Comparison of different approaches to frost protection in cold regions

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04-12-2014

Presentation outline

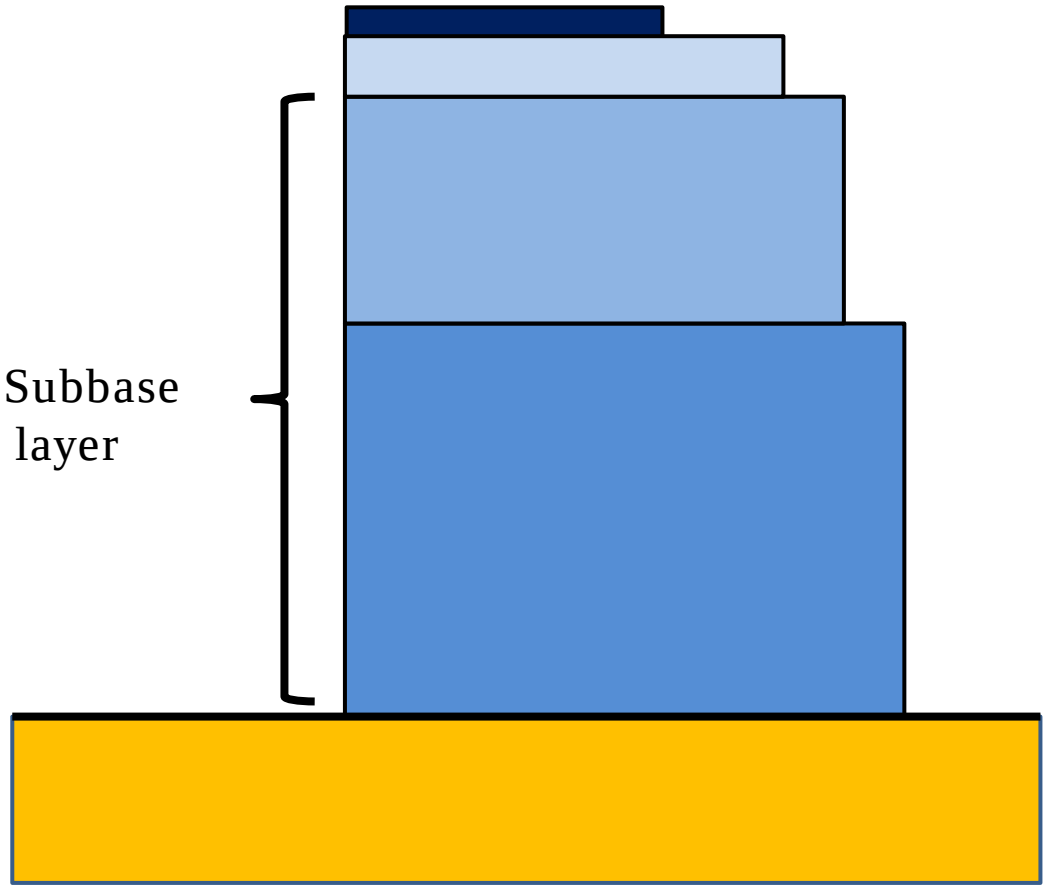
- Context
- Cold regions pavement
- Comparisons of frost protection in different countries
- Examples of different approaches

Cold regions Pavements

Foto: Martin Ystenes
Place: Rv 17, ved Steinkjer, på vei mot Namsos, rundt 1 km etter at man tar av fra E6

Foto: Lars Andreas Solås
Alta, road FV26

Pavement Layers



Cold regions pavements

- Frost action – important sourse of excess water
  - Temperature
  - Moisture
  - Frost susceptibility
- Frost heaving:
  - In subgrade soils
  - In pavement granular materials

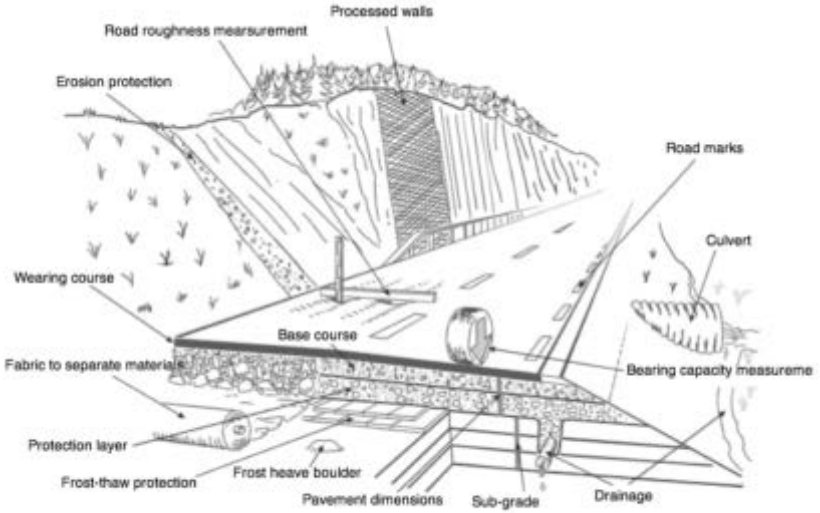


Fig. 5 Cross section of Swedish roads according to specifications (STA 2003).

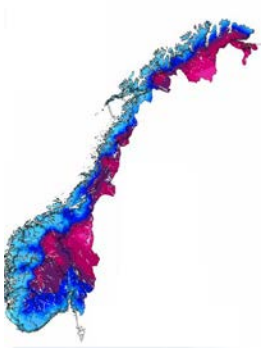
Frost Protection Practices

NO considerations for Frost heave

- Alaska, USA
- Iceland
- Norway

Considerations for frost heave

- Finland
- Sweden
- Quebec, Canada

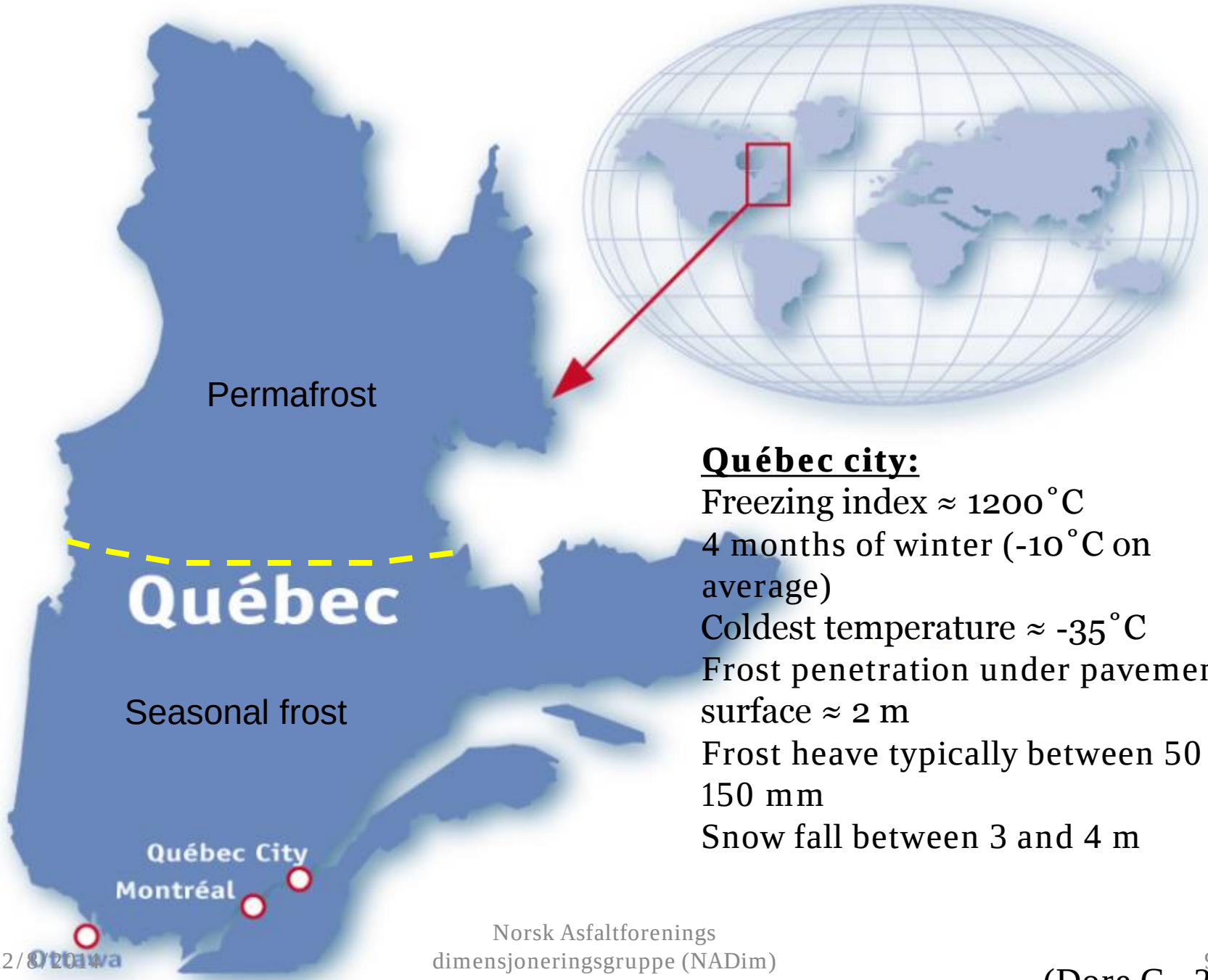


Without considerations of frost heave

Country, administration	Frost depth prediction	Frost susceptibility	Thickness
Alaska, USA 	Thermal analysis program (Berg2)	Full depth replacement or or rigid board insulation	Minimum 21 inches (53,34 cm) + insulation 18-36 inches (45-91 cm)
Iceland 	No	-	Min.thickness – 90 cm Maximum – 1,2 m dependent on the subgrade soil type
Norway 	Frost depth (H_0) $H_0 = \sqrt{\frac{7200 \cdot F_d \cdot \lambda_f}{L + C \cdot \theta_m}}$	**Soils:** T1 (no frost susceptibility) to T4 (high frost susceptibility) **Granular material:** 2-15 % (material<0.063 mm calculated from material <22.4 mm)	• Frost susceptible subgrade (T3, T4) – maximum or 1.8 m, or 2.4 m (depends on AADT) • For subgrade category T1, T2 – frost protection is not required

With considerations of frost heave

Country, administration	Frost heave prediction	Frost susceptibility	Thickness
Sweden 	PMS Objekt ver. 4.4 design software Calculated frost heave is compared with an acceptable heave	< 9 % (material<0.063 mm)	Pavement: min 500 mm Frost protection layer = 0-1000 mm
Finland 	1.PMS Objekt ver. 4.4 design software 2.TPPT frost design method developed by Seppo Saarelainen	Segregation potential of subgrade soils	Maximum thickness 2 m. Max. allowed frost heave depends on road class/type
Quebec 	Chaussee II design software SSR model	Based on segregaion potential, soils properties	Chaussee II design software Allowable frost heave



Québec city:

Freezing index ≈ 1200˚C

4 months of winter (-10˚C on average)

Coldest temperature ≈ -35˚C

Frost penetration under pavement surface ≈ 2 m

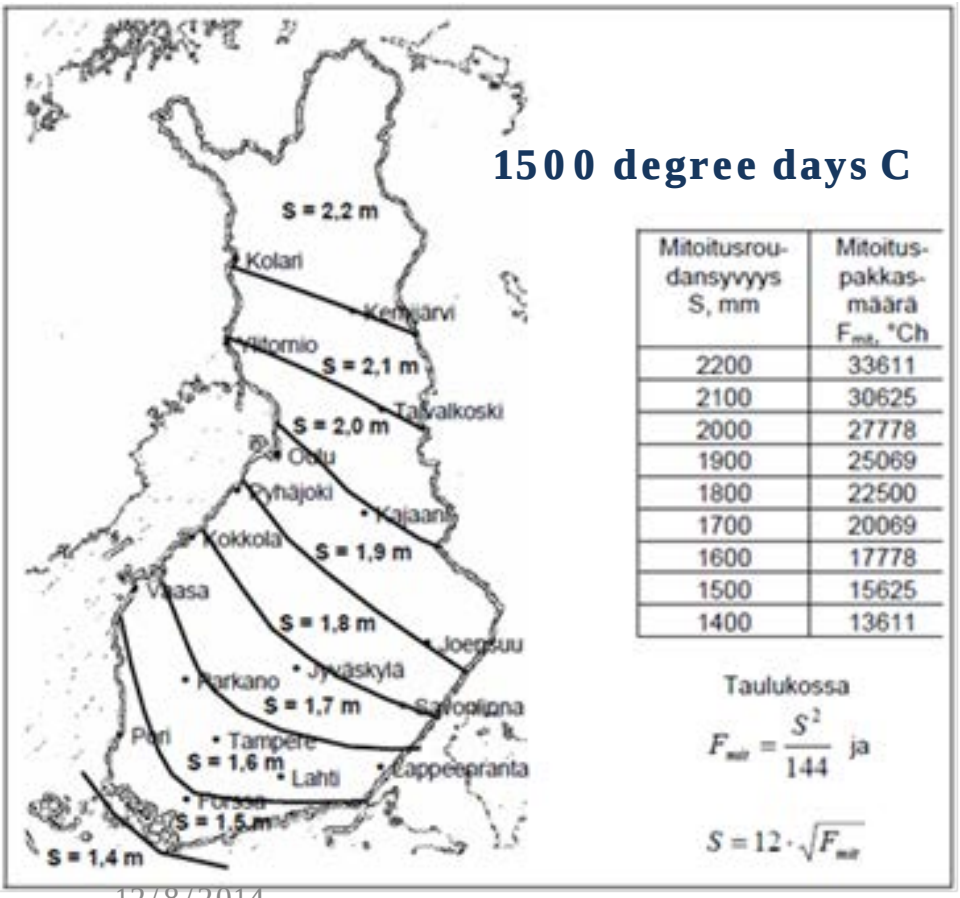
Frost heave typically between 50 and 150 mm

Snow fall between 3 and 4 m

(Dore G., 2013)

Freezing index

FINLAND



1500 degree days C

Mitoitusroudansyvyys S, mm	Mitoituspakkasmäärä F_{mit}, °Ch
2200	33611
2100	30625
2000	27778
1900	25069
1800	22500
1700	20069
1600	17778
1500	15625
1400	13611

Taulukossa

$$F_{mit} = \frac{S^2}{144} \text{ ja}$$

$$S = 12 \cdot \sqrt{F_{mit}}$$

560 degree days C

SWEDEN

Climate Zone 6: 2000 degree days C

Climate Zone 1: 50-100 degree days C

Frost design (Quebec and Finland)

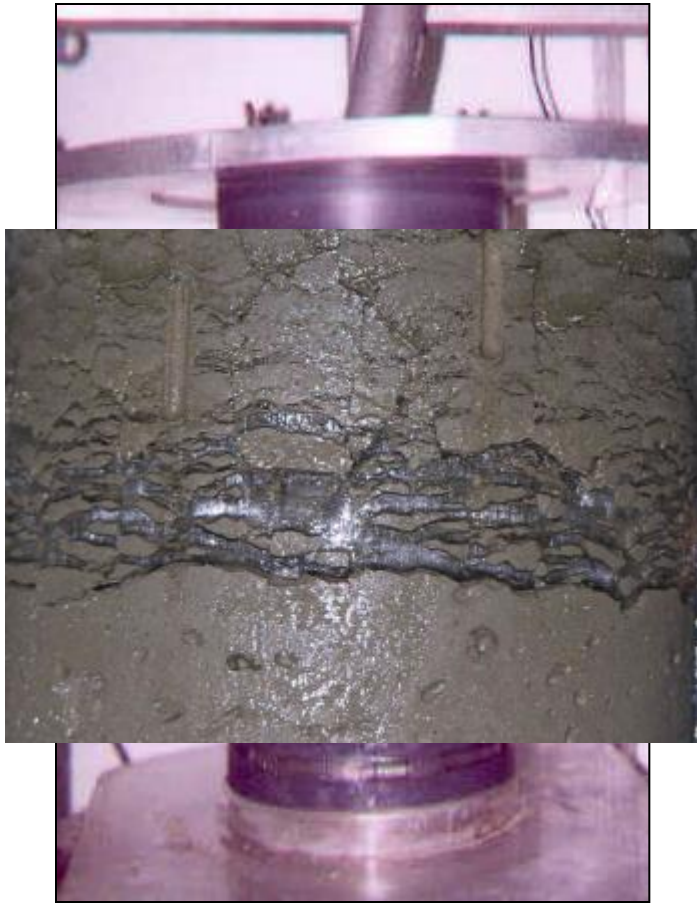
- Frost heave calculated based on:
  - Segregation potential (SP) of subgrade soil
  - Climatic conditions (Freezing index)
  - Site specific conditions (water content, water table, etc)
- SSR model used for computation of frost penetration and heave
- Frost heave compared to allowable frost heave criterion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

(Dore G., 2013)

Frost susceptibility (SP) Segregation Potential

Frost susceptibility	SP ($mm^2/^oC \cdot hour$
Negligeable	< 0.5
Low	0.5 to 1.5
Moderate	1.5 to 3
High	3 to 8
Very high	> 8

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

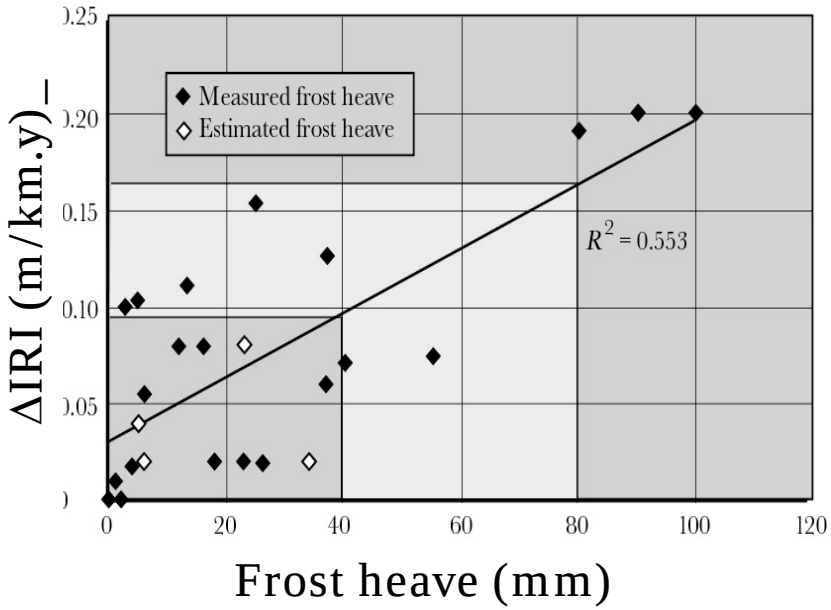


Method based on J.M. Konrad (1980)

(Dore G., 2013)

Allowable frost heave

- Criterion based on relationship between roughness development and frost heave

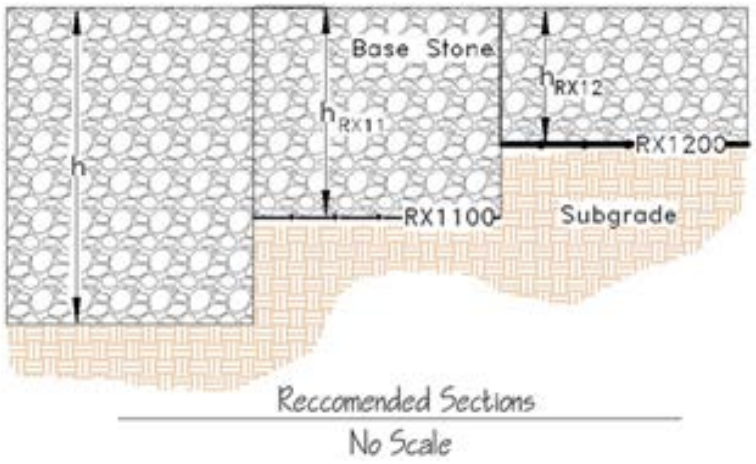


(Dore G., 2013)

Country/ structure	Freeways	National	Regional	Local
Quebec, Canada	< 50 mm	< 55 mm	< 60 mm	< 70 mm
Finland	< 30mm	< 50mm		< 100mm

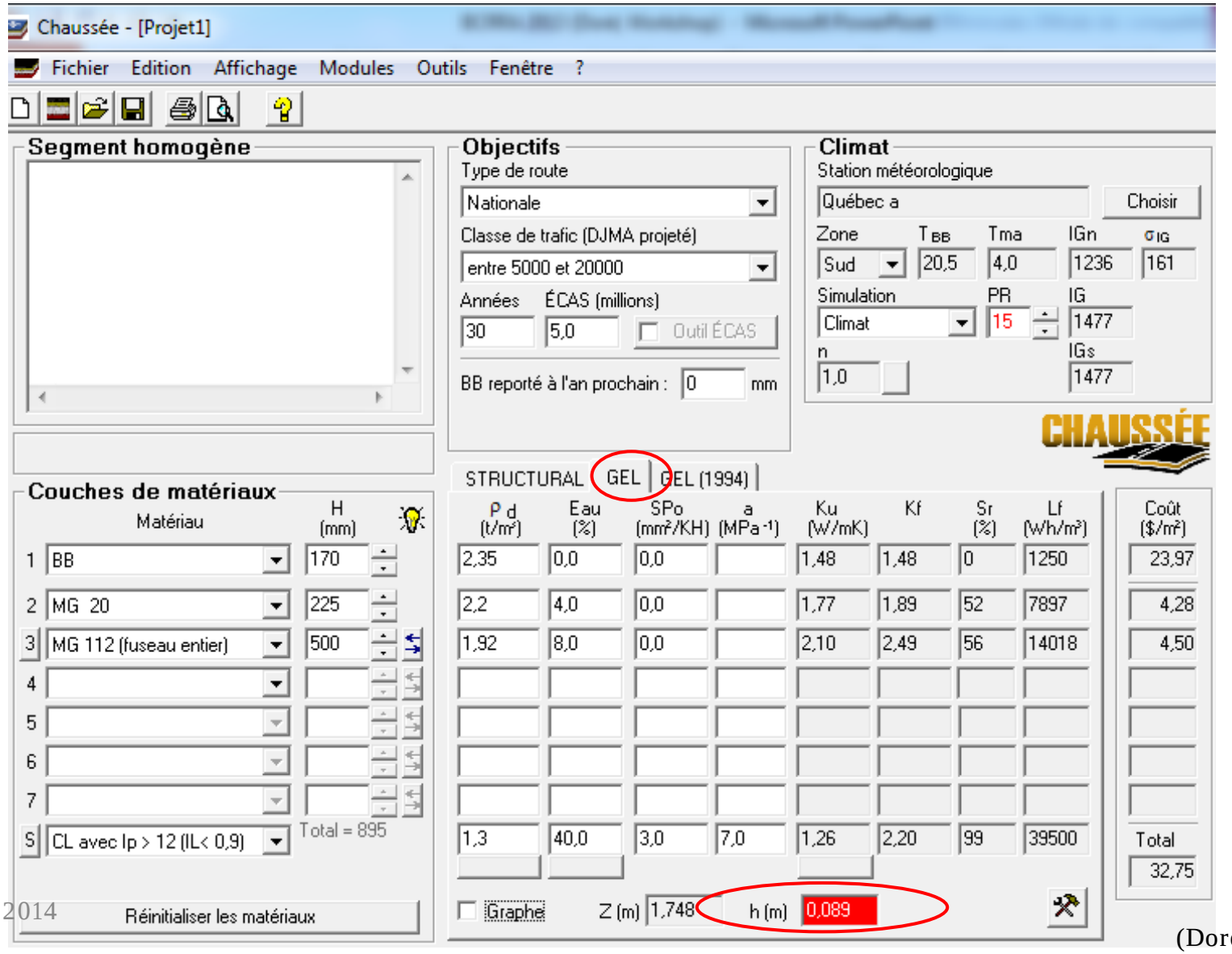
Pavement adjustment to meet frost heave criterion

- Increase thickness of granular subbase
- Pavement insulation



(Dore G., 2013)

Frost design (Chaussee II design software)



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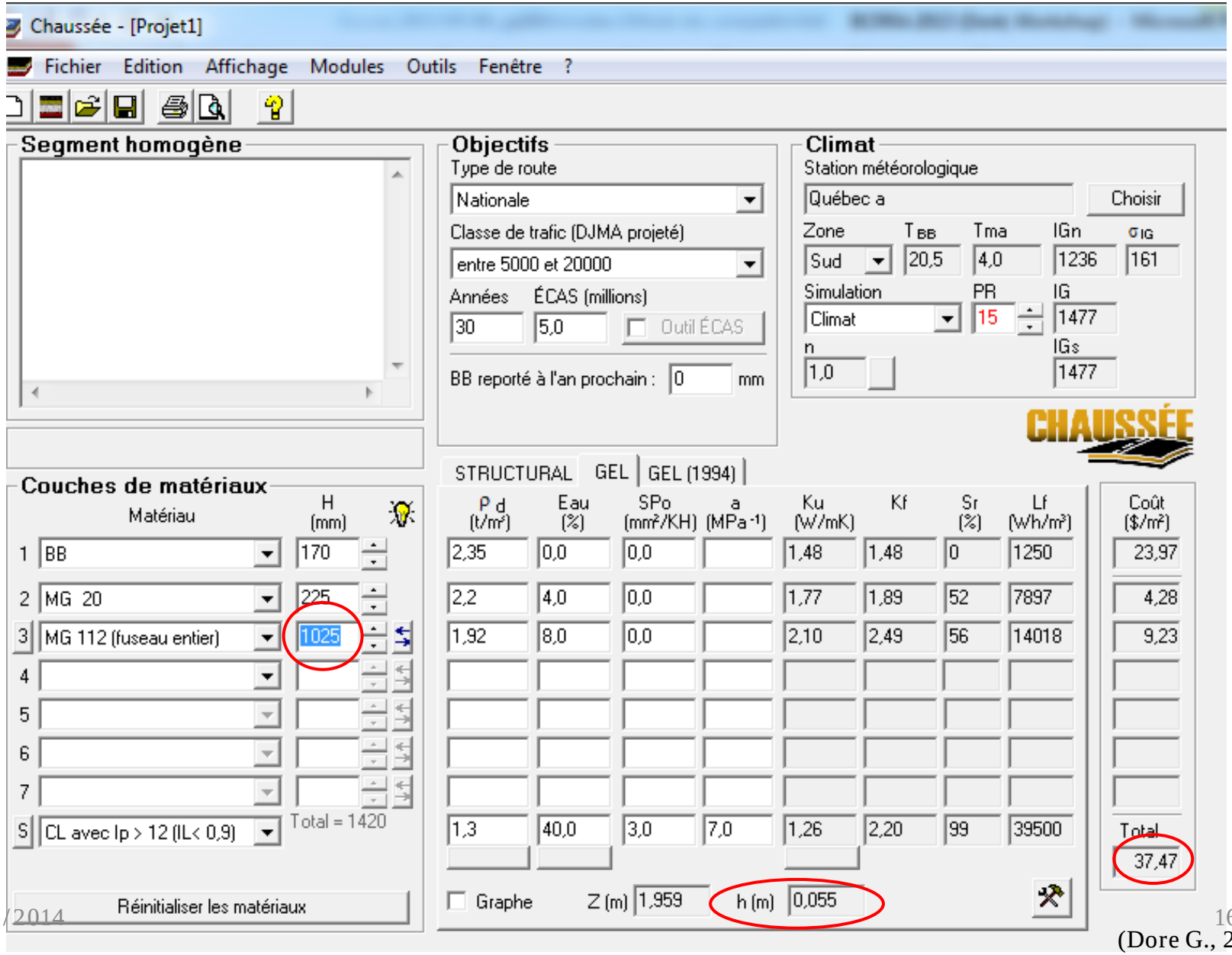

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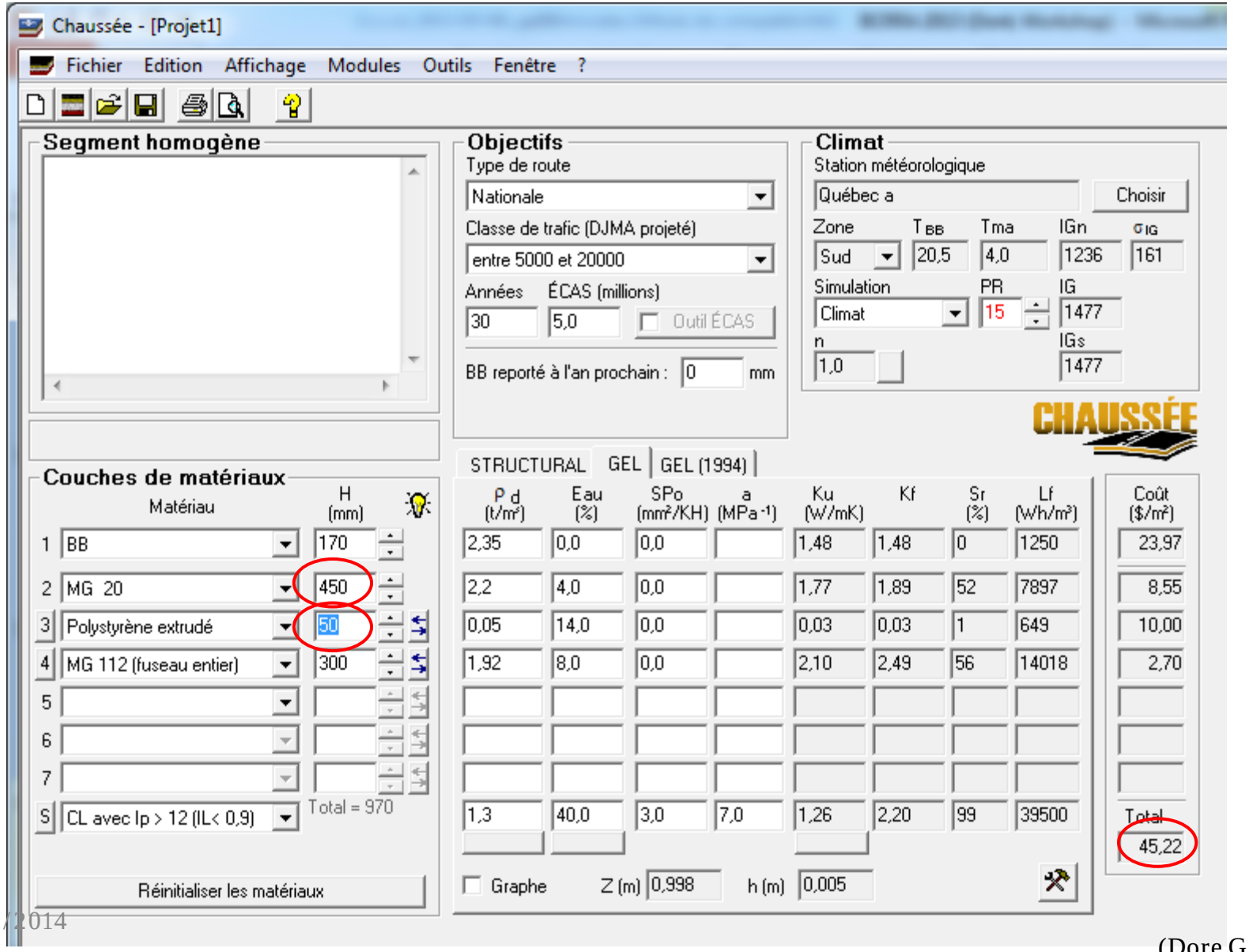

(Dore G., 2013)

Pavement rehabilitation (Quebec)

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

(Dore G., 2013)

Pavement rehabilitation (Quebec)

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

(Dore G., 2013)

CONCLUSIONS

- Frost heave should be considered in frost protection calculations
- Laboratory and field data / input
  - Segregation potential of subgrade soils
  - Site specific conditions (water table, soils etc)
  - Frost penetration depth

THANK YOU FOR YOUR ATENTION

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