resolution ERT on the permafrost underneath the paved roads using the Wenner and Wenner-Schlumberger arrays. The multi-electrode resistivity technique uses a syscal R+, a switch pro and several multi-core cables. A unit of 96 electrodes was plugged into the ground at a fixed distance of 1-5 m. According to the drilling survey, the ground materials were identified with hand drilling equipment (TANAKA Japan) at all sites during the fieldwork in August 2017.

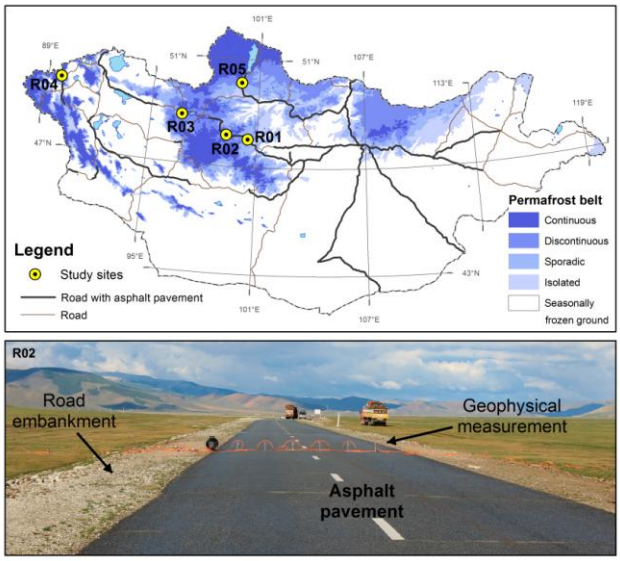

Figure 1. Study sites along roads in Mongolian permafrost zones. An example photo shows the geophysical measurement at the paved road at R02 site during the fieldwork.

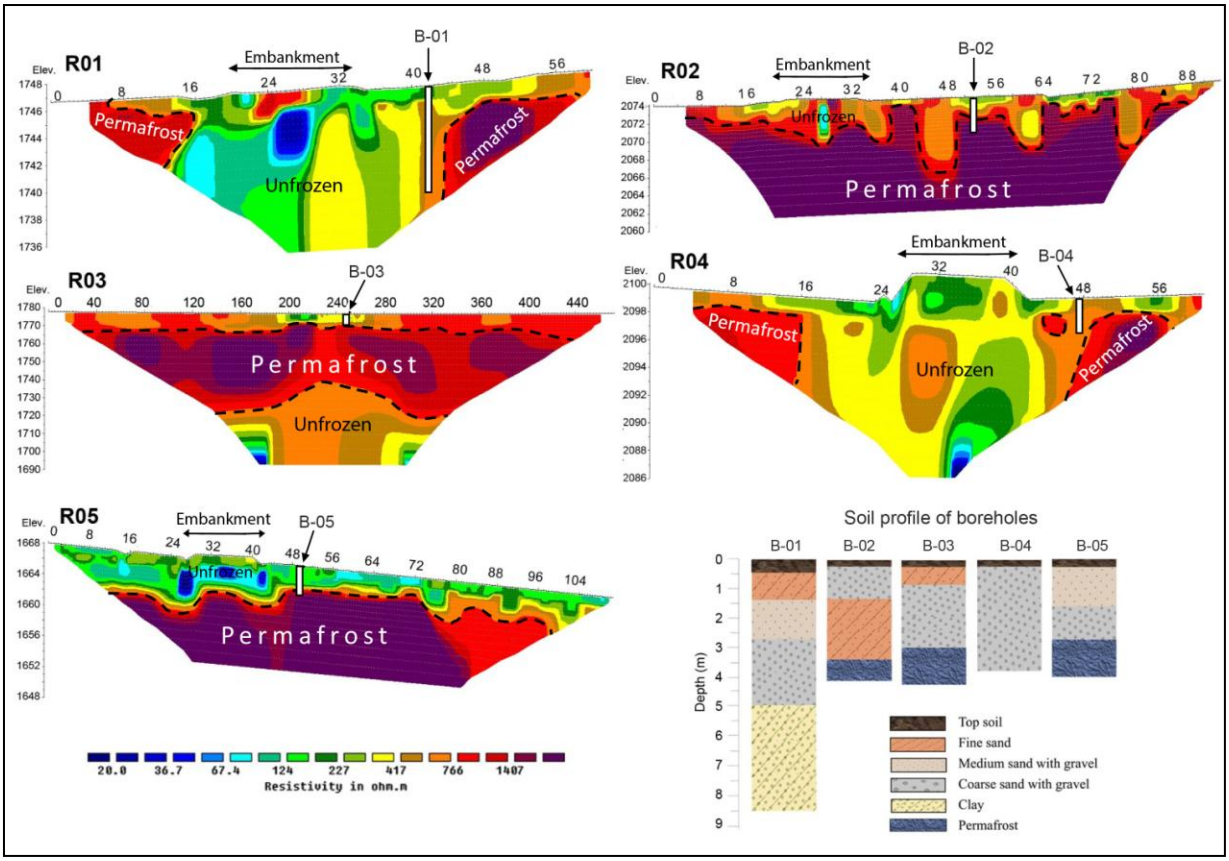

Figure 2. 2-D profile results of ERT, and soil profile of boreholes at experimental sites.

Results and Discussion

Figure 2 shows a series of five resistivity images across paved road embankments and natural ground surface, and the drilling at all sites. An 8.4 m borehole was drilled at the R01 site near the road embankment. There was no permafrost at 8.4 m, but settlements (20-30 cm) and deformations were observed on the asphalt pavement. Frozen ground was identified at several boreholes in the R02 (3.4 m depth), R03 (3.0 m depth), R05 (3.2 m depth) sites, but not at the R04. In these sites, ground temperatures ranged from -0.40°C to -1.2°C during the fieldwork.

According to ERT, the resistivity of the ground ranged from 20 Ωm to >1878 Ωm at all sites. We delineated the upper and lower permafrost limits with resistivity values of 1022 Ωm. These permafrost limits were associated with drilling results of boreholes. Besides the R03 site, the embankments of paved roads were constructed from 2012 to 2014 (Adhikari, 2013). Since that time, the permafrost underneath the embankments has been continuously thawing with different rates (Fig. 2). The R03 site lies in the area where we are planning to construct a paved road. At all sites excluding the R03 site, the settlement and deformation of the road surface were found with different rates between 5 cm and 30 cm. ERT measurements clearly show the permafrost thawing, especially the permafrost thawed down to 11 m below the embankment in the R01 and R04 sites. Ground surface was destroyed around embankments of paved roads; under these surfaces the permafrost was also thawed.

Acknowledgments

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References

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