

# Freezing Temperature Flows in Railway Tunnels and its Consequence on the Rock Supporting Structure, the Rock and the Reinforcing Elements

Temperaturflöden i järnvägstunnlar och dess konsekvens på det bärande systemet, berget och de förstärkande elementen

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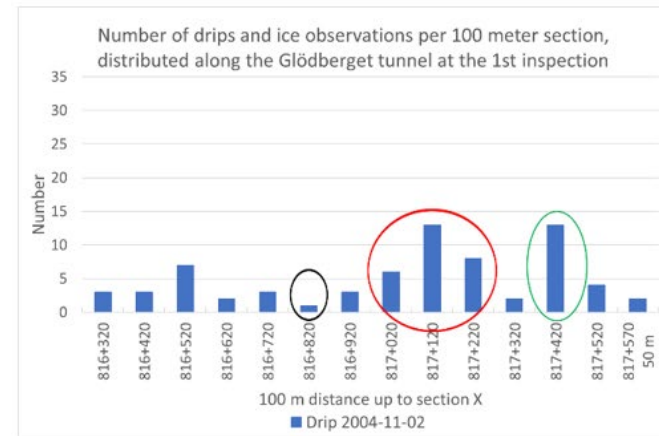
## Ice formation

Ice formation in tunnels is a major problem that must be addressed frequently to ensure the continuation of train and road traffic, as well as the safety. Cold outside air penetrating the tunnels during the winter causes water leaking into the tunnel to freeze and form ice. Icicles, ice pillars and ice layers can damage the tunnel construction and its installations such as handrails, cables, overhead contact lines and drainage systems.

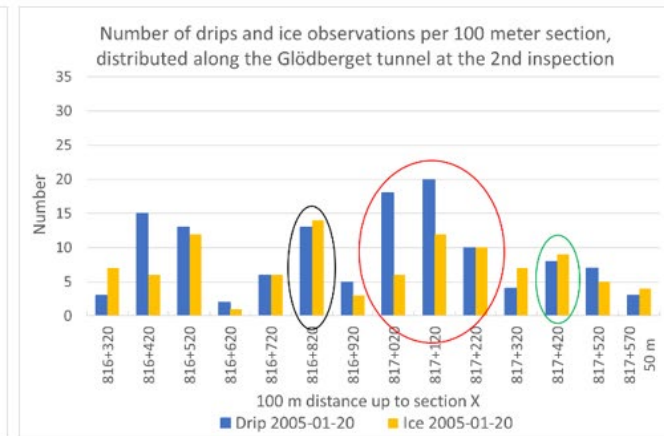


# Field observations of problems relating to water and ice

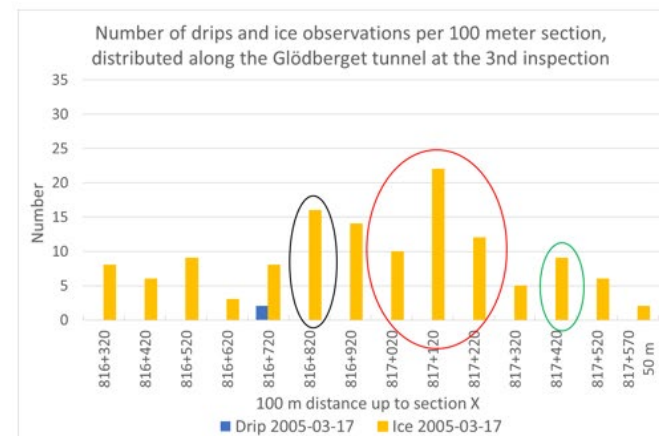
- To collect information on problems caused by ice formation, field observations were in five Swedish railway tunnels.
- The tunnels were inspected on four different occasions in order to determine the seasonal impact of the problems.



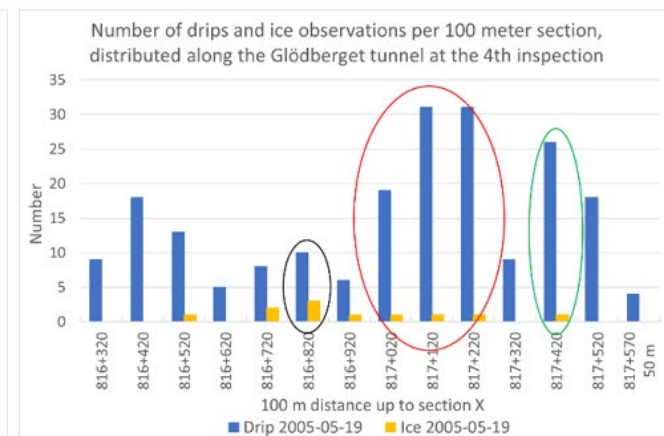
a)



b)



c)



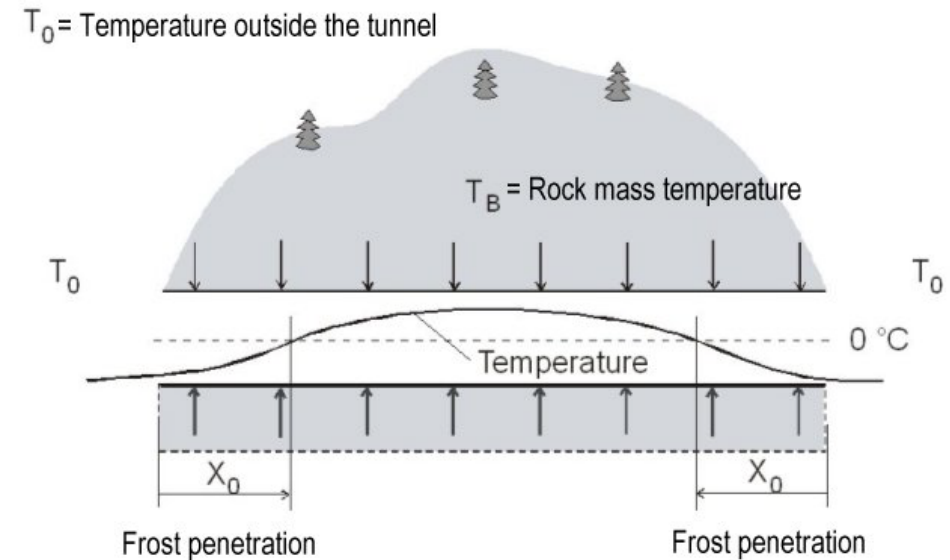
d)

# Field observations of problems relating to water and ice

- Short tunnels
  - Can adopt the same temperature as the outside air and ice formations can occur along the entire tunnel length.
  - Depending on the heat transfer from the rock mass, leakages might ‘freeze dry’ or continue to leak, with ice formations as a result.
- Long tunnels
  - The sections close to the tunnel entrances often become frozen, while the inner parts are warmer due to heat transfer from the rock mass. The leakage paths stay open with ice formation as a result.
  - More ice is formed from leaks in the inner parts of the tunnel than from the leaks near the entrances.

# Frost penetration

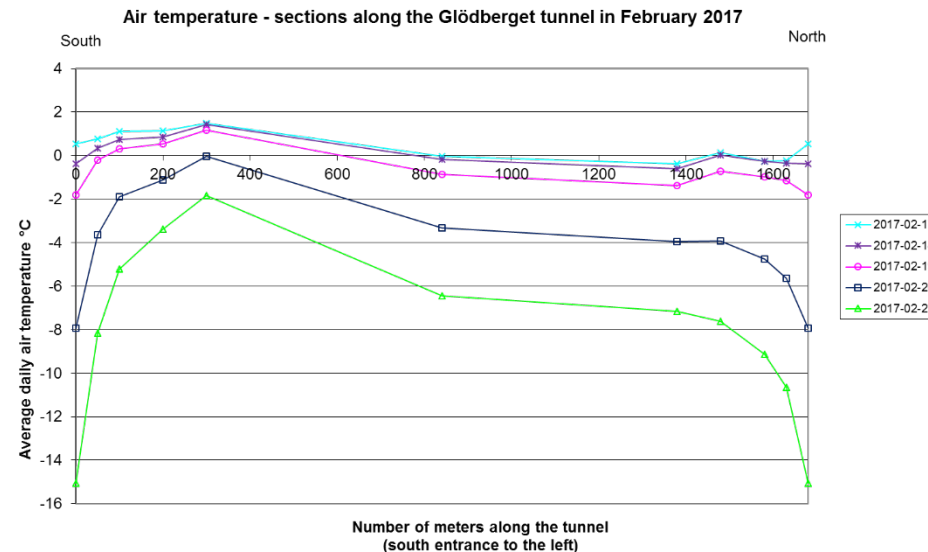
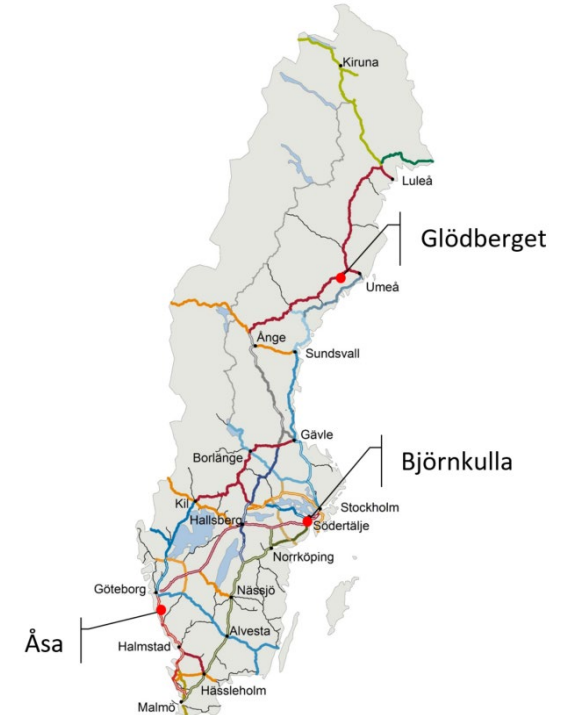
- Frost penetration in a tunnel occurs when the tunnel air is set in motion by:
  - thermal produced airflow
  - a train passing through the tunnel
  - wind pressure
- The predominant cause of frost penetration is the thermally induced airflow, since it is continuous and fairly constant.
- In the longer tunnels, the inclination of the tunnel affects frost penetration the most.



From Sandberg et al., 2002

# Field measurements of frost penetration

- Monitoring systems were installed in the Glödborget tunnel, the Åsa tunnel and the Björnkulla tunnel.
- They measure the tunnel air, rock surface and rock mass temperatures, as well as air pressure and wind velocity along the tunnel.

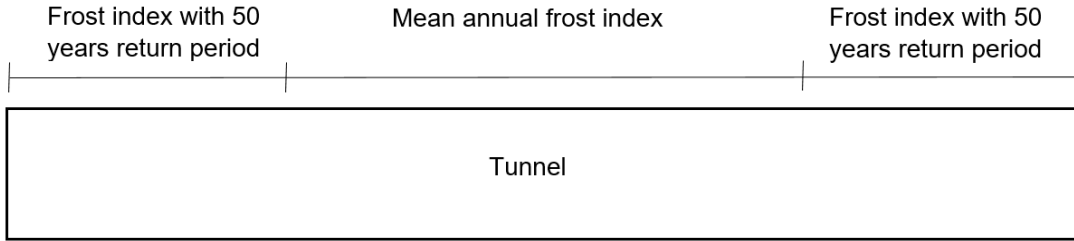


# The Swedish Transport Administration's requirements and regulations (TRVINFRA-00233)

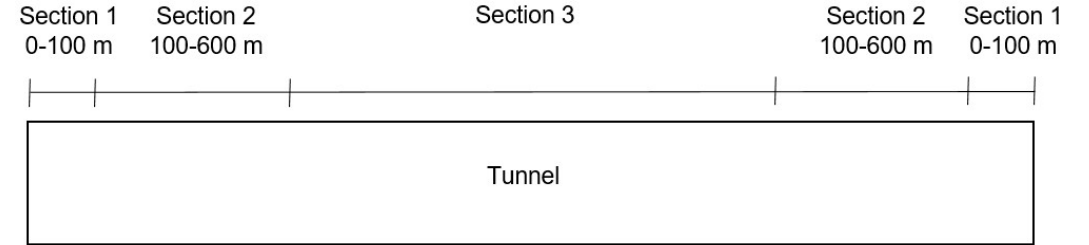
- Due to climate changes, the requirements for the frost index inside a tunnel have to change.
- In order to propose new requirements for the frost index, division of sections inside a tunnel, and to find out if these values are relevant, the field measurements carried out in this work have been used for the evaluation.

# Current and future requirements for different climate zones

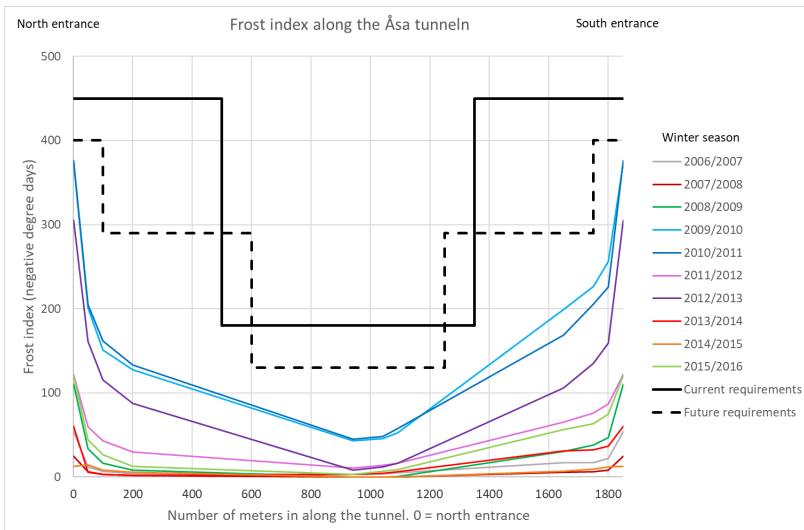
## Current sections



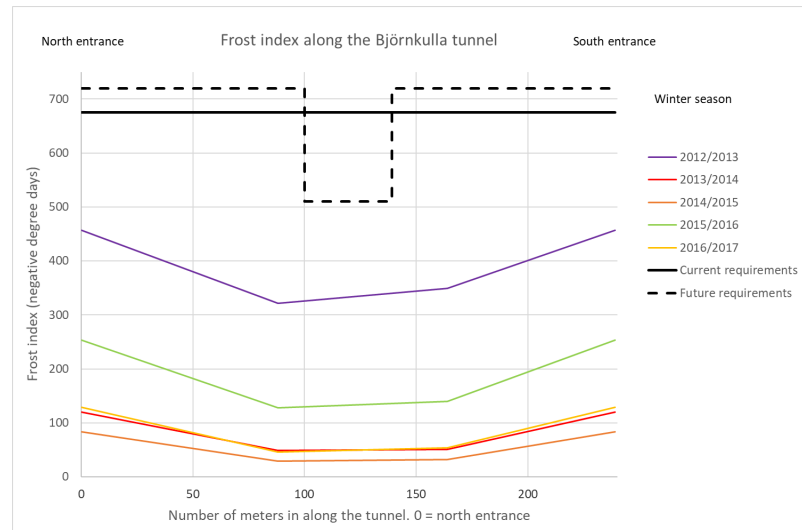
## Future sections



## Climate zone 1



## Climate zone 2



## Climate zone 4

