Railways on Permafrost: Unique Challenges Observed at Bridge Crossings along the Hudson Bay Railway

Natalie Arpin¹, Andy Take¹, and Ryley Beddoe²

¹Queen's University, Civil Engineering, Kingston, Canada (natalie.arpin@queensu.ca)
²Royal Military College of Canada, Kingston, Canada

The Hudson Bay Railway (HBR) serves as the singular land pathway connecting the Pas to Churchill, Manitoba, Canada. Hence, it is an essential means of transportation for northern communities, enabling the transport of both goods and individuals. However, it has faced many operational challenges because of its remote geographical location and the permafrost conditions it passes over. Over its 1000-kilometre length, the permafrost conditions transition. The railway starts in the isolated permafrost zone in its most southern portions before passing over discontinuous permafrost and then reaching continuous permafrost in its northern section. One of the unique operational challenges present at bridge crossings is the phenomena of “frost jacking”.

Frost jacking refers to the upward displacement of pile bridge foundations caused by forces generated from frost heave in the surrounding ground. If the driving force from frost heave exceeds the frictional resisting forces anchoring a pile into the ground, uplift occurs. When designing pile foundations in cold regions, the potential effects of frost jacking must be considered, as any significant differential heave between piers or the abutments can lead to track geometry issues that affect operations and, in extreme cases, require bridge maintenance. However, research on frost jacking experienced by operational infrastructure has been very limited, which hinders the ability to account for its impacts.

The Horn Creek Crossing on the Hudson Bay Railway is a 30-metre-long, steel ballast deck bridge supported by H-piles. Over a 10-year period, the foundations of the bridge underwent hundreds of millimetres of differential heave before repairs were completed to level the structure in July 2022. Because of the bridge's remote location, there is limited information on the rate and timing of when frost jacking occurred. Therefore, in 2022, a multi-sensor monitoring program was designed and subsequently installed on the bridge with the purpose of collecting data to explore the mechanism of frost jacking at this site.

Preliminary results from the first monitored winter season resulted in an average upward movement of 33 mm of the spans surrounding the northern pier. This upward movement occurred throughout the winter and ended when daily average temperatures became above 0°C. Afterwards, limited recovery was present in the spring when temperatures rose and was measured to be 11 mm, less than the upward movement measured. The monitoring process is still...
ongoing, with the aim of identifying longer-term trends and analyzing the outcomes of the repair work. Furthermore, using this site as the location of known differential heave at a railway bridge, methods are being developed to explore whether a parallel data source (track geometry data) can capture patterns and rates of seasonal differential heave at this and other bridges along the HBR.