

Properties of the crushed rocks used as frost protection layer of the Norwegian roads: field and laboratory investigations

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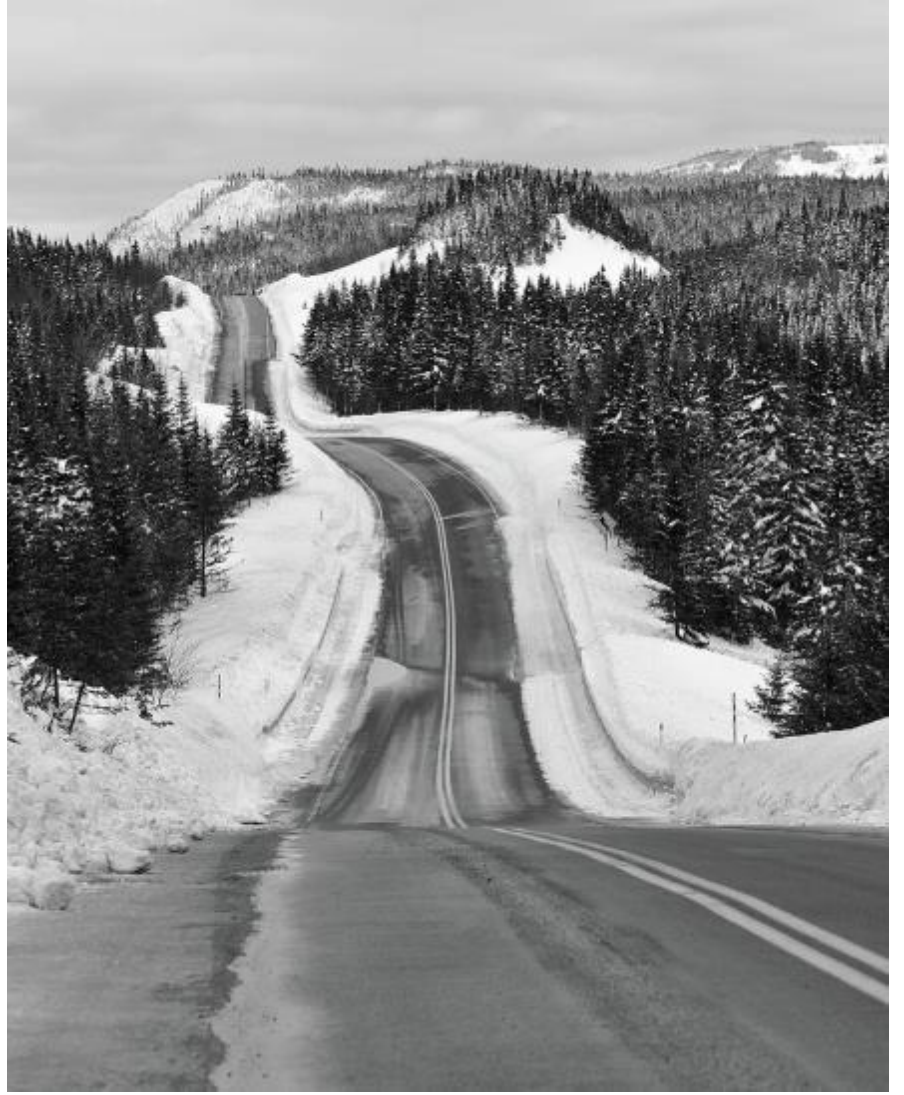
18-June-2015



ECTRI – FEHRL - FERSI

Young Researchers Seminar 2015



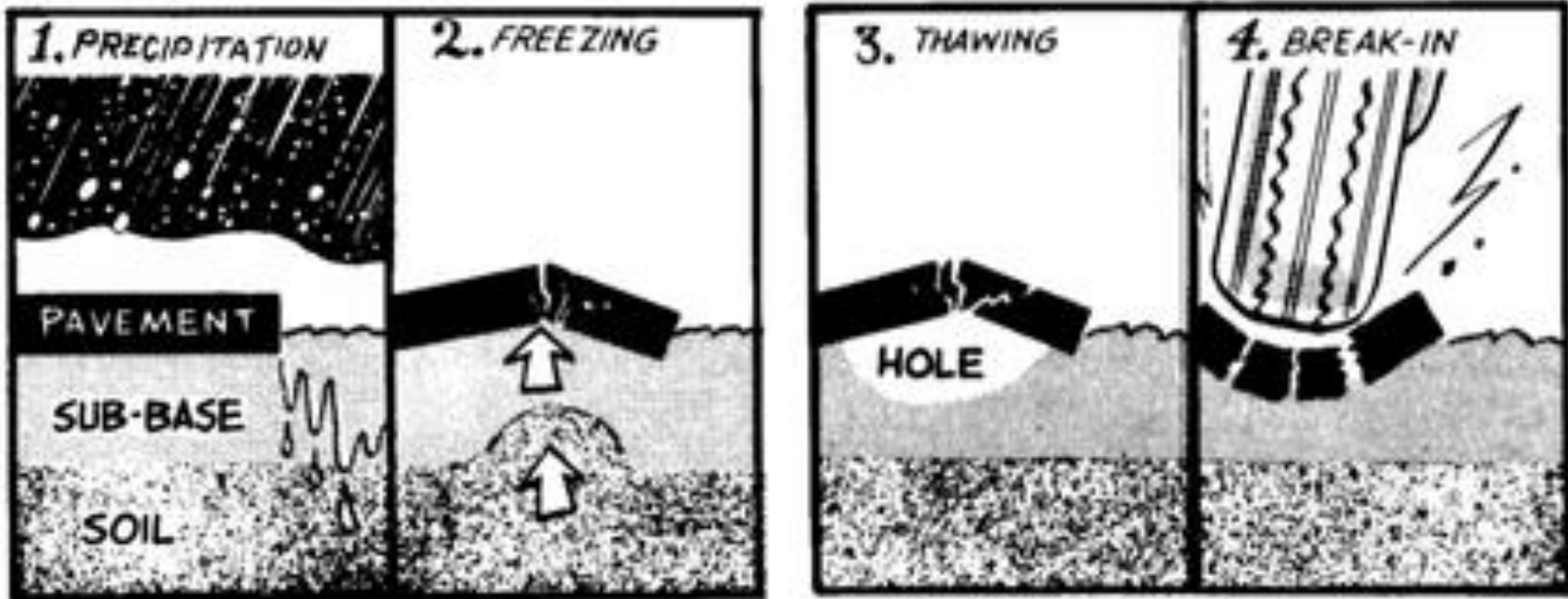


Alta



Foto: Lars Andreas Solås
Alta, road FV26

Freezing-thawing effect on pavements



<http://www.asphaltsolutionsplus.com/asphalt-crack-repair/>

Climate change

Warmer winters

freezing-thawing
cycles instead of
stable winter
conditions

frost heave
problems

Winters 2010/11, 2011/12



2012-2013

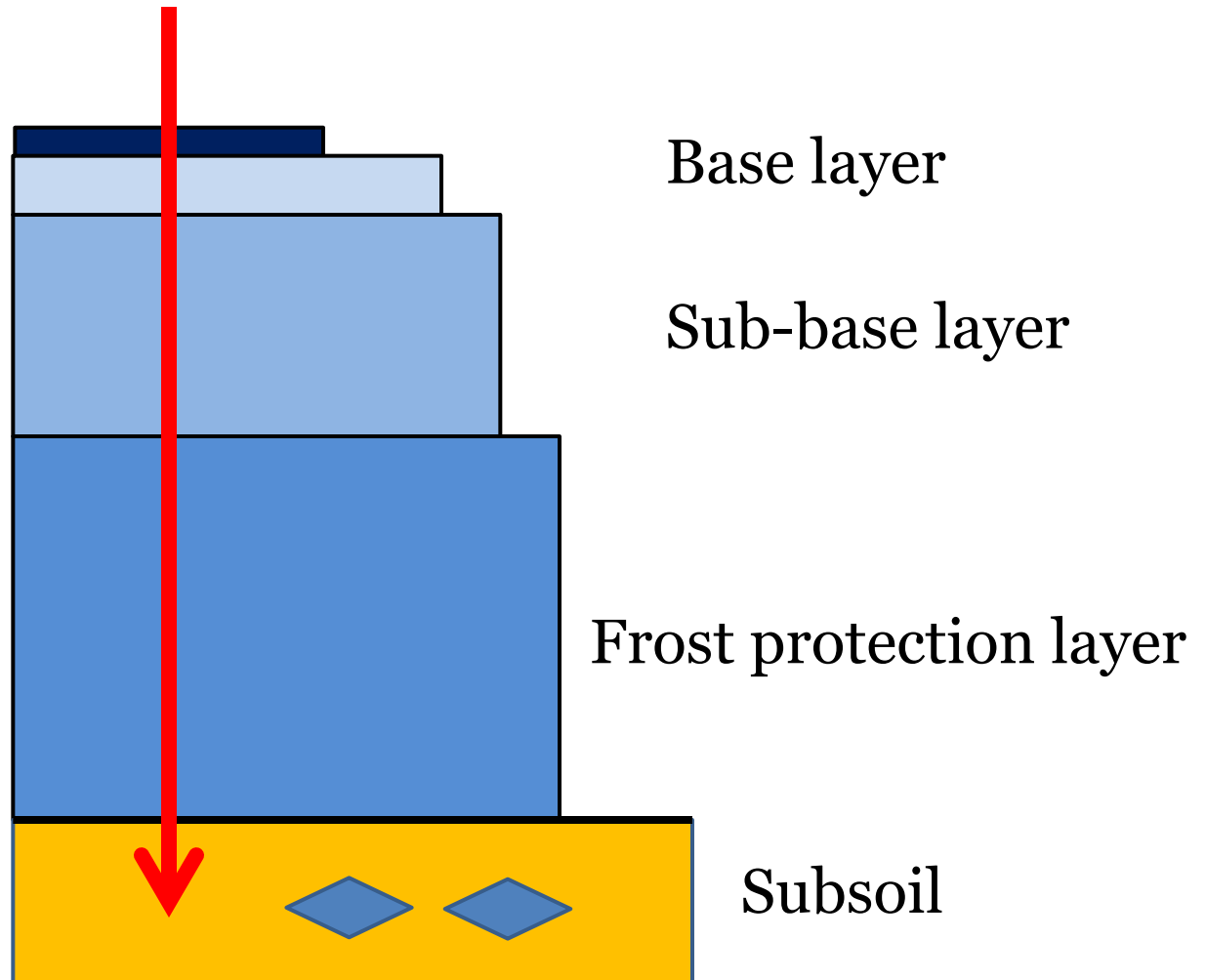


2007

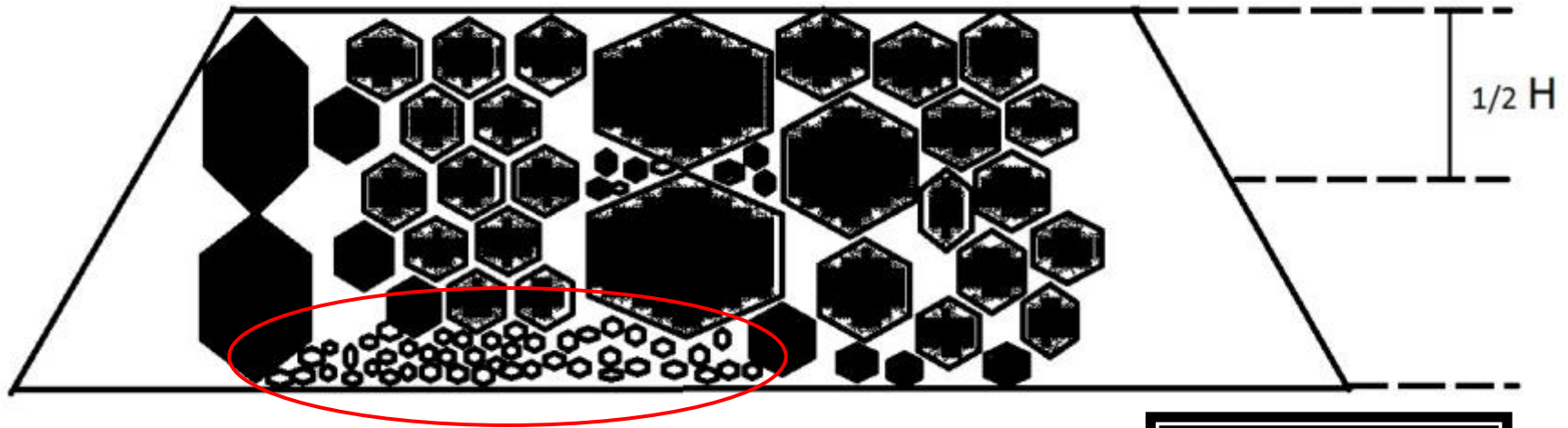


2014

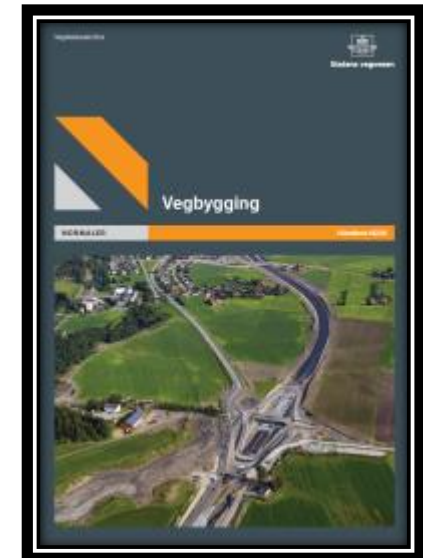
Layers performance



Frost protection layer requirements



- ❖ D_{max} 500 mm or $1/2$ layer thickness
- ❖ Minimum 30 % material smaller than 90 mm
- ❖ Fine content: 2-15 % (material < 0.063 mm calculated from material < 22.4 mm)
- ❖ No requirements for the amount of material < 22.4 mm

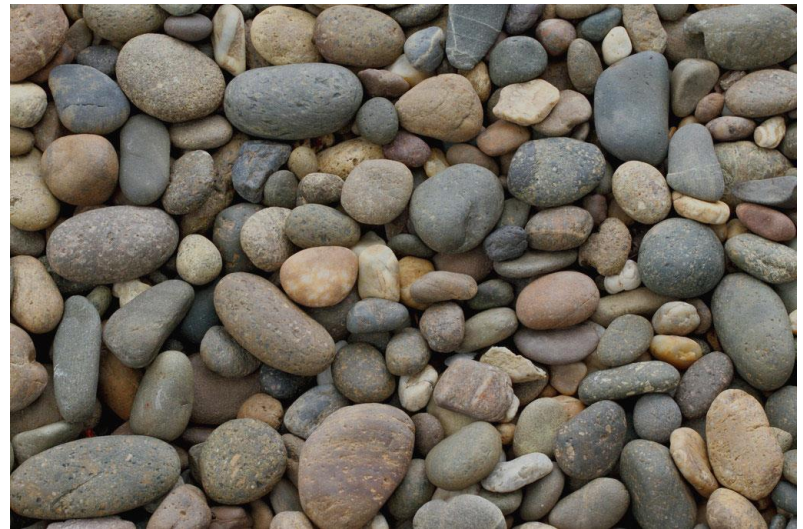




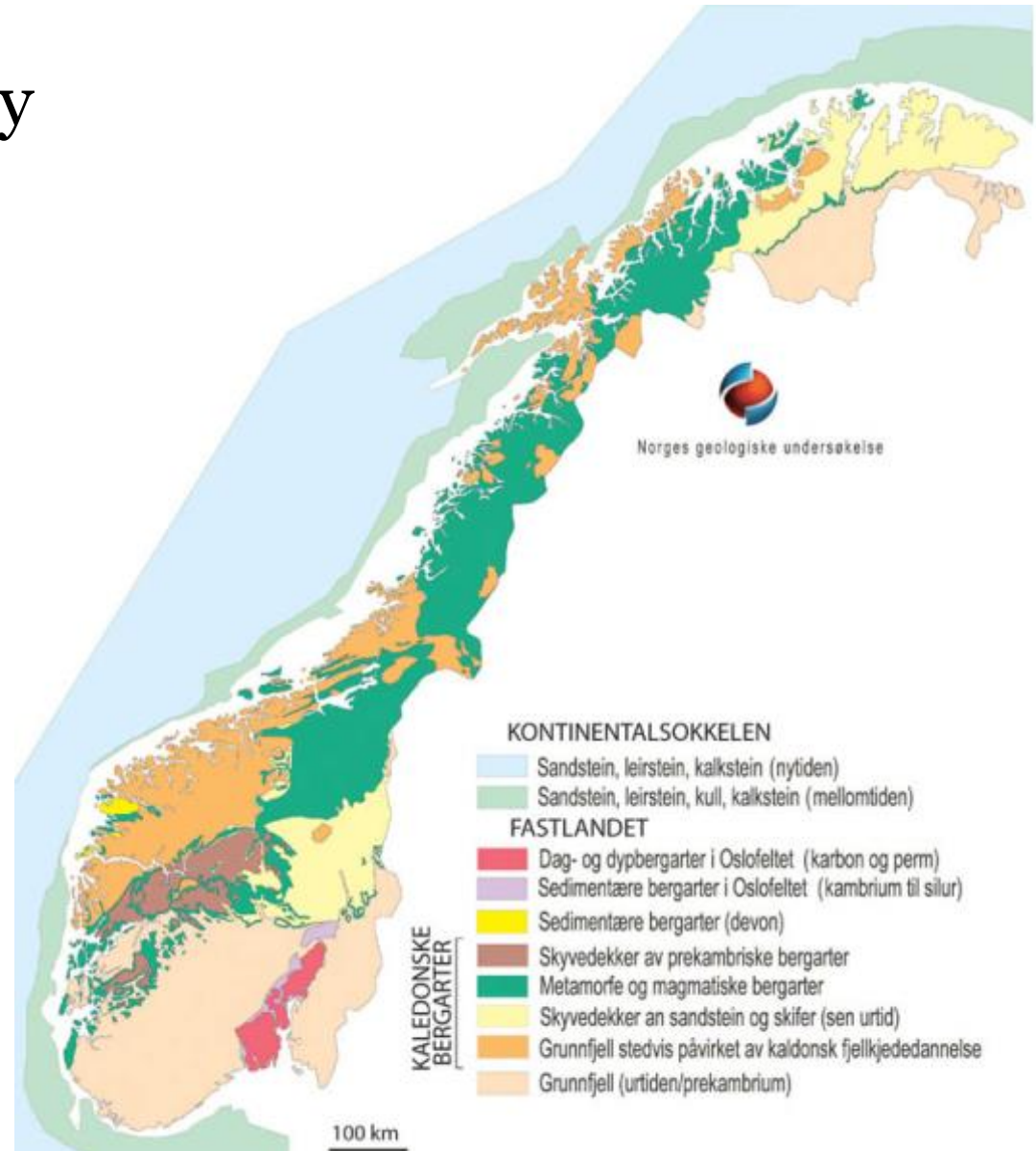
- ✓ 1970-1976 “Frost i jord”
- ✓ Frost susceptibility classification – based on gradation
- ✓ Granular material :
 - ✓ Before: gravel
 - ✓ Now: crushed rock
- ✓ Fine materials:
 - ✓ Before: less than 7%
 - ✓ Now: up to 15%

Crushed aggregates versus natural gravel

- Particle shape
- Density
- More fines
- Un-weathered particle surface
- More polymineral
- Local bedrocks



Bed rocks in Norway



Frost penetration depth

$$H_0 = \sqrt{\frac{7200 \cdot F_d \cdot \lambda_f}{L + C \cdot \theta_m}}$$

Predefined thermal conductivity and heat capacity not reflecting the difference in petrology

Frost protection layer, Bodø (Northern Norway)



Foto: Lars Andreas Solås

Different Grain Size Distribution Leads to Different Heat Transfer Dominance

Radiation: 



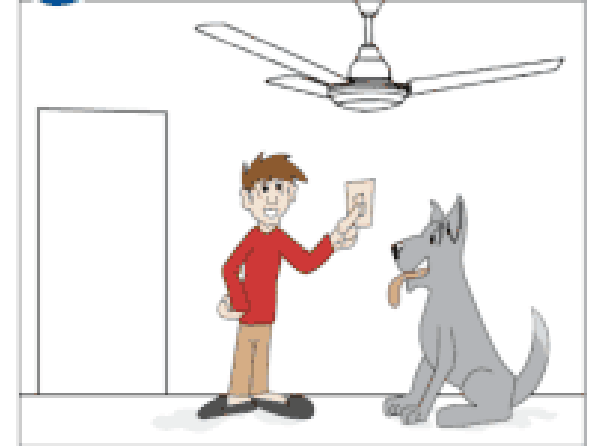
"Hey Duke, doesn't that fire feel good."

Conduction: 



"Ouch! That poker's too hot to hold with my bare hands."

Convection: 

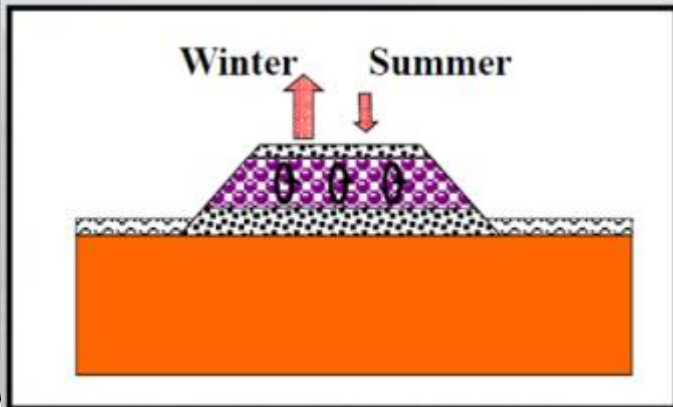


"I'll turn on the fan. All the warmest air is up near the ceiling."

Air convection embankments



Thompson Drive
Fairbanks Alaska



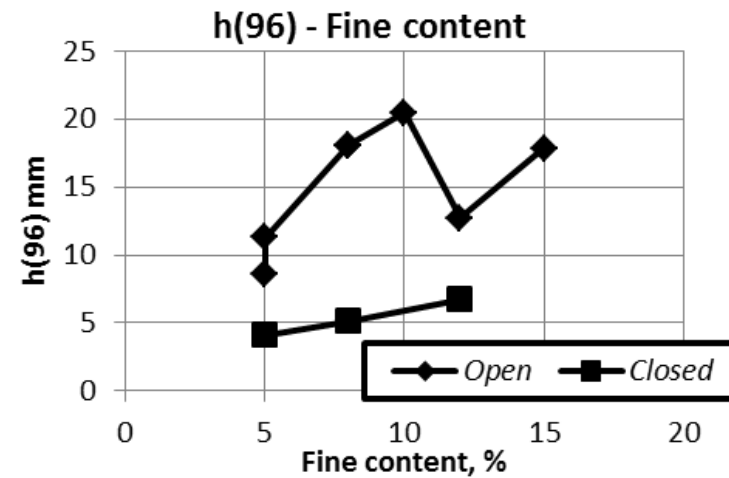
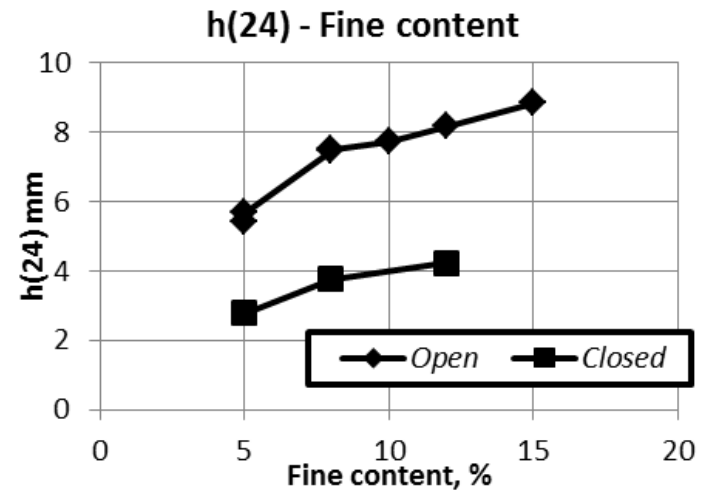
Qinghai-Tibetan Hwy
China



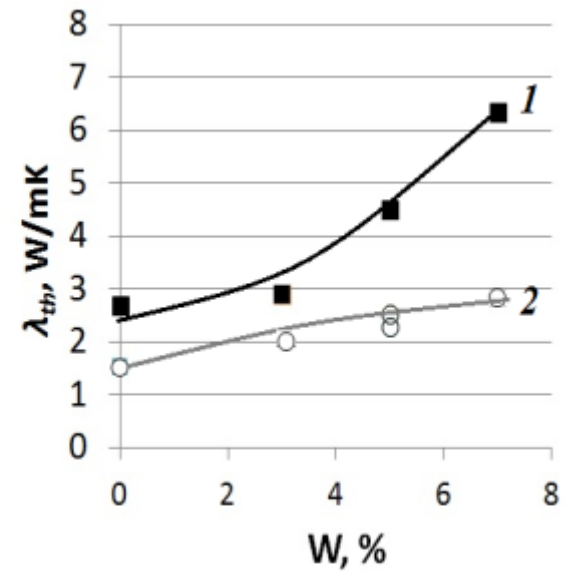
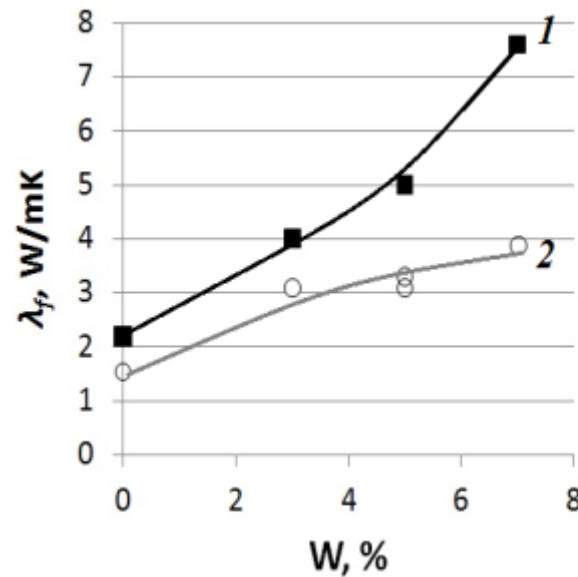
To be considered:

Frost susceptibility: <ul style="list-style-type: none">• subgrade soils• aggregates	<ul style="list-style-type: none">• Frost heave• Segregation potential
Frost penetration depth	Thermal properties: <ul style="list-style-type: none">• Thermal conductivity• Heat capacity
Heat transfer in granular pavement	Heat transfer mechanisms: <ul style="list-style-type: none">• Conduction• Convection• Radiation

Laboratory results: frost susceptibility



Laboratory results: thermal conductivity

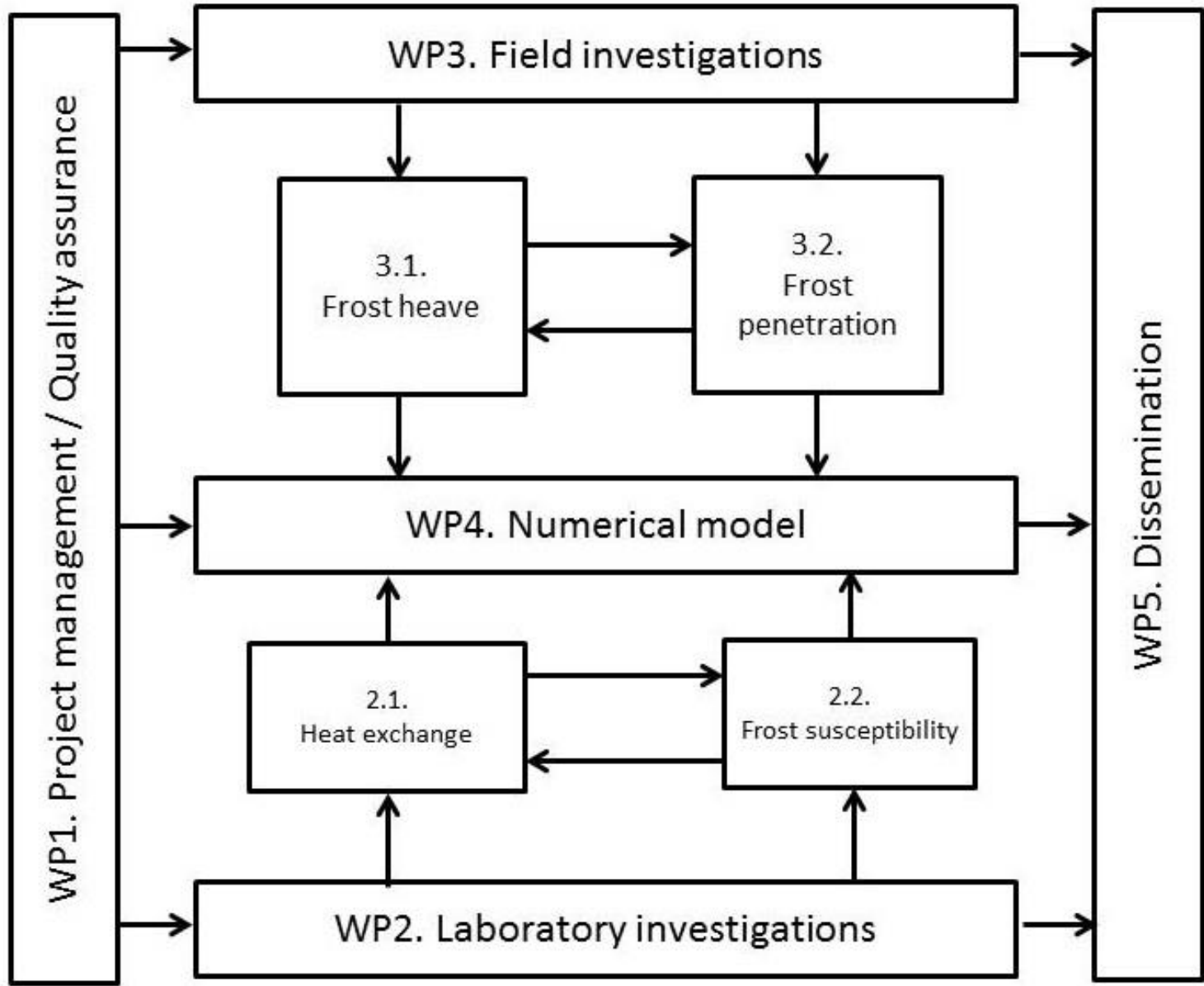


Thermal conductivity of crushed rock is higher than 1 W/mK

Project «Frost protection of roads and railways»

- **Funded** by Norwegian Research Council (NRC)
- **Duration:** 4 years (2015-2019)
- **Partners:**
 - **Universities:** NTNU (Norway) and Laval University (Canada)
 - **Research institute:** SINTEF
 - **Agencies:** Norwegian Public Road Administration (NPRA) and Norwegian Railway Administration
 - 2 PhDs





CONCLUSIONS

- ❖ Use of crushed rock materials in road construction requires:
 - ❖ Complex approach
 - ❖ Optimization of their properties (gradation, water content, mineralogy)
 - ❖ Consideration of thermal behavior

- ❖ Laboratory investigations showed:
 - ❖ Frost heave in open system is higher than in closed system
 - ❖ Thermal conductivity is 1.5-2.0 to 4-7.5 W/mK in frozen and 3.0-6.2 W/mK in unfrozen states

- ❖ A large Norwegian R&D project is to develop further frost protection design





**THANK YOU FOR YOUR
ATTENTION**

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