



XIII
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Québec 

SUSTAINABLE WINTER SERVICE FOR ROAD USERS

*Water Infiltration And Ice Problems In Rock
Tunnels In Sweden*

Per Andersson

Swedish Road Administration

Head Of Road Engineering Section

per.andersson@vv.se



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

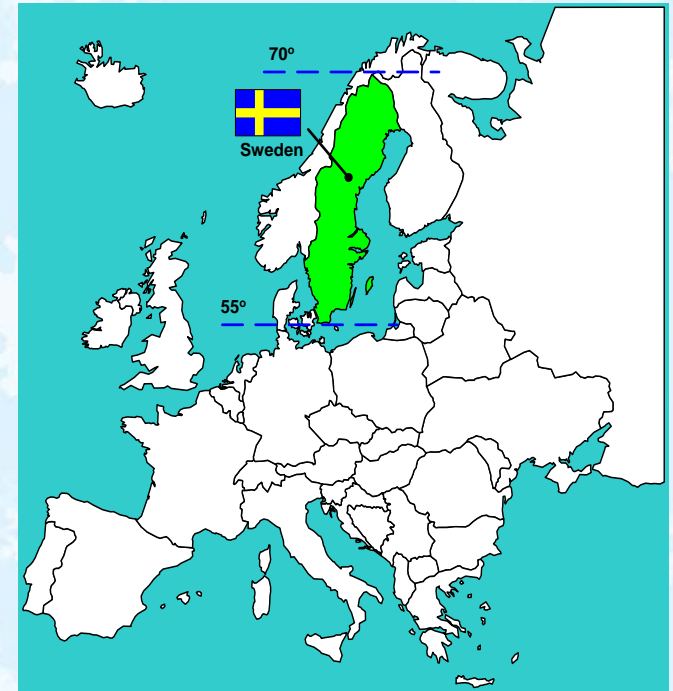
CONTENTS

- General description of the Swedish conditions
- Problems/ challenges for road tunnels during winter conditions related to
 - a) Operation
 - b) Maintenance
- The Life Cycle Cost Approach
- Some Conclusions
- Open Questions

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

CLIMATE CONDITIONS

- The temperature variation is high from $-40\text{ }^{\circ}\text{C}$ in winter to $+30\text{ }^{\circ}\text{C}$ in summer
- The number of frost cycles is high, typically 7 to 15 per year
- The use of de-icing salt is high, typically 1.5 kg/m^2 a year on roads



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

THE SWEDISH ROAD NETWORK

- 98,400 km state owned public roads
- 41,000 km municipal streets
- 76,000 km of private roads receiving state subsidies and
- private roads

- On the road network:
 - ~16,000 bridges
 - 31 tunnels and
 - 38 ferry routes



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

TYPICAL, ROCK TUNNEL



**50 year old rock tunnel, good stability,
no water leakage: No problems!**

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

OLDER RURAL TUNNELS



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

NEW, URBAN TUNNEL SYSTEMS



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

SWEDISH GENERAL REQUIREMENTS

Presented in the document “Tunnel 2004” (SRA)

- Based on common European rules in
 - essential requirements in The Construction Products Directive, CPD
 - harmonized technical standards
 - regulations on road tunnel safety, *Directive 2004/54/EU*

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

THE GROUNDWATER SITUATION

The protection of the groundwater levels and flow have been significantly strengthened in Sweden.

→ results in very harsh demands on the tunnelling activities.

For example, in the completed road tunnel project “Gotatunneln” in Gothenburg the amount of in-leaking water to the tunnel was partly restricted to a maximum of 0,5 litres/minute and 100 meter!

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

CONVENTIONAL DRILL- AND BLAST



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

SUPPORTED ROCK TUNNEL ROOF



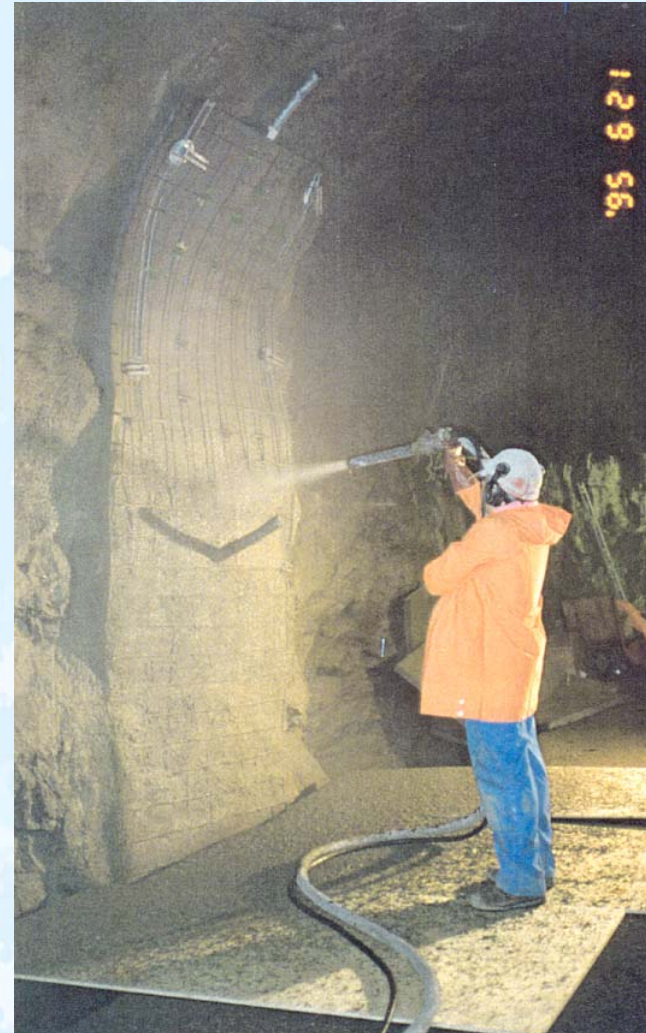
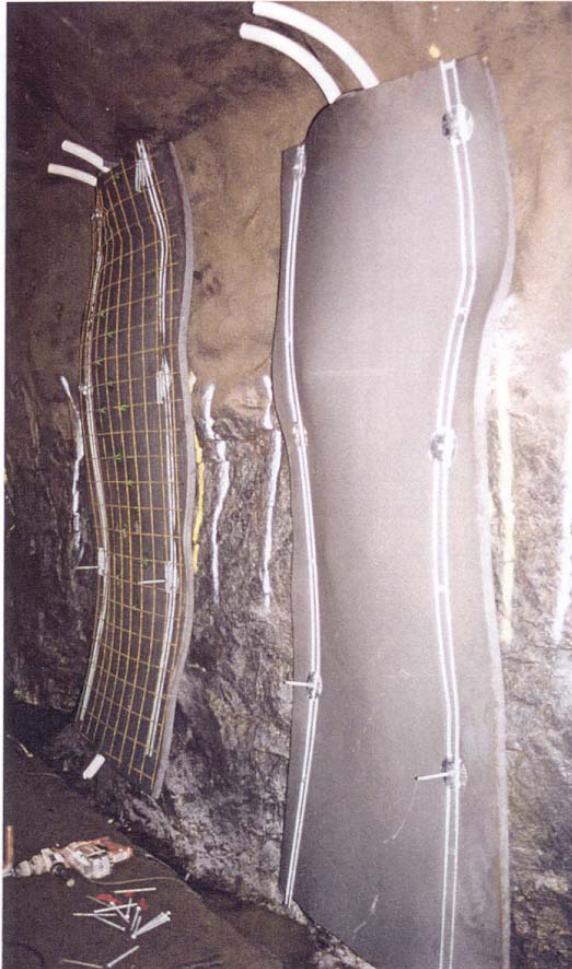
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WATER LEAKAGE DURING TUNNELING



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

APPLIED DRAINS



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

OPERATION:

FREEZING OF INLEAKING WATER



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

OPERATION:

FREEZING OF INLEAKING WATER



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

OPERATION: CLEANING OF ROAD TUNNELS



Water-based solutions → impossible to perform.

→ internal environmental problem inside the road tunnels with potential dust and particle problems

→ at worst, cause sight problems for the road users.

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

OPERATION: CLEANING OF ROAD TUNNELS



Traffic signs and safety devices are always cleaned – by hand if needed.

Mechanical wipers installed to clean the lenses on the CCTV-cameras.

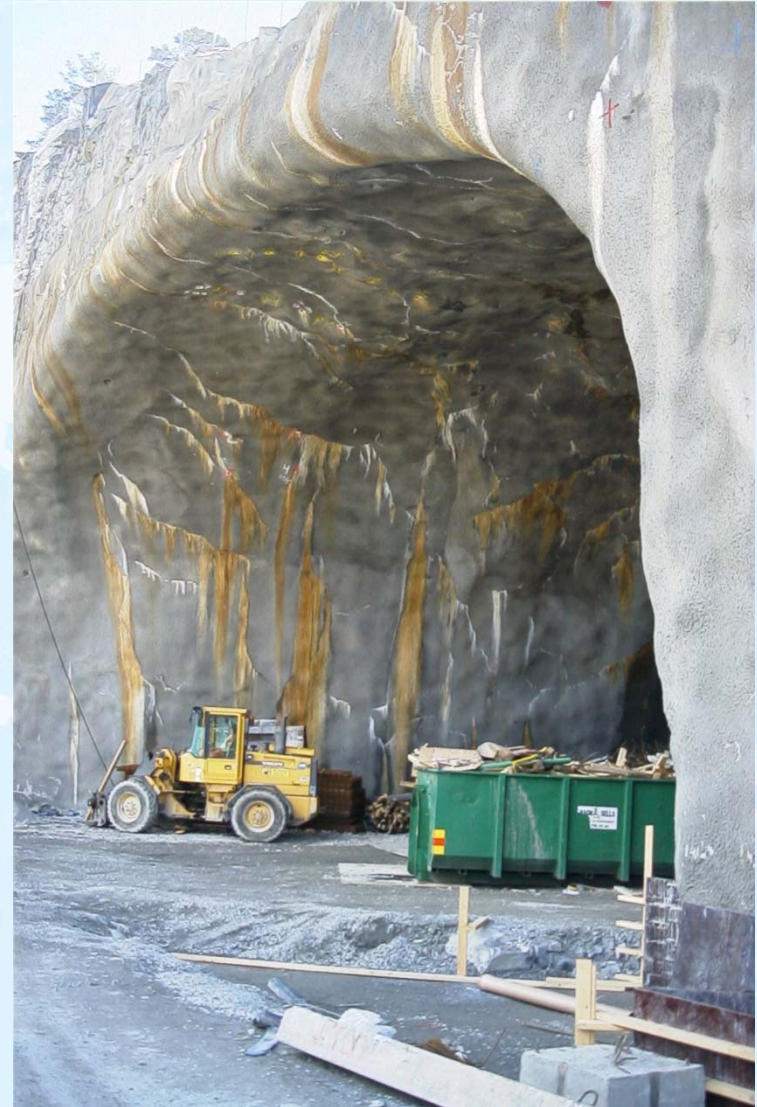
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OPERATION: CORROSION



WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

MAINTENANCE: WATER LEAKAGE

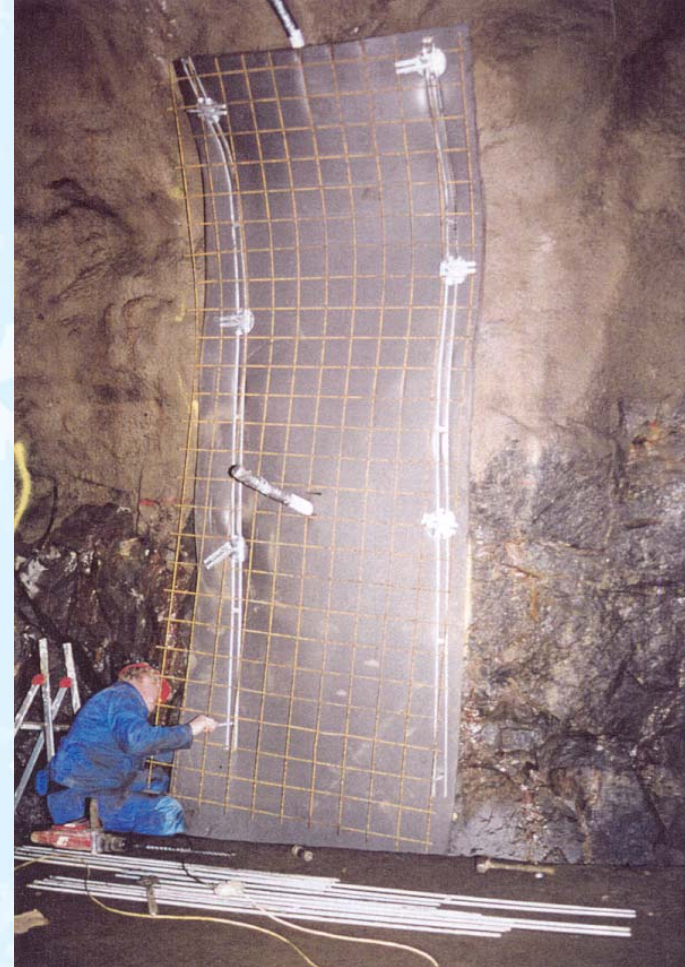


WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

MAINTENANCE:
FREEZ-THAW EXPANSION



Rock falls and/or sliding



“Blasting” of drains

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

LIFE CYCLE COST APPROACH

- Operation → Removal of ice/ cleaning
- Maintenance → Ensure chosen standard/function
- Design/Construction → Mitigate the water

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

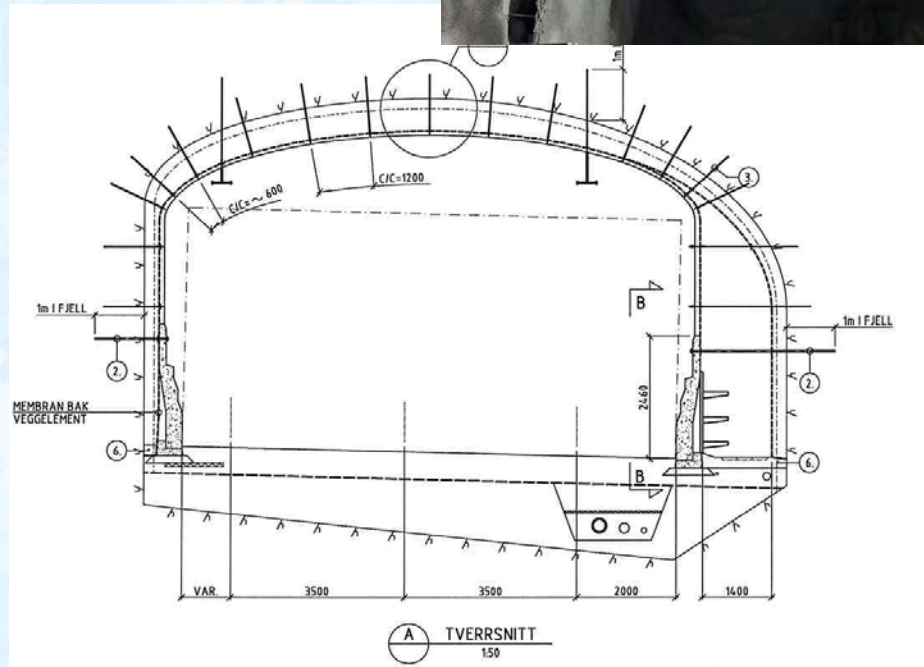
DESIGN & CONSTRUCTION: NEW CONCEPTS



“Tunnel vid Grind” –
secondary lining

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

DESIGN & CONSTRUCTION: NEW CONCEPTS



“Norra Lanken” – stiff inner waterproof lining

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

SOME CONCLUSIONS

In cold areas even very small water leakages will cause problems, such as icicles

Water ingress strongly affects the durability of the structure and the installations

Due to the normally very high ground water pressure it is often very hard to repair leaking cracks

Extremely important that the initial philosophy is robust when building new or refurbishing old road tunnels.

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

QUESTIONS

What is an acceptable amount of water drops per minute?

Watertight yes, but is it really a need for frost insulation?

Is it possible to construct a watertight single lining of sprayed concrete?

What is the best procedure to construct a concrete tunnel or lining without getting any cracks? Also for the sprayed concrete!

WATER INFILTRATION AND ICE PROBLEMS IN ROCK TUNNELS IN SWEDEN

THANK YOU, FOR YOUR ATTENTION!

