



XIII
INTERNATIONAL
WINTER ROAD
CONGRESS

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Québec 

SUSTAINABLE WINTER SERVICE FOR ROAD USERS

*Prediction of sliding resistance on asphalt pavement
surface due to freezing of sodium chloride solution*

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BACKGROUND

- ◆ Salting is the most popular anti-freezing measure for winter road management
- ◆ It is difficult to carry out the salting work appropriately



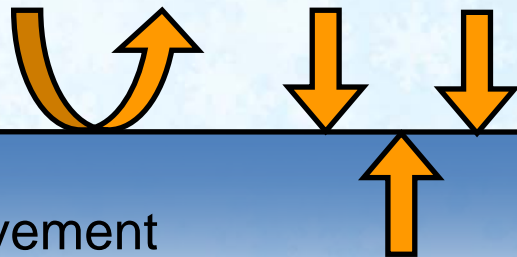
ROAD FREEZING PREDICTION MODEL

Past model

Proposed model

Heat transfer

(radiant heat, sensible heat, etc.)



Pavement

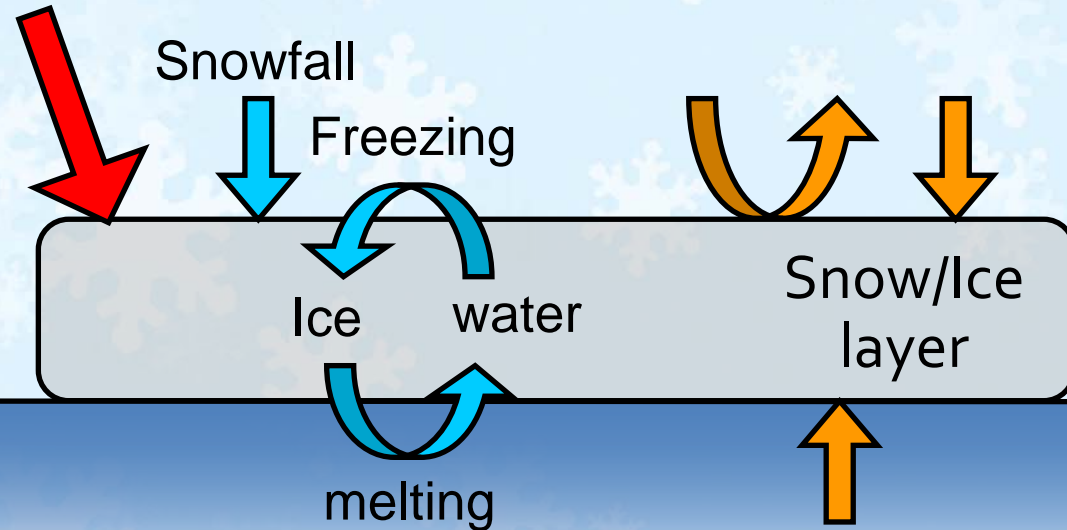
Output

Road surface temperature

Salting

Mass transfer

Heat transfer



Snowfall

Freezing

Ice

water

melting

Snow/Ice layer

Output

Road snow/ice condition
(snow density, height, ice content)

μ

Salt concentration

PURPOSE

1. To develop a coupled heat and mass balance model (**HMB model**)
2. To examine the validity of HMB model by comparison between calculated results and experimental ones

ASSUMPTIONS AND CONDITIONS

1. Solar radiation, snow/rain fall, road drainage and traffic related heats are ignored.
2. Salt (NaCl) solution does not flow out of the road surface (it stays on the road surface).
3. Heat moves only in the vertical direction, and any horizontal movement of NaCl solution is ignored.

MASS BLANCE OF WATER, ICE AND SALT

Mass balance of water

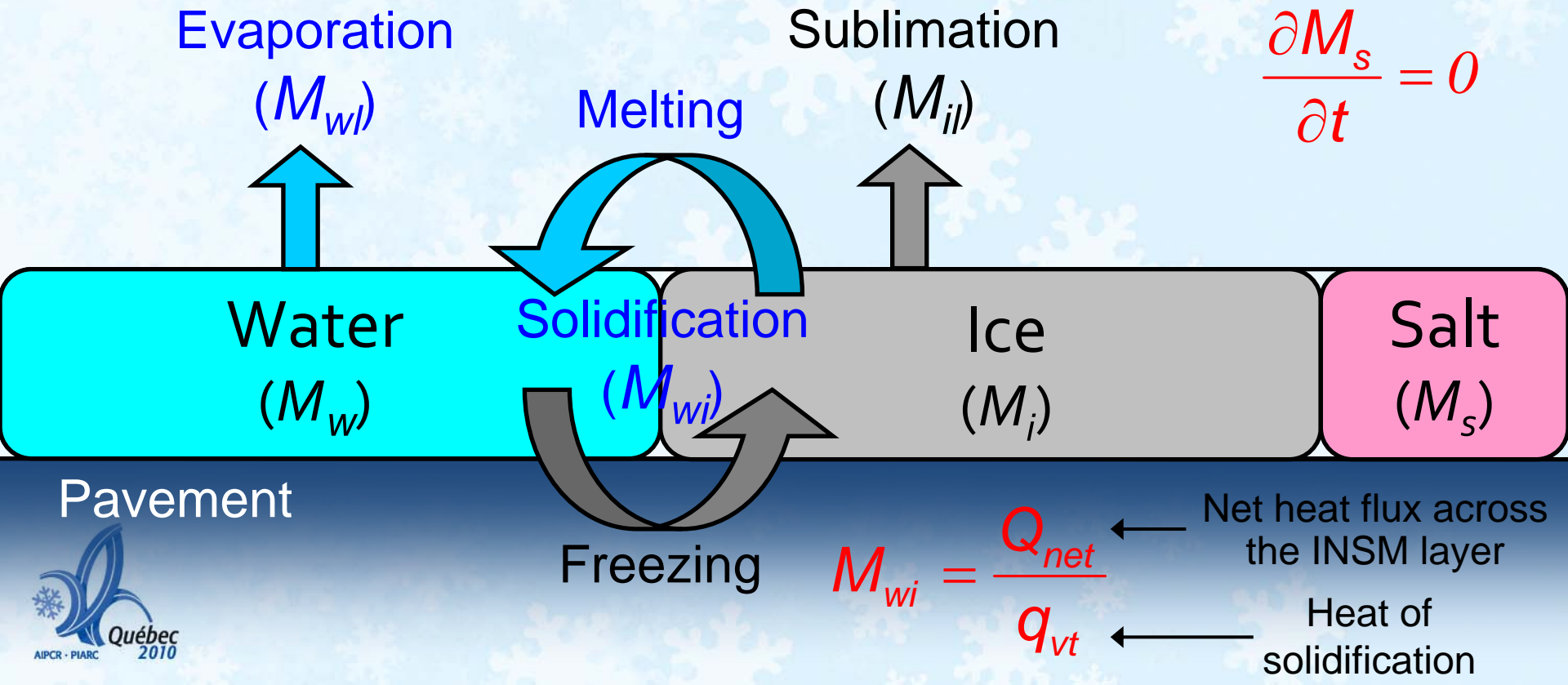
$$\frac{\partial M_w}{\partial t} = -M_{wl} - M_{wi}$$

Mass balance of Ice

$$\frac{\partial M_i}{\partial t} = -M_{il} + M_{wi}$$

Mass balance of salt

$$\frac{\partial M_s}{\partial t} = 0$$



HEAT BALANCE

Long-wave radiation
from INSM

Sensible heat
due to natural wind

(R_{lu})

Sky radiation

(S_a)

Latent heat due to
Evaporation/sublimation

(R_{ld})

(L_e)

z_s

Latent heat due to
solidification

(L_m)

Ice-NaCl
solution mixture
(INSM)

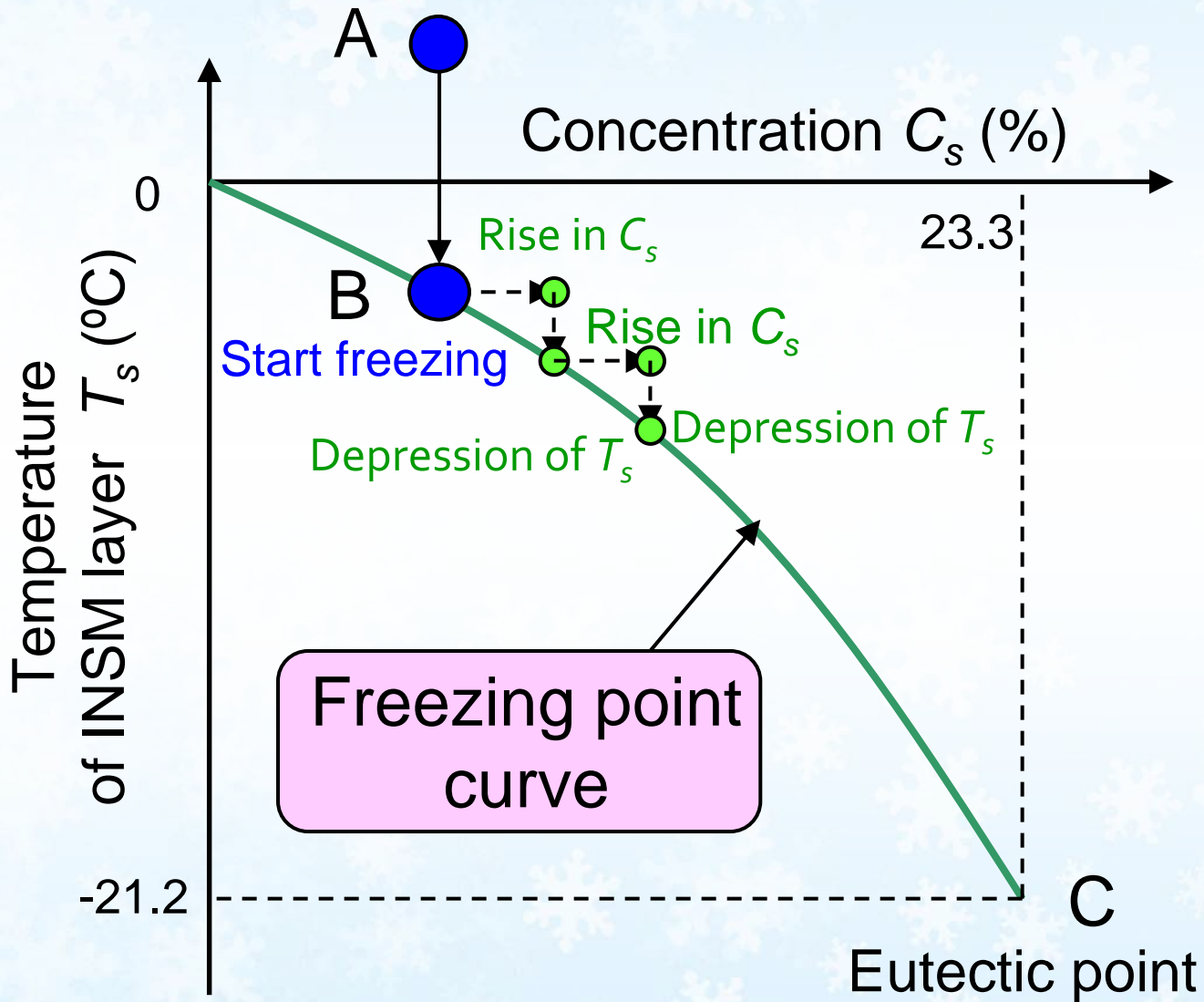
Pavement heat

(C_{sp})

Pavement

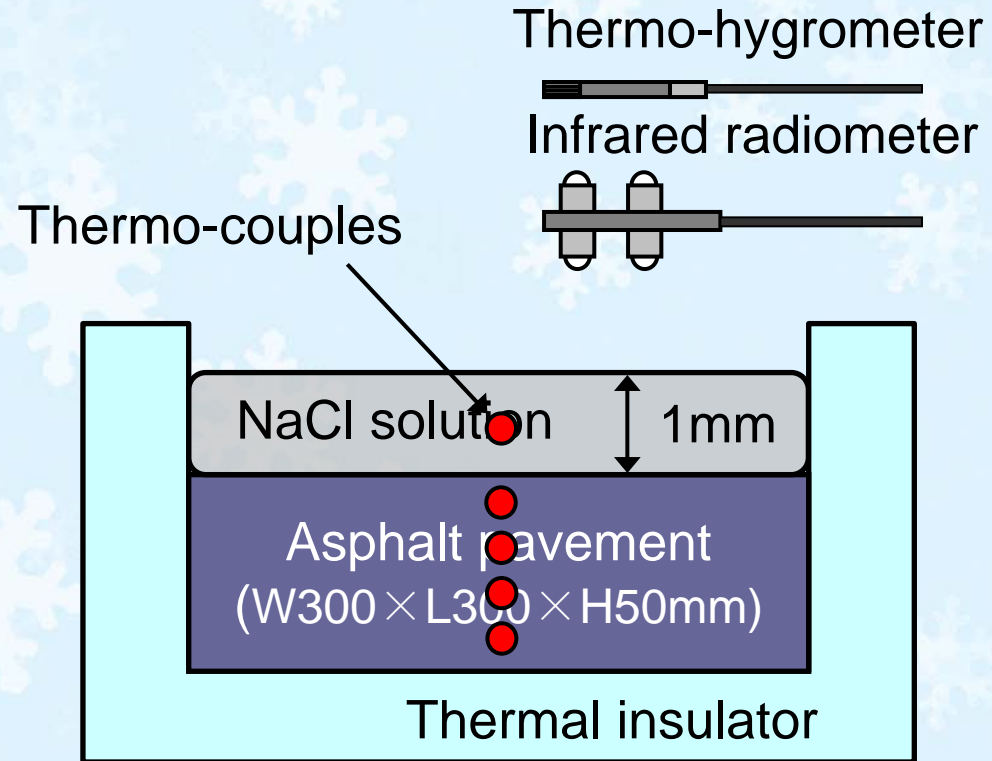
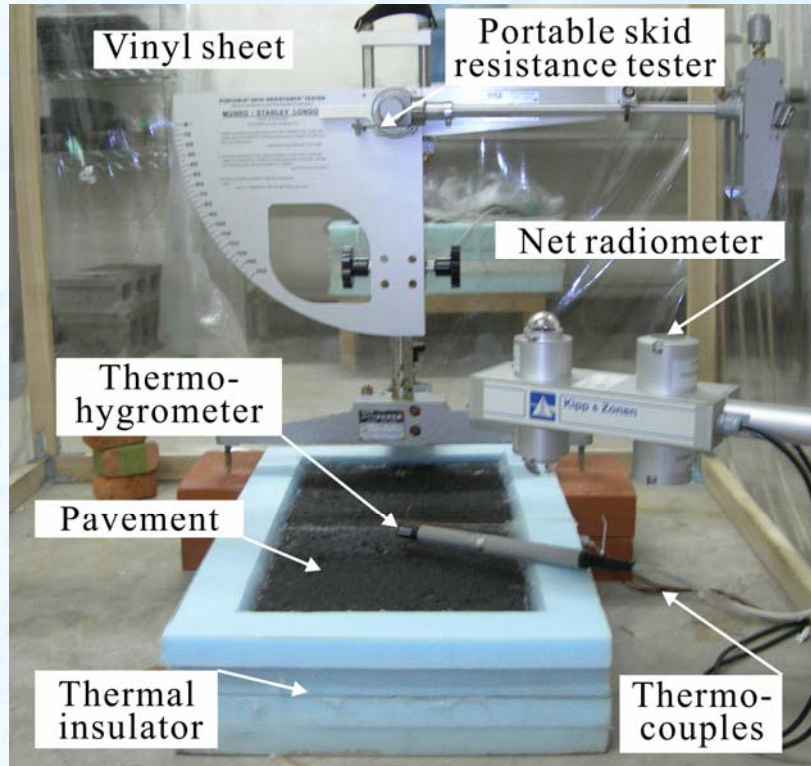
$$\frac{\partial}{\partial t} \{ (\rho c)_s z_s T_s \} = C_{sp} - R_{lu} + R_{ld} - S_a - L_e + L_m = Q_{net}$$

MODELING OF FREEZING INSM



FREEZING AND SLIDING RESISTANCE EXPERIMENTS

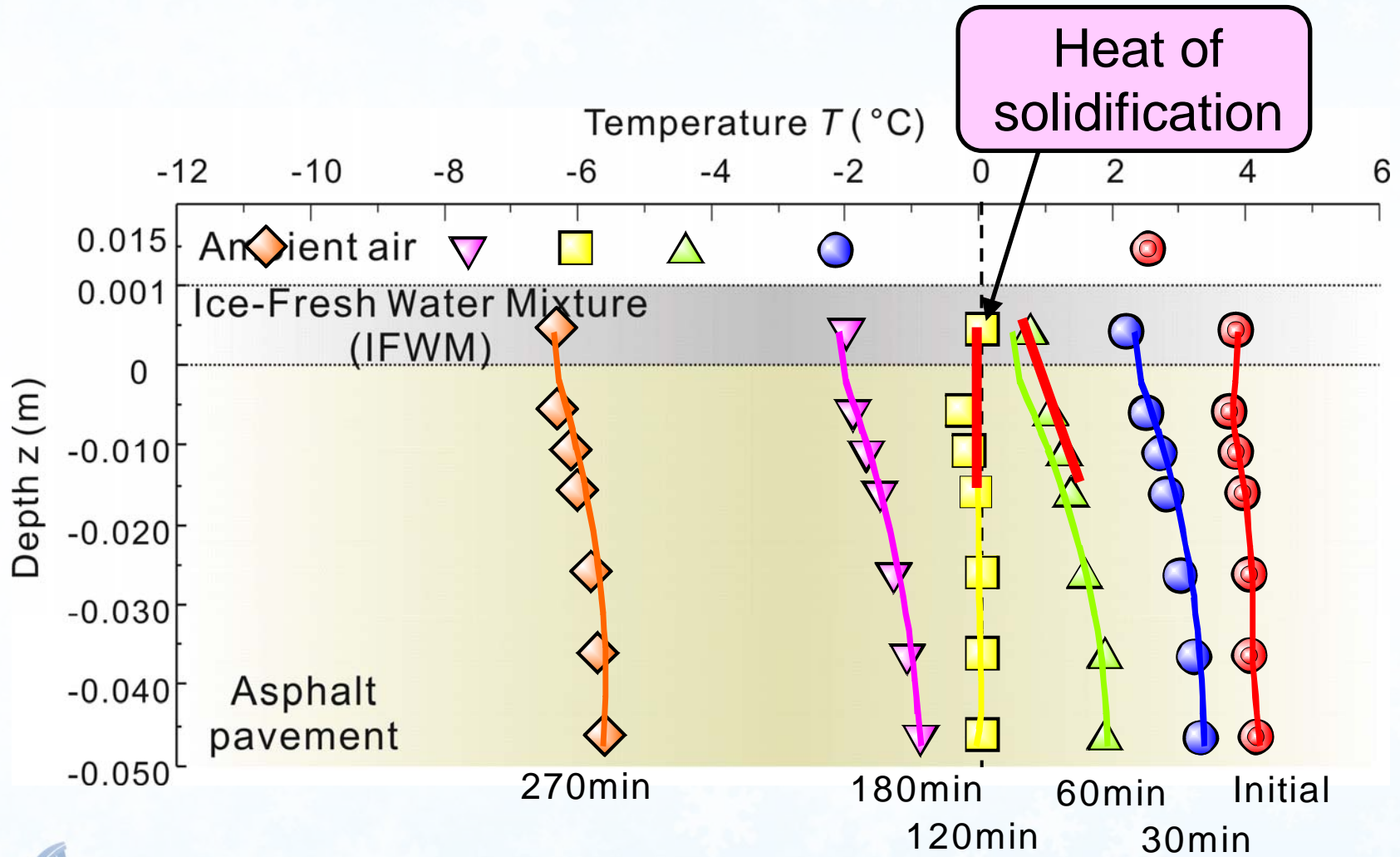
Low-temperature room



Initial concentration { 0% (Fresh water)
2%、4%、8% (NaCl solution)

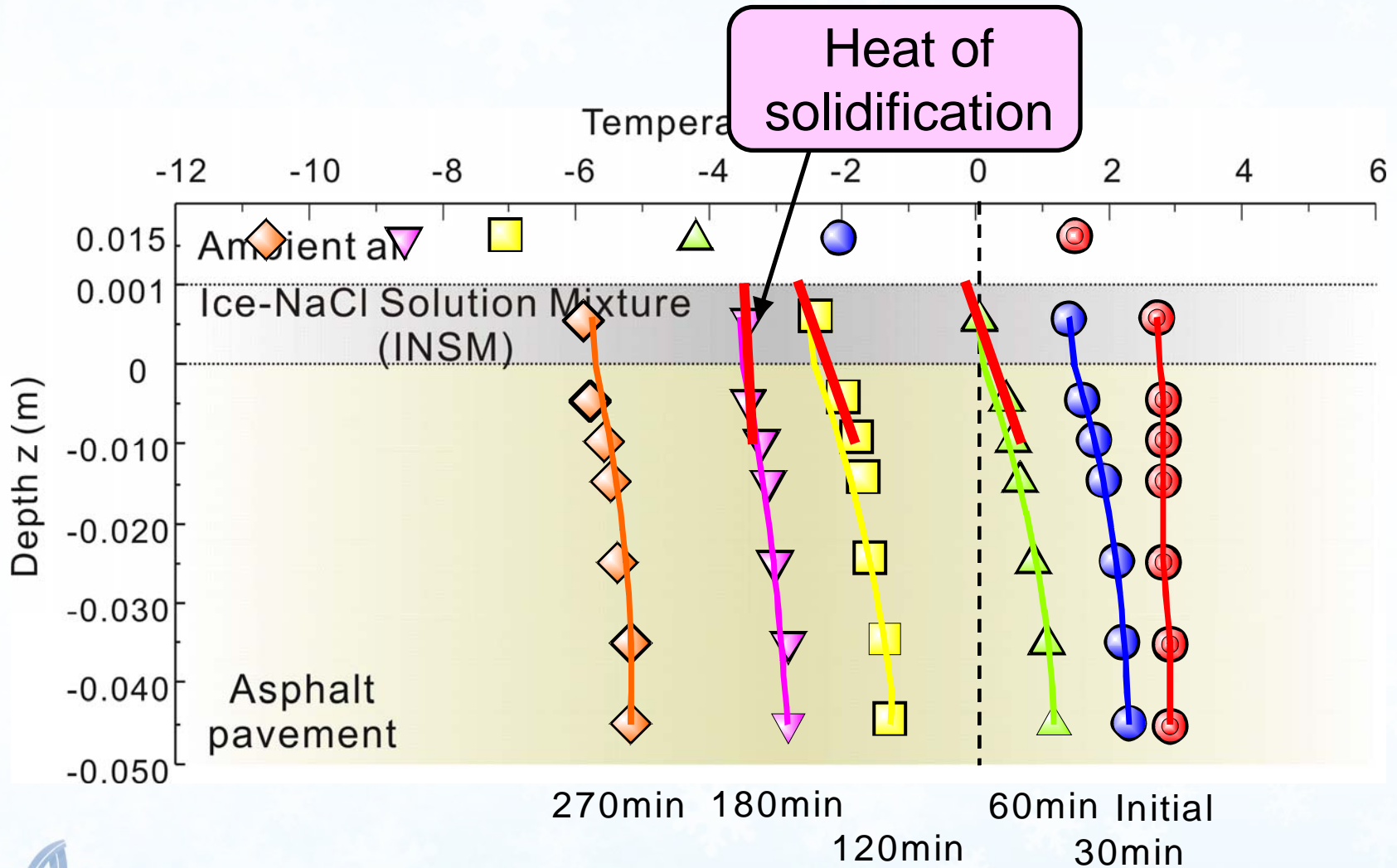
RESULTS

- Temperature of Ice-Fresh Water Mixture (IFWM) -



RESULTS

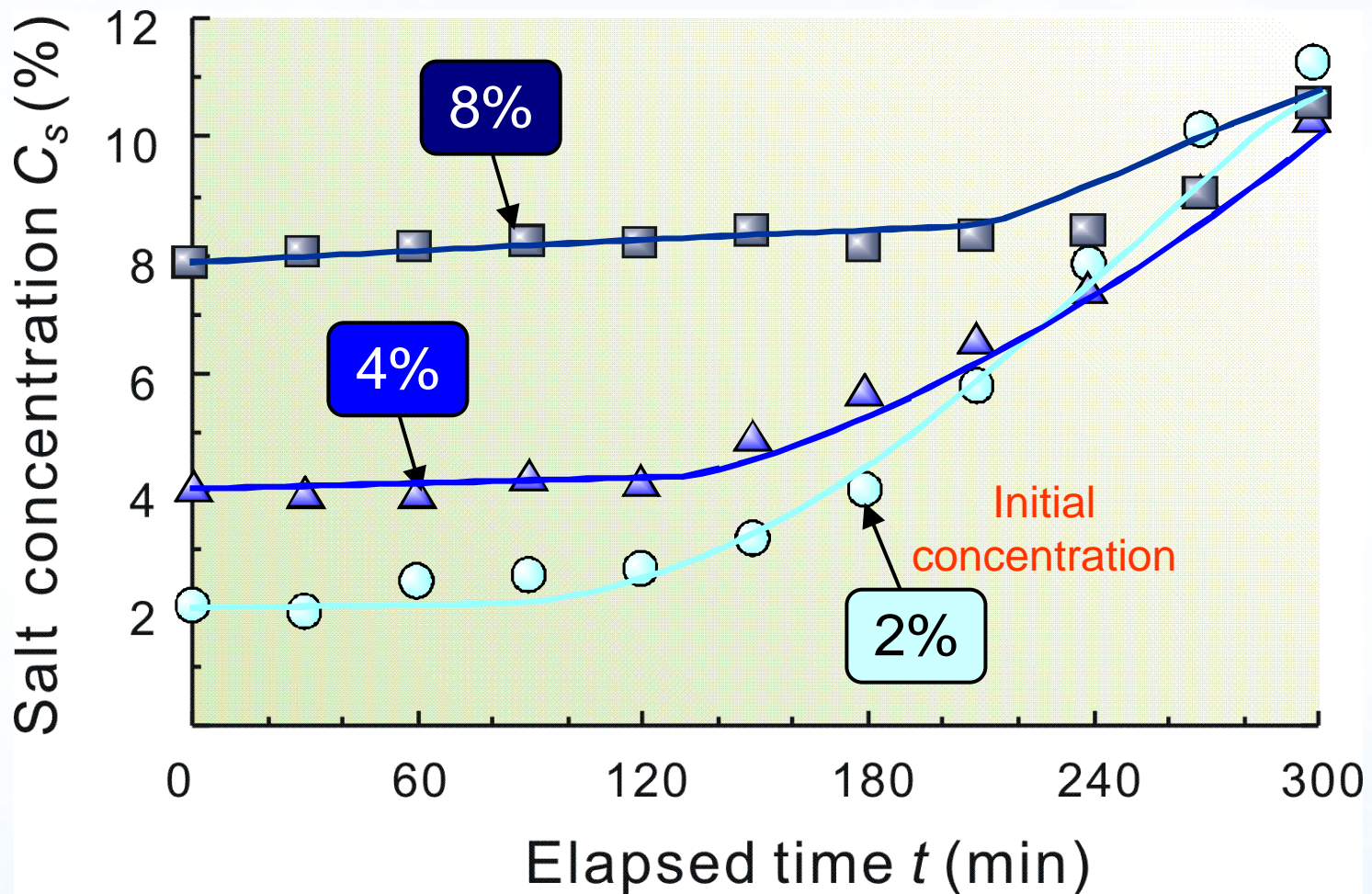
- Temperature of Ice-NaCl Solution Mixture (INSM) -



Initial salt concentration: 4%

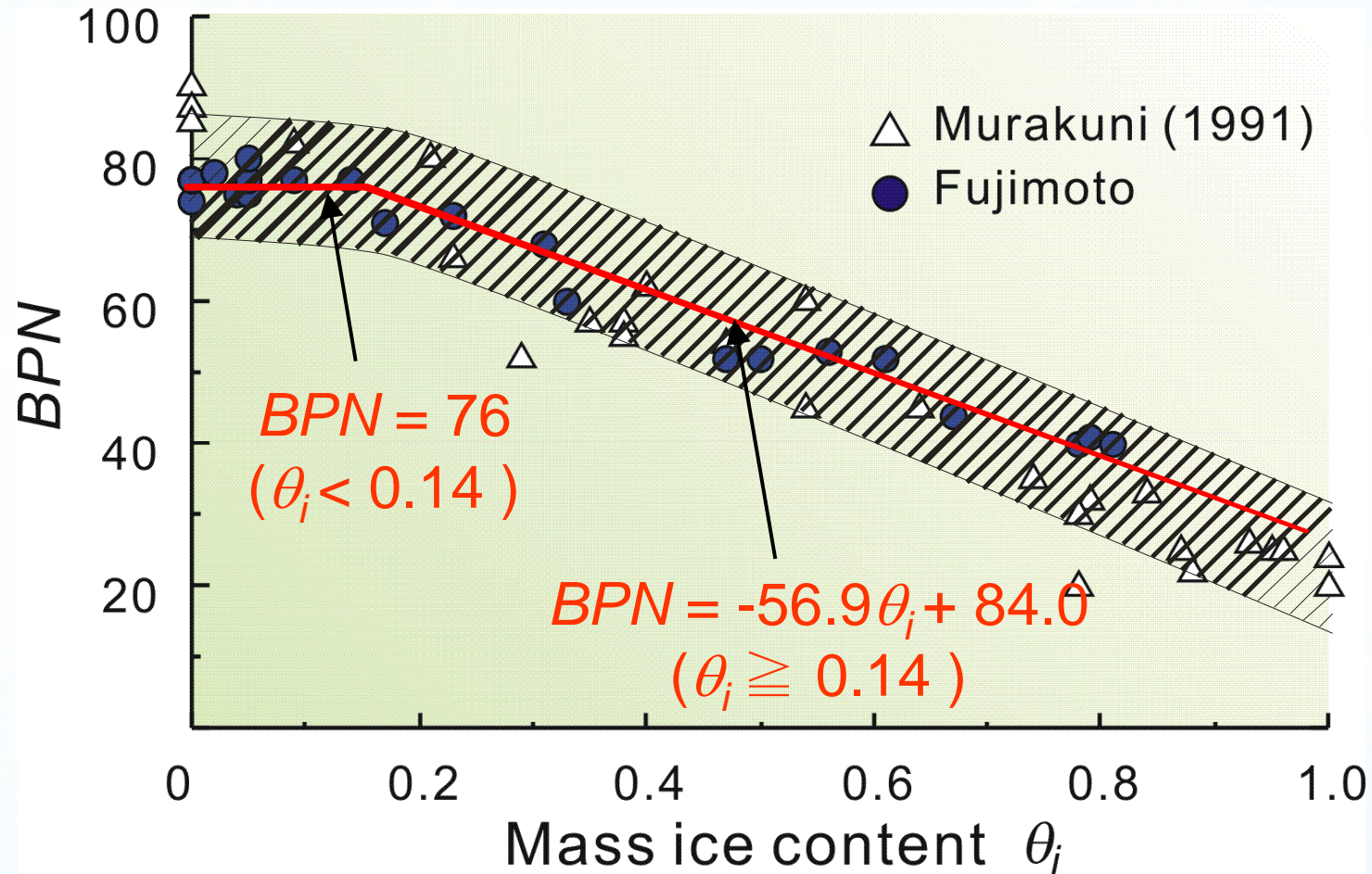
RESULT

- Time variation of salt concentration -



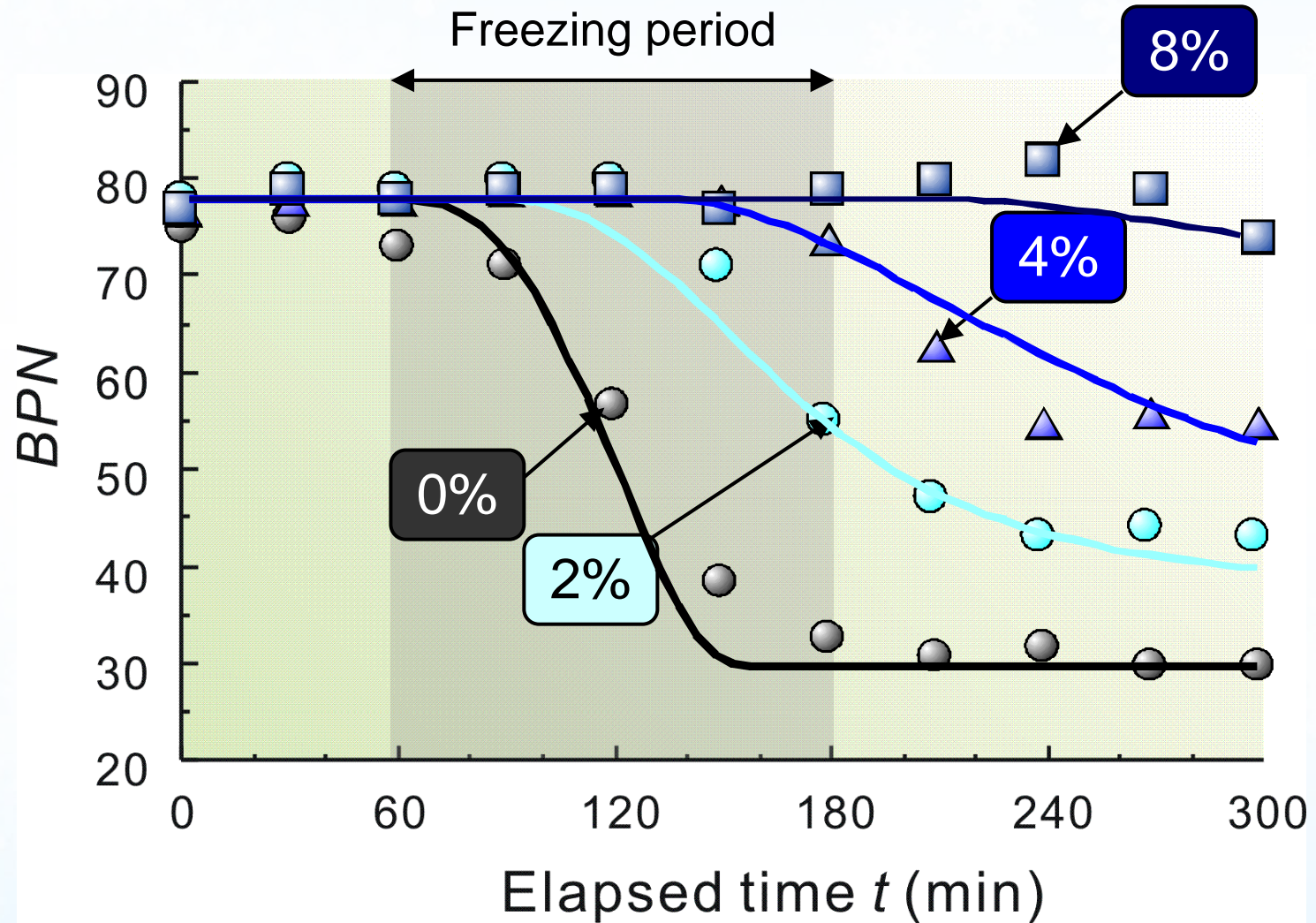
RESULT

- Relationship between BPN value and mass ice content -



RESULT

- Time variation of BPN value -



CONCLUSIONS

The HMB model was able to reproduce the rise in salt concentration and the reduction of the skid resistance with time associated with the expansion of freezing of both fresh water and NaCl solution.

Thank you