

**Study of frost susceptibility on existing
roadway**

Problem

Most maintenance or improvement techniques can produce only partially successful outcomes on pavement structures that annually undergo deformation under frost action. This reality must therefore be taken into account during the design process or when deciding upon the type of intervention. The process is simplified when the pavement structure is an existing roadway, since all that is needed is to track its behaviour over winter and collecting some additional basic data. Problems resulting from freezing manifest themselves through more or less uniform upward movements, or frost heaves (Figure 1). Occurrence is most pronounced toward the end of winter when the frost depth is at its maximum. Heaving is caused by the formation of ice lenses produced by cryosuction in frost-susceptible soils. This phenomenon can be reproduced in laboratory (*Info DLC*, Vol. 7, No. 2). There are also some theoretical methods for simulating it in a climate and material layer calculation (*Info DLC*, Vol. 11, No. 6).

Methodology

The steps of the recommended method are:

1. Conduct a visual survey and mark the locations to be measured. Priority should be given to conducting the survey in the winter (February-March) to target frost-sensitive areas.
2. Collect stratigraphic data. Generally, a number of bore holes are carried out and some soil samples are characterized (particle size distribution, water content, Atterberg limits). This data may be available in previous study reports.
 - a. Optional: insert a frost-depth gauge in one of the bore holes and perform additional soil analyses (sedimentation analysis, methylene blue value, segregation potential).
3. Measure surface elevations in the winter (February-March) and summer (May-November). The most affordable method is a rod and level survey (Figure 1). Measurements must be repeated at exactly the same location, which involves marking accordingly (paint, survey marker nails).

They must also be referenced with respect to a fixed reference point (rock, building or other structure) so as to be able to subtract the values of the two readings.

- a. Optional: add profilometer readings to increase point density (continuous measurement) and interpret ride comfort ($\Delta IRI = IRI_{winter} - IRI_{summer}$).
4. Plot the results on a graph (Figure 2). Delineate homogenous sectors. Interpret the results, draw conclusions, and identify avenues for solutions. Select the characteristic points for the thermal design calculations.
5. Import the climate data of the winter corresponding to the data measured in Step 3. Daily temperatures are published monthly on Environment Canada's website. Chapter "8.2.2 Editing a CLM file" of the user guide for the software program Chaussée 2 describes the procedure.
6. Calibrate the Chaussée 2 software to ensure its representativeness in relation to the site studied.

To do this, select the winter of measurements and enter the other data available (materials, thicknesses, water contents, densities). The software will display the saturation percentage (Sr) to assist in selecting a dry density compatible with the water content used. The soil layers can be subdivided according to their nature or the position of the water table. Adjust the soil's segregation potential so that the results of the calculation are representative of the observed site behaviour (frost depth and heave) (Figure 3).
7. Retain the soil characteristics obtained in the previous step, select the winter of design and simulate the possible pavement structure variants. Design these variants so as to maintain the heaves within the acceptable threshold. The threshold is between 50 mm and 70 mm, according to Table 2.4-1 of the MTQ standard (*Normes-Ouvrages routiers* collection, *Tome II - Construction routière*, Chapter 2).

Case study

The measurements from an actual study are shown in Figure 2, illustrating the longitudinal profiles of summer and winter, and the difference between the two (frost heave depicted in red). The red dots represent measurements made with rod and level, while the dashed line represents the readings from a portable profilometer. The vertical lines illustrate the location of bore holes for which the stratigraphy is known.

Even before turning to the program Chaussée 2, several inferences can be made. The bore hole located at chainage 5+150 had reached rock at a depth of 1.2 m: the heave there is null—a logical finding—and the profile of frost heaves precisely delineates the extent (20 m) of this rock outcrop. The soil/rock transition at that location is considered deficient with IRI_{10 metre} peaks of 4.7 m/km and 11.3 m/km in October and March, respectively. The IRI is poor at various other points where the profile is irregular (e.g. 5+250, 5+300 and 5+400). Overall, the frost heaves exceed 150 mm at the worst locations. The cracks, distortions and meandering cracks will most assuredly reappear the following winter if asphalt work or full-depth reclamation alone is chosen. Eliminating the problem requires a more intense intervention such as overexcavation or insertion of polystyrene insulating panels. Figure 2 highlights the locations of sites with no heaving that could be chosen as a start-end segment for laying polystyrene. These locations could correspond to the two extremities of the sector studied (5+050 to 5+520). They may also be located between the different "frost-susceptible" sectors, in cases where budgets could allow only a portion of the project to be repaired.

Lastly, Chaussée 2 software makes it possible to design the intervention variants. For the purpose of this exercise, we chose the initial stratigraphic profile of the bore hole located at 5+410, where we measured, on March 19, 2009, a frost depth (Z) of 2.37 m and a frost heave (h) of 139 mm. The first

calculation is shown in Figure 3, which contains survey data and segregation potential values (SP_o of 4.8 and 8.5) calibrated against the frost depth and the frost heave measured on the roadway. A representative model of roadway behaviour at this location can thus be obtained. Then, the winter of design is selected and the pavement structure modified according to the possible variants. The software will indicate the expected consequences with respect to frost heave. For this specific case, the study suggests raising the roadway by almost 1 m (rejected variant), rebuilding it up to a depth of 2.25 m or rebuilding it up to a depth of 650 mm to insert 50-mm thick polystyrene panels.

Conclusion

The proposed method is based on commonly accessible parameters and leads to quantifiable performance indicators. Calibration of the calculation with *in situ* frost heave measurements assures the representativeness of the analysis from the standpoint of the soil-roadway-climate system. Given the need for a winter follow-up, this approach requires some planning but is very valued as it effectively addresses frost issues. It has been used successfully a number of times at the Ministère.

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Figure 1:
Measurement of frost heaves (rod and level and portable profilometer)



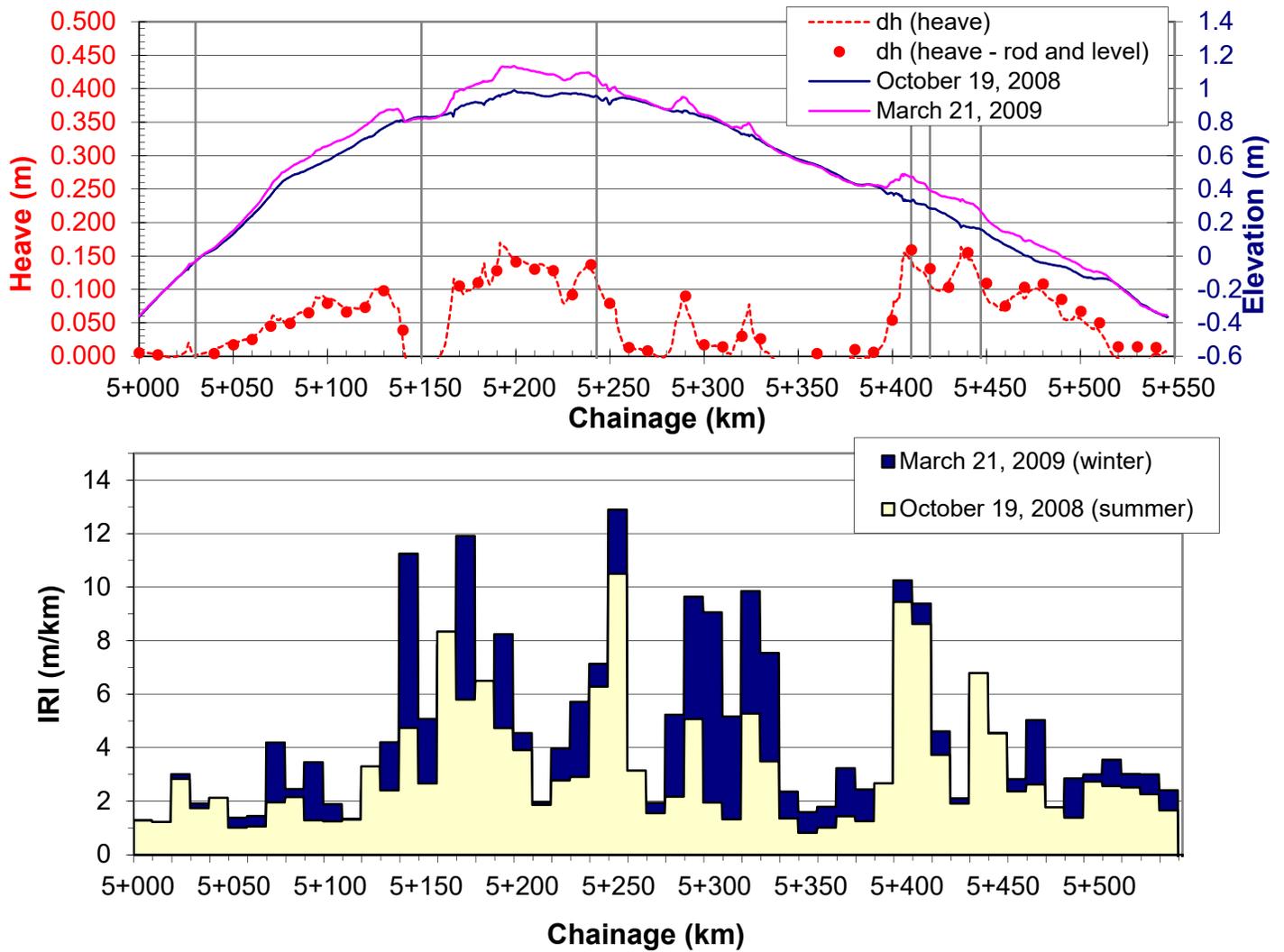


Figure 2: Graphic presentation of profiles, frost heaves and IRI values

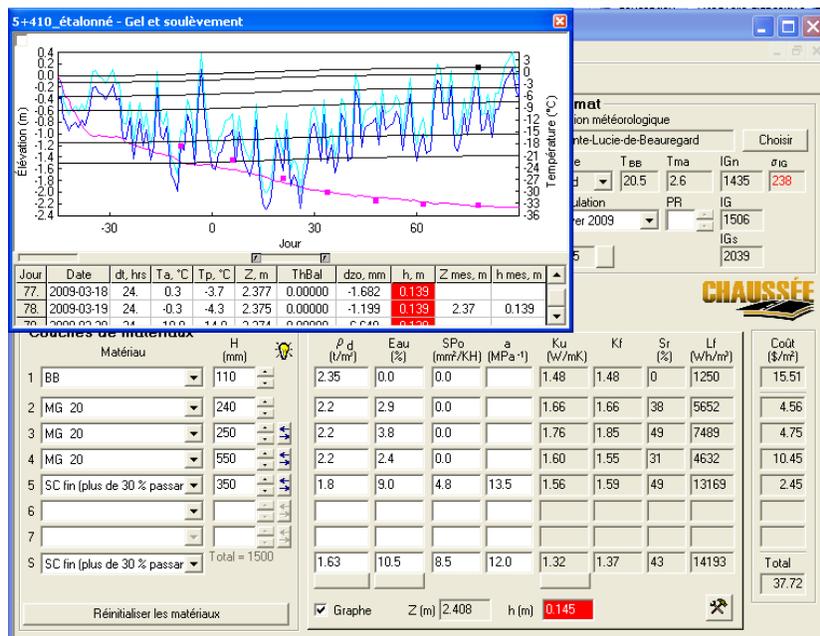


Figure 3: Chaussée 2 simulation, calibrated for the bore hole at 5+410