Chaire de recherche industrielle du CRSNG sur l'interaction Charges lourdes/Climat/Chaussées

Frost Protection For Pavements in Quebec Province (Canada): Curent Practice And Perspectives

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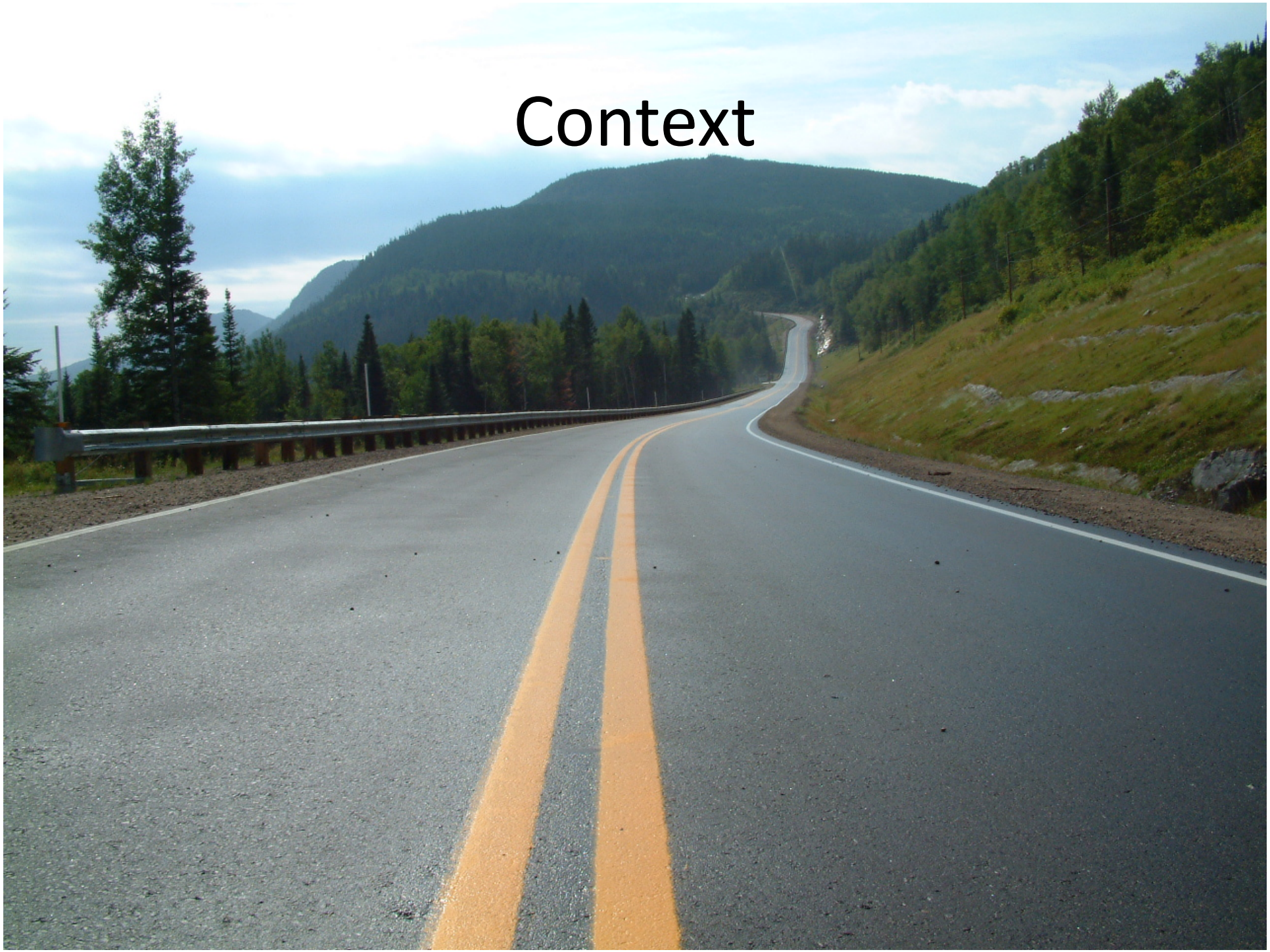
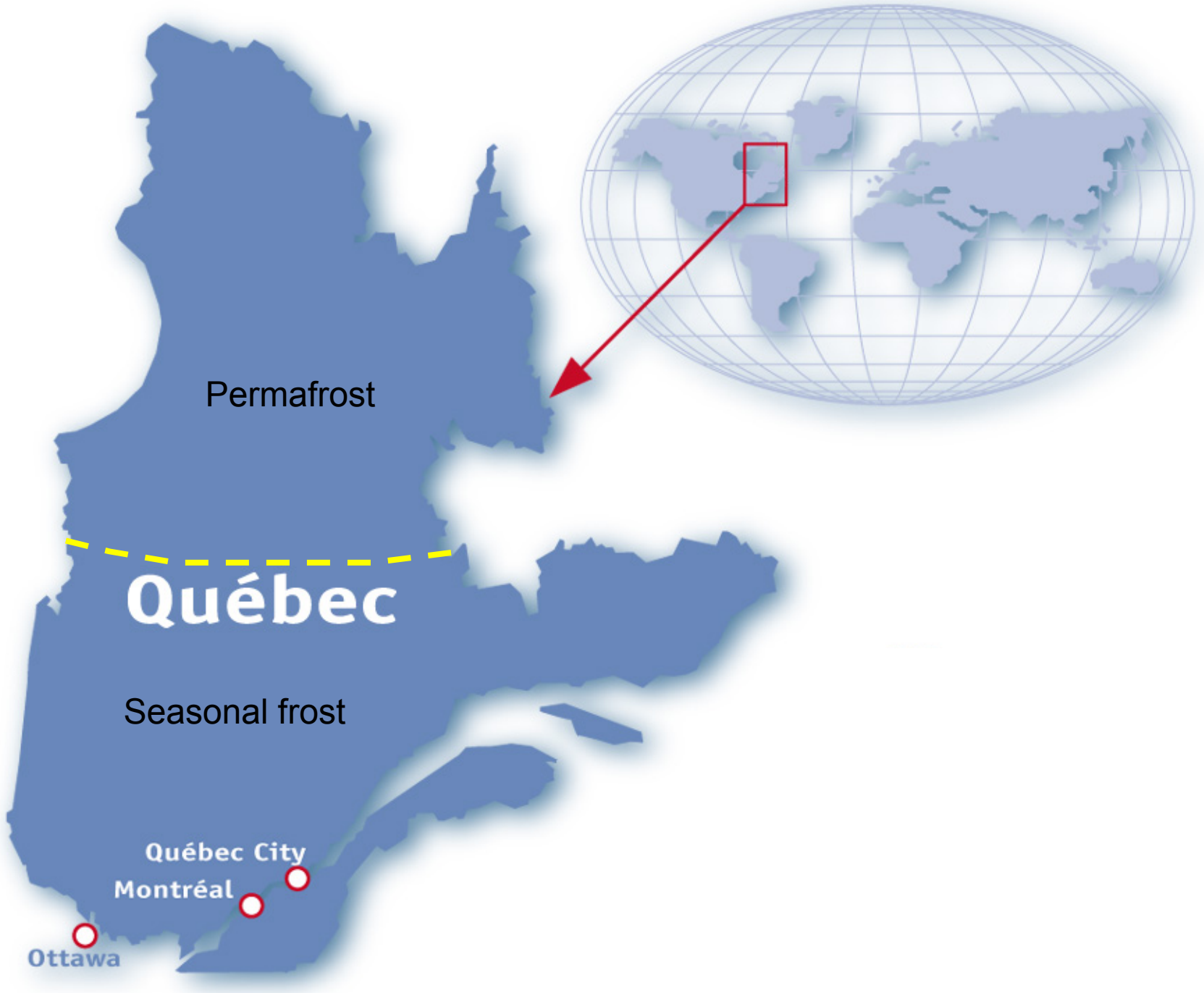
GRINCH GROUPE DE RECHERCHE EN INGÉNIERIE DES CHAUSSÉES

CRSNG NSERC

Presentation outline

- Context
- Frost design practice in Quebec province
  - New pavements
  - Pavement rehabilitation
- Research and development
  - Pavement performance related to frost action
  - Control of winter roughness
  - Thaw weakening


Context


Permafrost
Québec
Seasonal frost
Québec City
Montréal
Ottawa

Challenges

- Large road networks and low population densities
  - Vital communication links need to be established and maintained
  - Low levels of fundings
- Difficult geological context and resources difficult to access
  - Large linear structures and complex interaction with variable soils
- Severe climatic conditions
  - Moisture and frost action

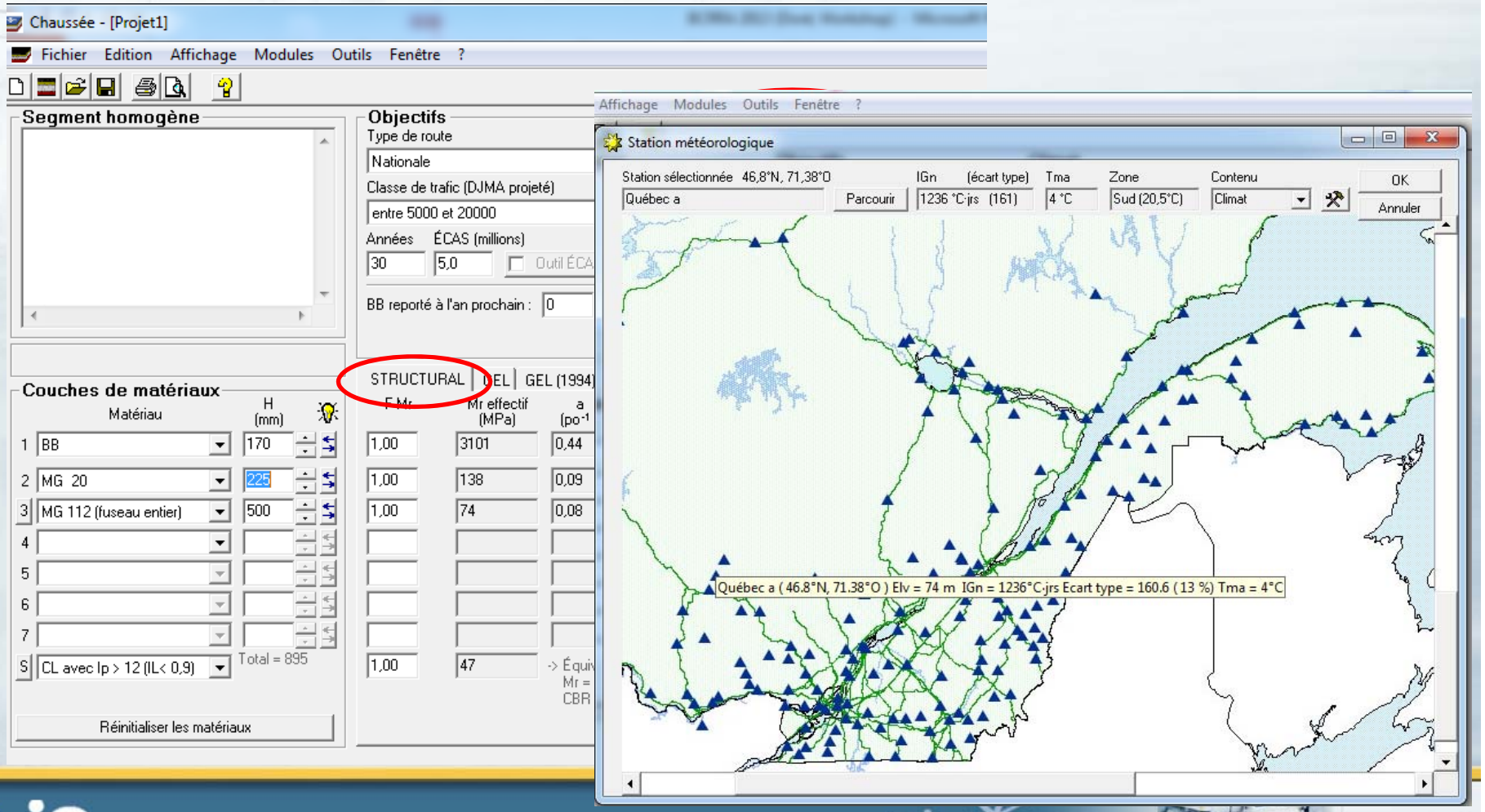

Québec city:
•4 months of winter (-10˚C on average)
•Coldest temperature ≈ -35˚C
•Freezing index ≈ 1200˚C
•Frost penetration under pavement surface ≈ 2 m
•Frost heave typically between 50 and 150 mm
•Snow fall between 3 and 4 m

Frost action on pavements

Design practice in Quebec

- Pavement design (traffic)done using AASHTO method
  - HMAC designed considering regional temperature averages
  - Pavement granular materials assumed to be stable
  - Seasonal variation of subgrade soil properties dealt with using “effective modulus”
- Frost heave design based on an allowable frost heave criterion

Pavement design (traffic)



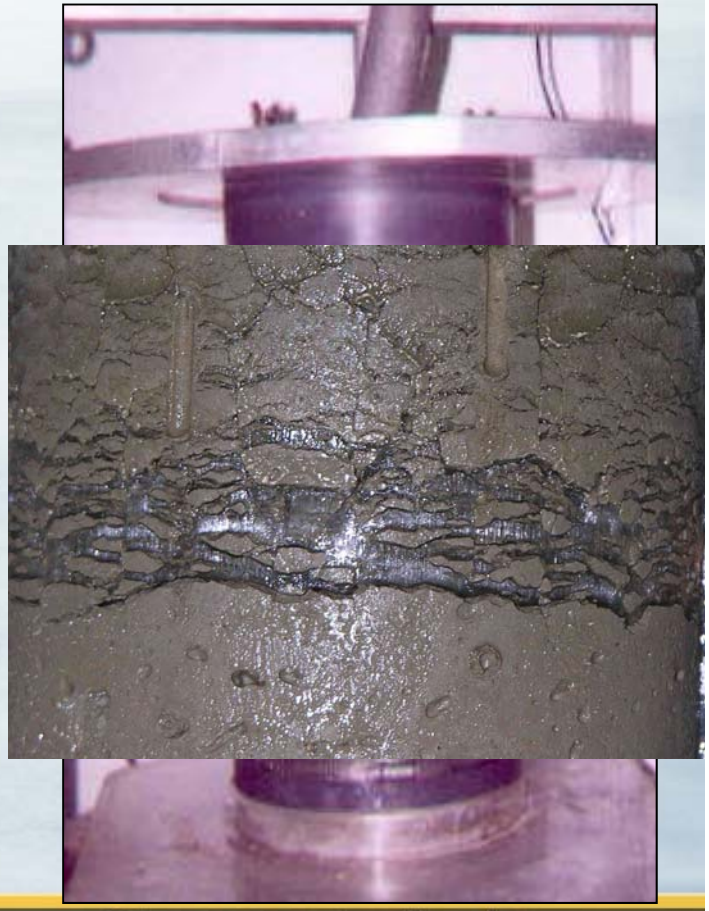
Frost design

- Frost heave calculated based on:
  - Segregation potential (SP) of subgrade soil
  - Climatic conditions (Freezing index)
  - Site specific conditions (water content, water table, etc)
- SSR model used for computation of frost penetration and heave
- Frost heave compared to allowable frost heave criterion
- Pavement structure adjusted to meet frost heave criterion

Frost susceptibility (SP)
Segregation Potential

Frost susceptibility	SP mm²/°C·hour
Negligeable	< 0,5
Low	0,5 à 1,5
Moderate	1,5 à 3
High	3 à 8
Very high	> 8

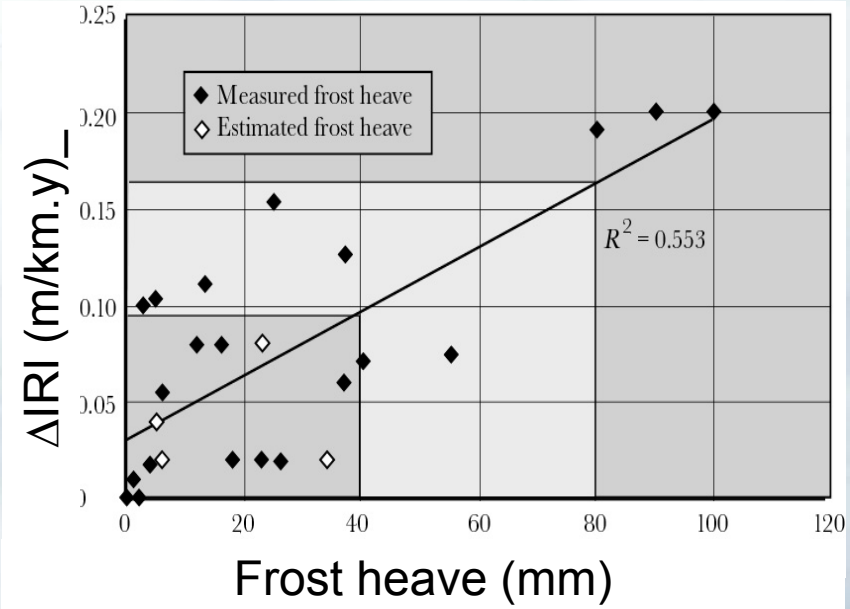
$$h = 1,09\ SP\ grad\ T \times t_f$$



Méthode d'essai LC 22-331
basée sur J.M. Konrad (1980)

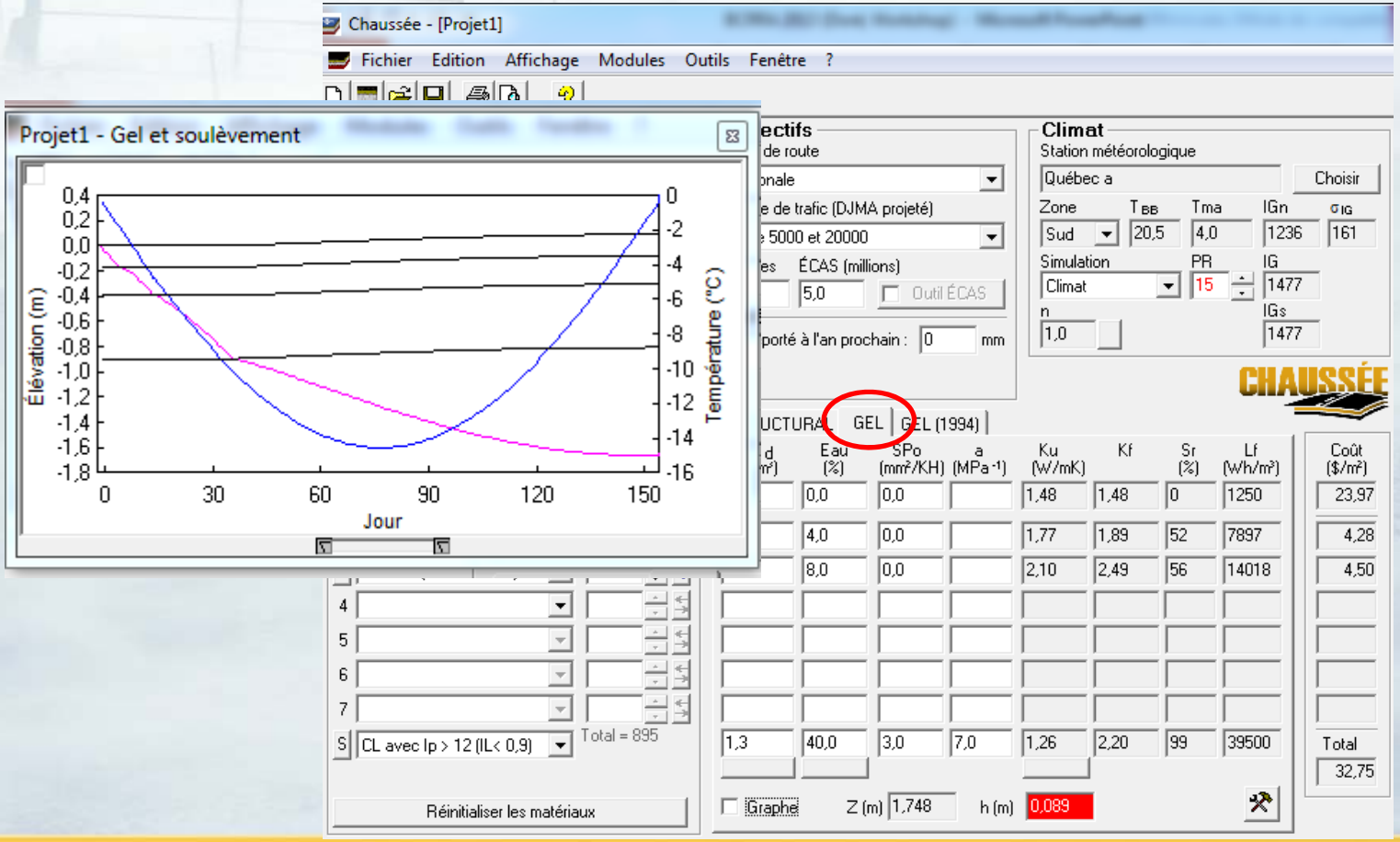
Allowable frost heave

- Criterion based on relationship between roughness development and frost heave



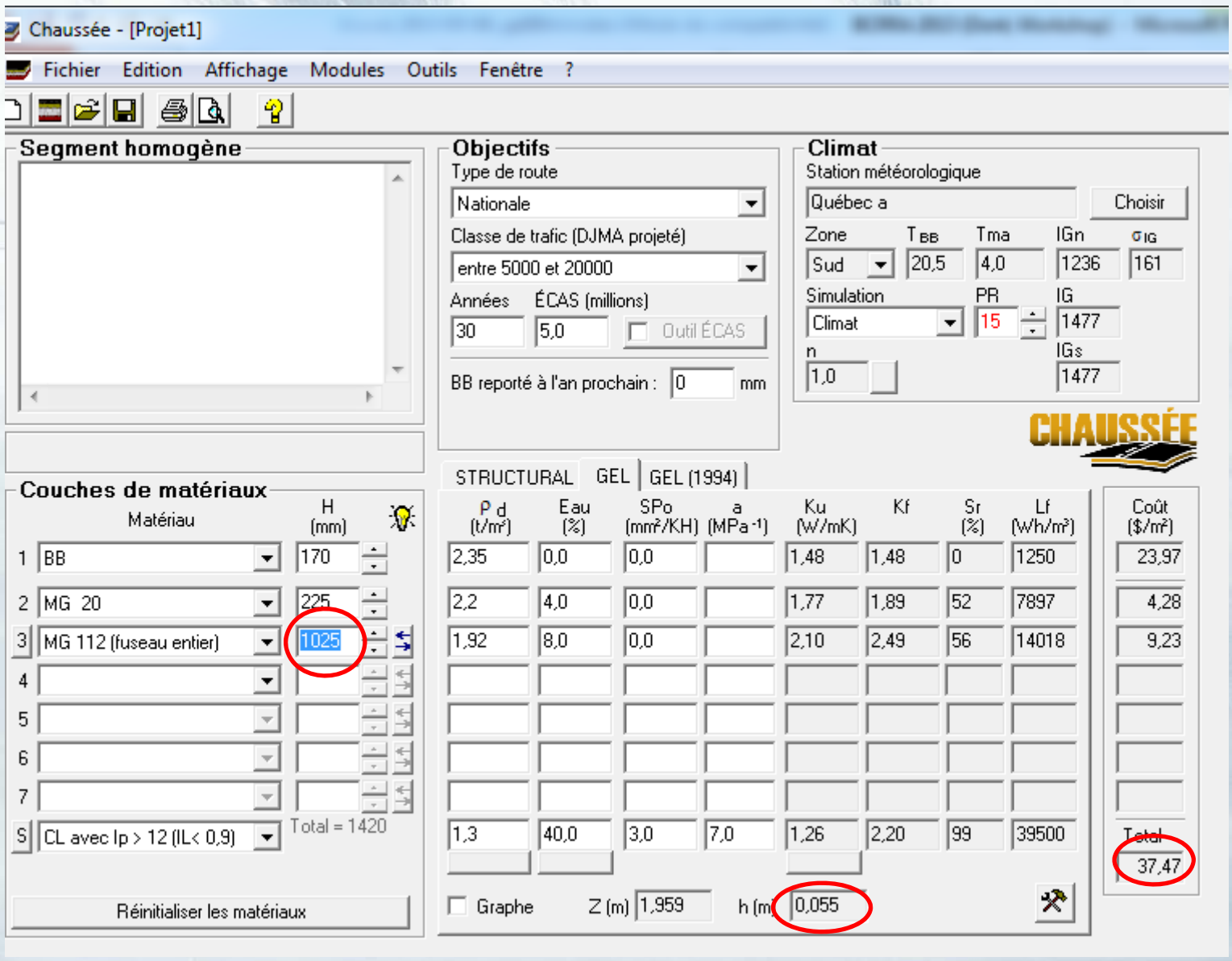
Freeways	< 50 mm
National	< 55 mm
Regional	< 60 mm
Local	< 70 mm

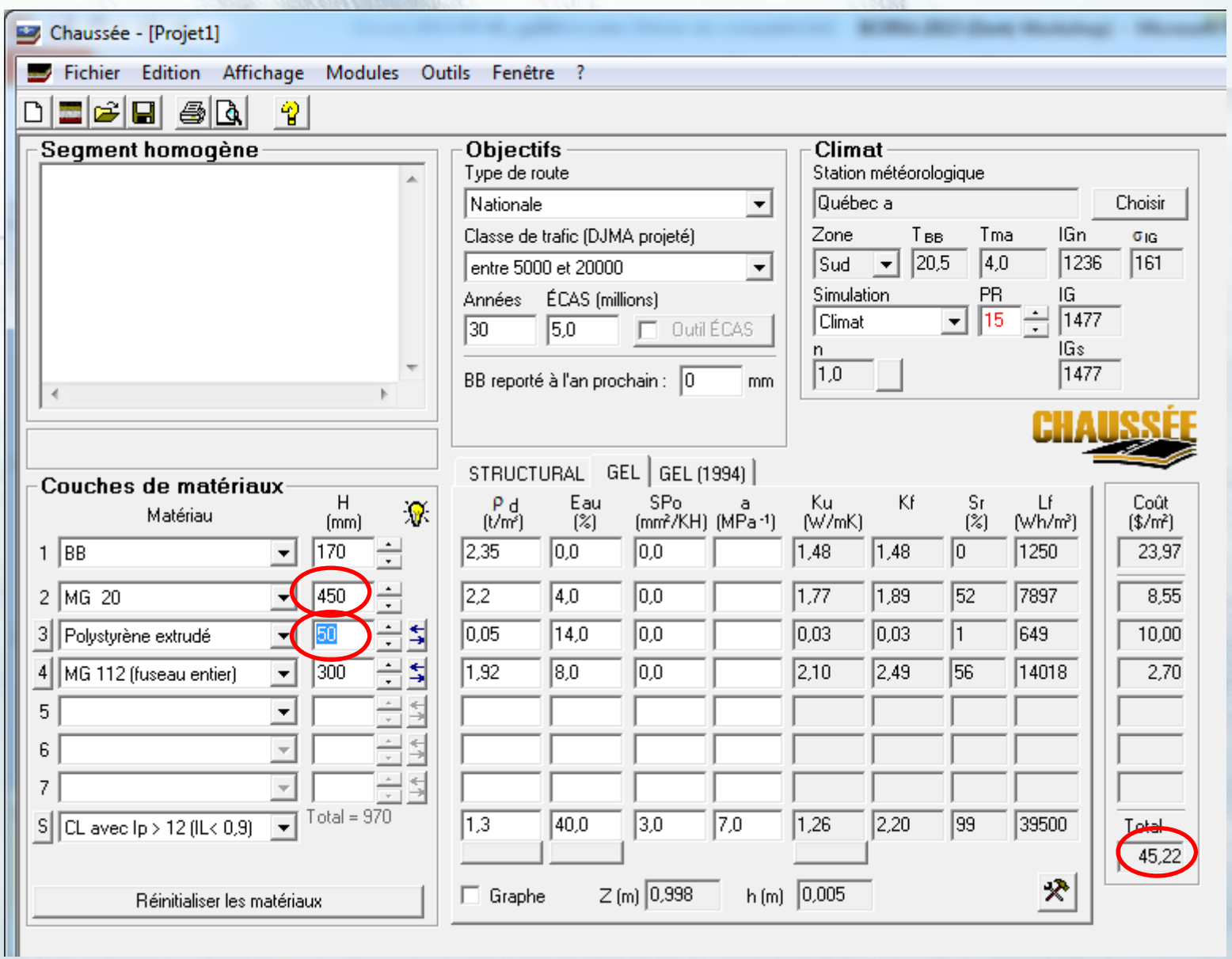
Frost design



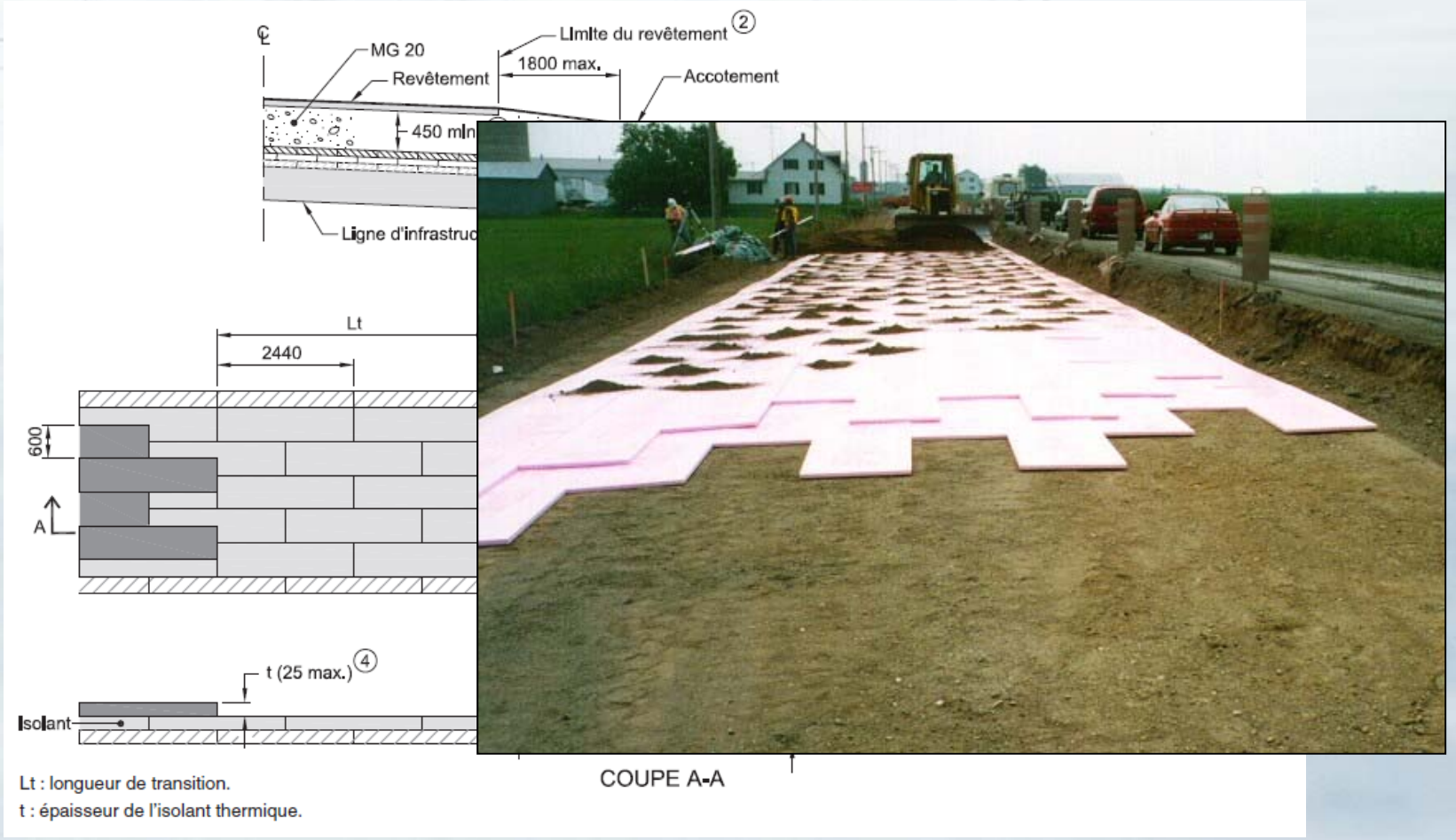
Pavement adjustment to meet frost heave criterion

- Increase thickness of granular subbase
- Pavement insulation


Chaussée - [Projet1]
Fichier Edition Affichage Modules Outils Fenêtre ?
Segment homogène
Objectifs
Type de route
Nationale
Classe de trafic (DJMA projeté)
entre 5000 et 20000
Années
ÉCAS (millions)
30
5,0
Outil ÉCAS
BB reporté à l'an prochain :
0
mm
Climat
Station météorologique
Québec a
Choisir
Zone
Sud
T BB
20,5
Tma
4,0
IGn
1236
σIG
161
Simulation
Climat
PR
15
IG
1477
n
1,0
IGs
1477
CHAUSSÉE
Couches de matériaux
Matériau
H (mm)
1 BB 170
2 MG 20 225
3 MG 112 (fuseau entier) 1025
4
5
6
7
S CL avec Ip > 12 (IL< 0,9)
Total = 1420
Réinitialiser les matériaux
STRUCTURAL
GEL
GEL (1994)
P d (t/m³)
Eau (%)
SPo (mm²/KH)
a (MPa⁻¹)
Ku (W/mK)
Kf
Sr (%)
Lf (Wh/m³)
Coût ($/m²)
2,35 0,0 0,0 1,48 1,48 0 1250 23,97
2,2 4,0 0,0 1,77 1,89 52 7897 4,28
1,92 8,0 0,0 2,10 2,49 56 14018 9,23
1,3 40,0 3,0 7,0 1,26 2,20 99 39500
Total
37,47
Graphe
Z (m) 1,959
h (m) 0,055


Chaussée - [Projet1]
Fichier Edition Affichage Modules Outils Fenêtre ?
Segment homogène
Objectifs
Type de route
Nationale
Classe de trafic (DJMA projeté)
entre 5000 et 20000
Années
ÉCAS (millions)
30
5,0
Outil ÉCAS
BB reporté à l'an prochain :
0
mm
Climat
Station météorologique
Québec a
Choisir
Zone
Sud
T BB
20,5
Tma
4,0
IGn
1236
σIG
161
Simulation
Climat
PR
15
IG
1477
n
1,0
IGs
1477
CHAUSSÉE
Couches de matériaux
Matériau
H (mm)
1 BB 170
2 MG 20 450
3 Polystyrène extrudé 50
4 MG 112 (fuseau entier) 300
5
6
7
S CL avec Ip > 12 (IL< 0,9)
Total = 970
Réinitialiser les matériaux
STRUCTURAL
GEL
GEL (1994)
ρ d (t/m³)
Eau (%)
SPo (mm²/KH)
a (MPa⁻¹)
Ku (W/mK)
Kf
Sr (%)
Lf (Wh/m³)
Coût ($/m²)
2,35 0,0 0,0 1,48 1,48 0 1250 23,97
2,2 4,0 0,0 1,77 1,89 52 7897 8,55
0,05 14,0 0,0 0,03 0,03 1 649 10,00
1,92 8,0 0,0 2,10 2,49 56 14018 2,70
1,3 40,0 3,0 7,0 1,26 2,20 99 39500
Total
45,22
Graphe
Z (m) 0,998
h (m) 0,005

Pavement insulation



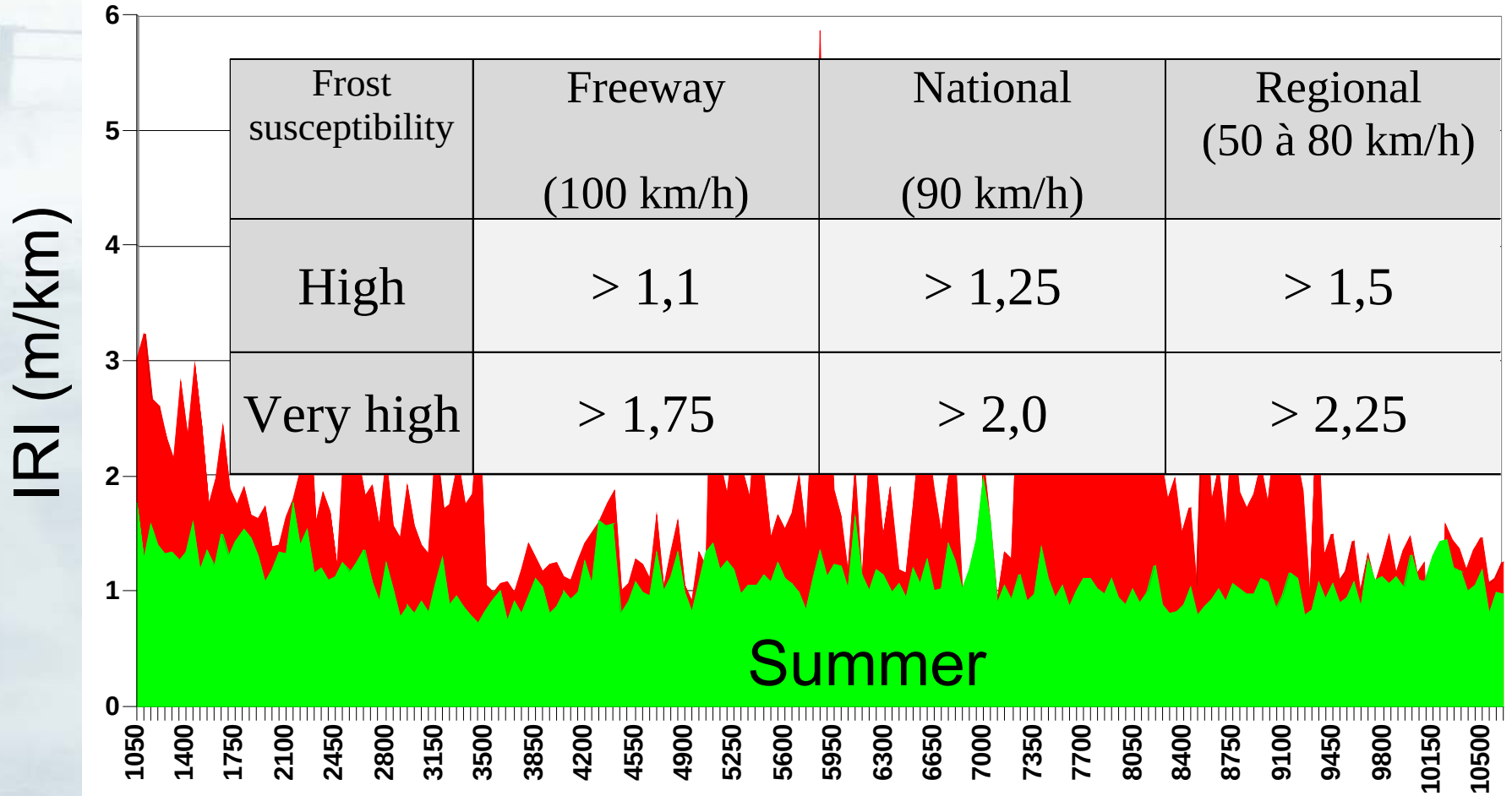
Lt : longueur de transition.
t : épaisseur de l'isolant thermique.

Pavement rehabilitation

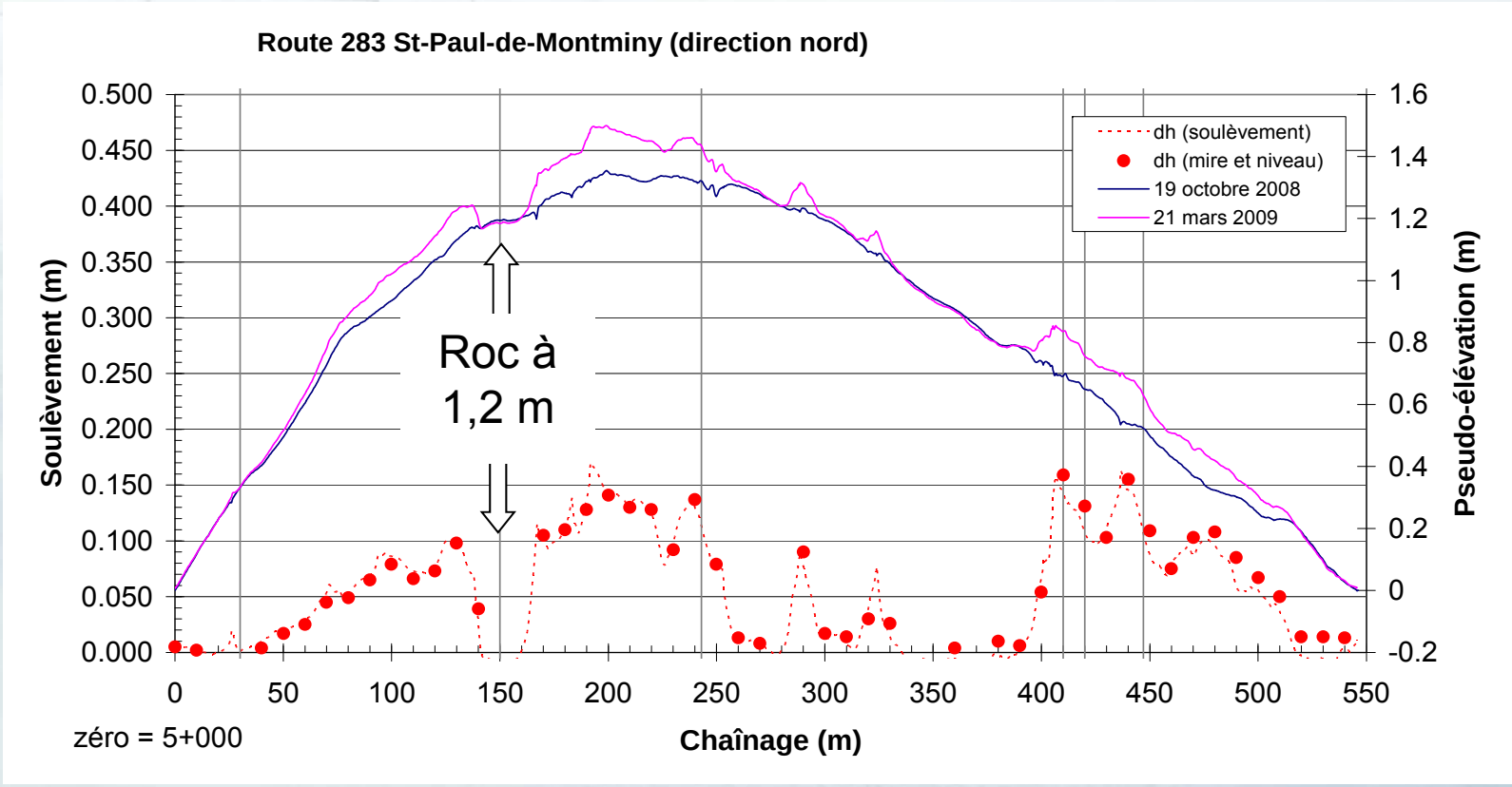
- Frost susceptibility (SP) of soils and pavement materials
- Frost susceptibility of pavement (ΔIRI)
- Analysis of seasonal profile variations

Frost susceptibility assessment using ΔIRI

Frost susceptibility	Freeway (100 km/h)	National (90 km/h)	Regional (50 à 80 km/h)
High	> 1,1	> 1,25	> 1,5
Very high	> 1,75	> 2,0	> 2,25



Analysis of winter/summer profiles



Pavement rehabilitation

- Replacement of frost susceptible pavement materials
- Increase thickness of granular layers
- Pavement insulation
- Drainage
- Construction/rehabilitation of granular wedges (transition)

Research and development

- Pavement design and performance in seasonal frost conditions
- Control of winter roughness
- Thaw weakening

Pavement performance related to frost action

- Moving towards M-E pavement design

Design factor	Response	Damage
Loading	Horizontal strain	Fatigue cracking
	Vertical strain	Permanent deformation
Frost action	Frost heave	Roughness (winter and long-term)
		Frost cracking

Rational approach to seasonal variation of properties based on changes in volume and moisture content

Performance models relating frost heave to roughness and frost cracking

Pavement design

- Development of a mechanistic-based method including consideration for differential frost heaving
- Project results presented at BCRRA

Pavement performance

- Development of a mechanistic-based model for roughness prediction taking explicitly into consideration frost heave

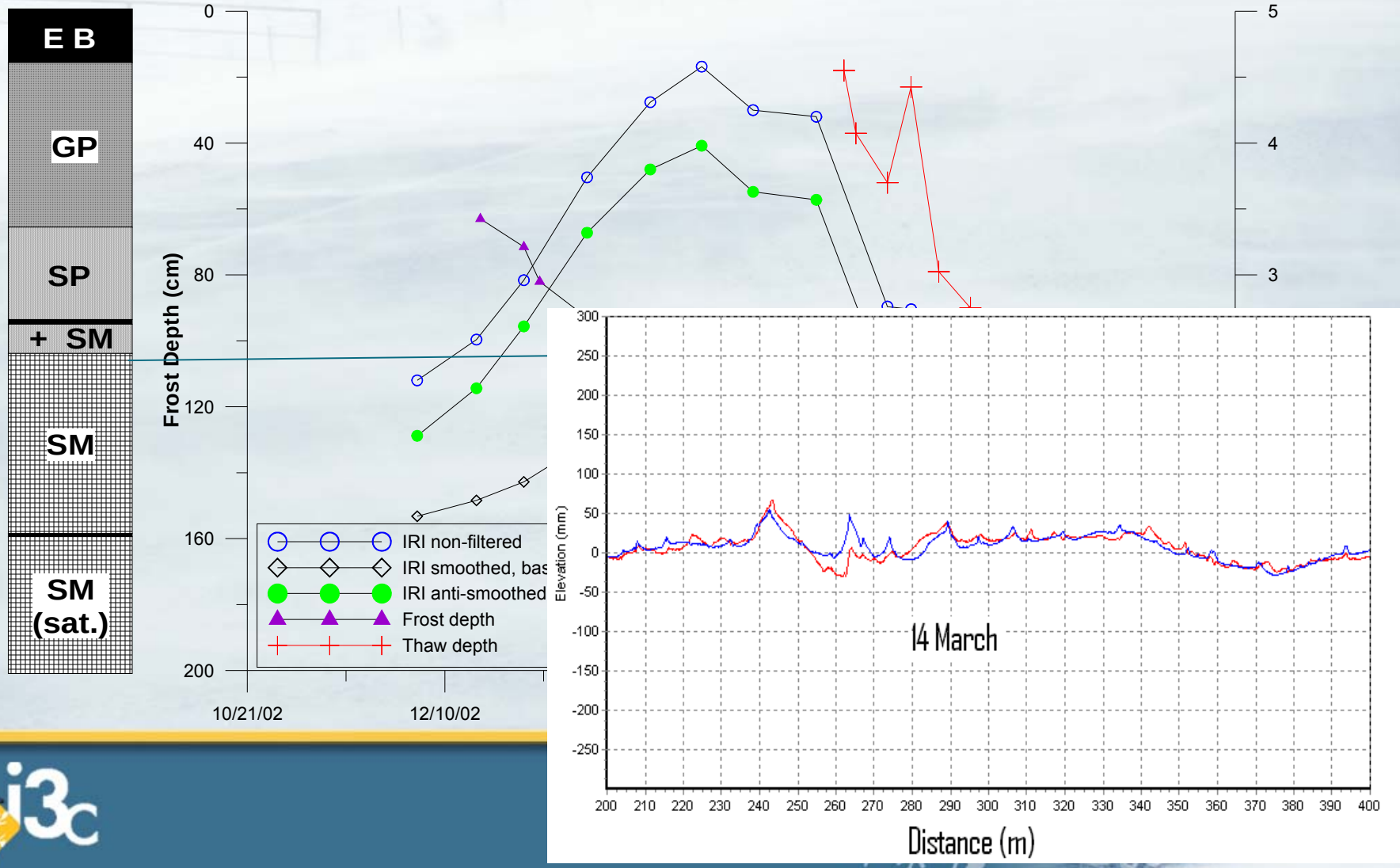
$$IRI_t = IRI_0 + k\left(v_\varepsilon \varepsilon_p + v_h h\right)$$

  - Numerical modelling
  - Small scale laboratory simulations
  - Field observations (LTPP sites)

Winter roughness

- Development of winter roughness
  - Contribution of differential frost heave occurring in subgrade soil
  - Contribution of crack heaving (frost heave in granular base materials contaminated by deicing chemical

Winter roughness



Thaw weakening

- Development and implementation of the Thaw Weakening Index (Twin)
  - Relationship between resilient modulus and Twin considering:
    - Volume change during frost
    - Rate of thawing
    - Rate of consolidation
- Experimental program in test pit with environmental control under load simulator

Conclusion

- Frost heave criterion used for frost design of pavements in Quebec
- ΔIRI and profile analysis used to assess frost action on existing pavement
- Several research projects are being conducted to improve frost design and analysis

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