Degrading Warm Permafrost Impact on Transportation Infrastructure in Arctic Regions

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Center Name: Pacific Northwest Transportation Consortium (PacTrans)

Research Priority: Improving the Mobility of People and Goods

Principal Investigator(s): Joey Yang (UAA), Utpal Dutta (UAA)

Project Partners: Port of Nome.

Research Project Funding: $40,000 federal; $40,000 non-federal match

Project Start and End Date: 8/16/2023 – 8/15/2025

Project Description: The ravage of climate change has created widespread effects on the permafrost environment and the built transportation infrastructure in many high-latitude communities in Alaska. The forecast is that the permafrost will thaw extensively in the decades ahead due to climate warming at a rate much faster than anticipated, and the associated ground settlement is causing substantial damage to the transportation infrastructure. By 2030, permafrost degradation is expected to raise the costs of maintaining public infrastructure by U.S. $3.6 billion to $6.1 billion.

Nome, a subarctic city in western Alaska, is underlain by 15-50 m thick permafrost, which has been warming and degrading under climate change in the last several decades. The thawing of warm permafrost and the subsequent ground settlement cause never-ending issues to the roads and bridges. In addition, being in a moderately seismic zone, the degrading warm permafrost can potentially amplify the ground shaking during seismic wave propagation through the uppermost recently thawed and unconsolidated soil layer, inflicting severe damage to the transportation infrastructure. These issues require a fundamental rethinking of the fate of various infrastructural facilities like transportation in the area. However, little effort has been devoted to such important and unique Arctic transportation engineering issues. This proposed project aims to fill such a knowledge gap in permafrost thaw settlement and seismic site response. Multi-method geophysical (electrical resistivity, seismic) and geotechnical investigations will be conducted at selected strategic sites in the Nome area to map the subsurface soil conditions to understand the settlement and dynamic properties of degrading permafrost so that remedial measures could be proposed for applications in the built transportation infrastructure. Additionally, the impact of future climate change on the infrastructure will be assessed by thermal modeling using downscaled climate predictions from CMIP6 for this area. The results will help assess the impact of degrading permafrost on and improve the resilience of Arctic transportation infrastructure considering climate change.

US DOT Priorities: This project directly contribute to the focus of PacTrans, i.e., developing human-centered and transformative multimodal mobility solutions for an equitable Pacific Northwest. Alaska is at the forefront of climate change and the sparsely distributed rural communities are bearing the brunt of climate change consequences, including the transportation infrastructure. This study will help identify the potential hazard zones, which will be invaluable for critical transportation infrastructure site

selection. The results of the seismic response of degraded permafrost will also help improve the resilience of the transportation infrastructure, including ports and bridges, in Alaska and other cold regions.

Outputs: At the end of the project, the following products will be available for selected key infrastructure sites in the Nome area. (a) Mapping of the permafrost distribution in the Nome area and the ground thermal status, (b) subsurface soil and seismic velocity profiles for understanding the degrading permafrost characteristics, and (c) evaluation of the settlement and site responses of typical geologic units for future planning of the transportation infrastructure.

Outcomes/Impacts: The significance of this project is elaborated in the following three aspects. First, the proposed geophysical surveys will help better understand the spatial variation of subsurface permafrost degradation, which will be a critical factor in assessing the transportation infrastructure's safety based on the ground characteristics. Second, the detailed subsurface imaging with the ambient ground vibrations and electrical imaging technique will be helpful for the quantitative estimation of evaluating the soil response and its relationship to the near-surface geological formations and related soil properties. Such analysis will help identify potential hazard zone and serve as the basis for selecting sites for critical facilities. Third, the project will investigate the influence of the degraded warm permafrost behavior during strong shaking and its impact on the surface structures. Such a study is critical for Arctic Alaska areas. Stiff frozen soils alter the ground and impact differently than unfrozen soil.

Final Research Report: *will be provided upon completion of the project*