VIA NORDICA 2008

Better performing inner liners

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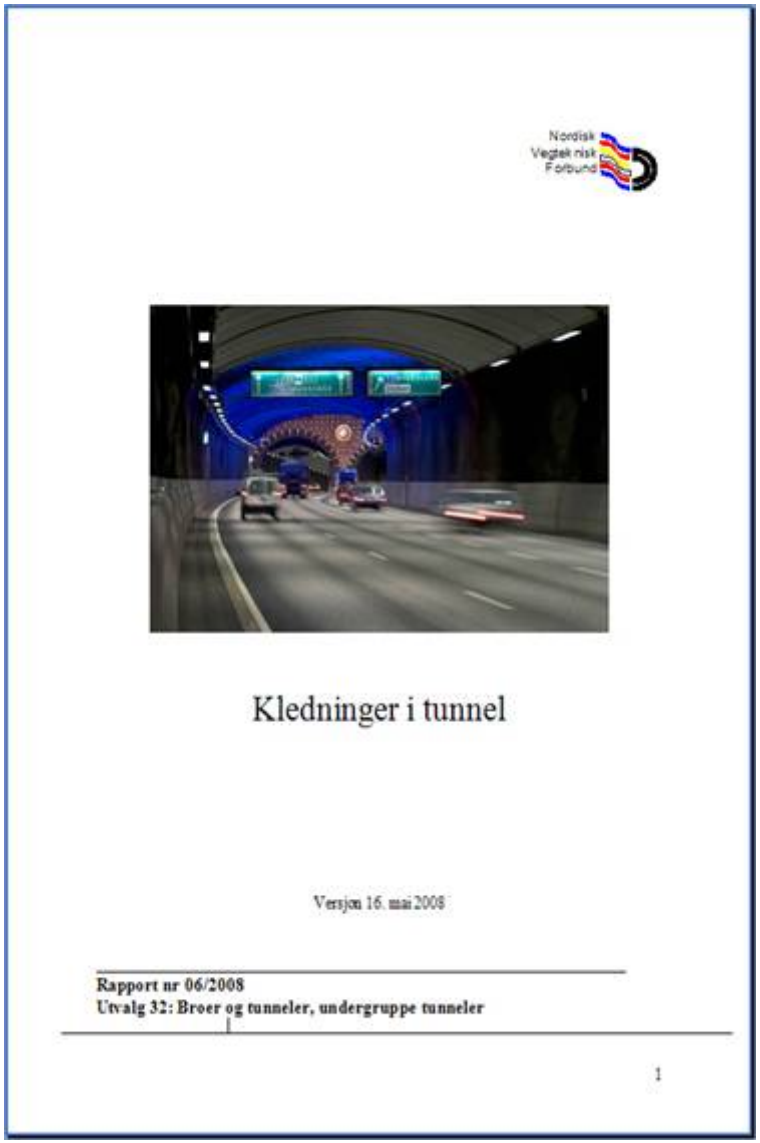

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NVF report 06/2008. Inner lining solutions

Report from a work-group of the 32 committee

- **Overview of different inner lining solutions**
- **Experiences**
- **To what extent are they used?**
- **New materials and methods**
- **Lifetime and durability**
- **Fire safety**

Base of experience

Norway

- More than 900 road tunnels in Norway (>800km in total)
- Build approximately 20-30 km of new tunnels each year
- 23 sub-sea tunnels
- Low traffic tunnels are the most common. High traffic tunnels only in the big cities.

Sweden

- 23 road tunnels, 15 with inner lining (>18km in total)
- Have experience with 7 different inner lining solution

Finland

- Only few tunnels in Finland is owned by the road department (~2,3km)
- 17km of road tunnels are under construction
- 1 sub-sea tunnel

Base of experience

Iceland

- 7 road tunnels (>20km in total)
- 1 sub-sea tunnel
- Mainly low traffic tunnels

Denmark

- 4 road tunnels (>20km in total)
- 1 sub-sea tunnel (Øresund, 4km)

The Faroe islands

- 18 road tunnels (>41,5km in total)
- 2 sub-sea tunnels
- Mainly low traffic tunnels

Functional and technical requirements

A comparison of the requirements to inner lining in tunnels, show a highly complex picture. The constructions complexity, altered in both functional and technical requirements, is unfortunately too often underestimated.

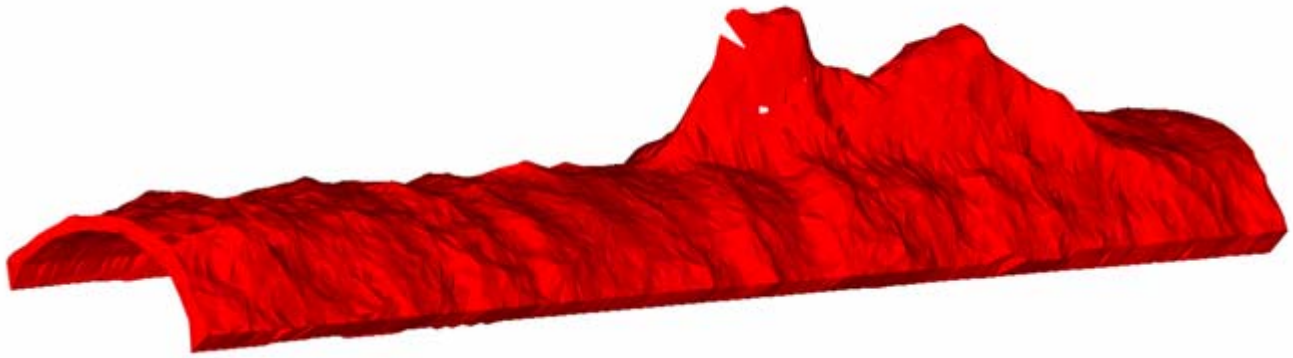
Both protection and sustainability towards:

- **Water**
- **Frost**
- **Fire**
- **Pollution**
- **High pressure cleaning**
- **Load**

Functional and technical requirements

In addition the lining must be:

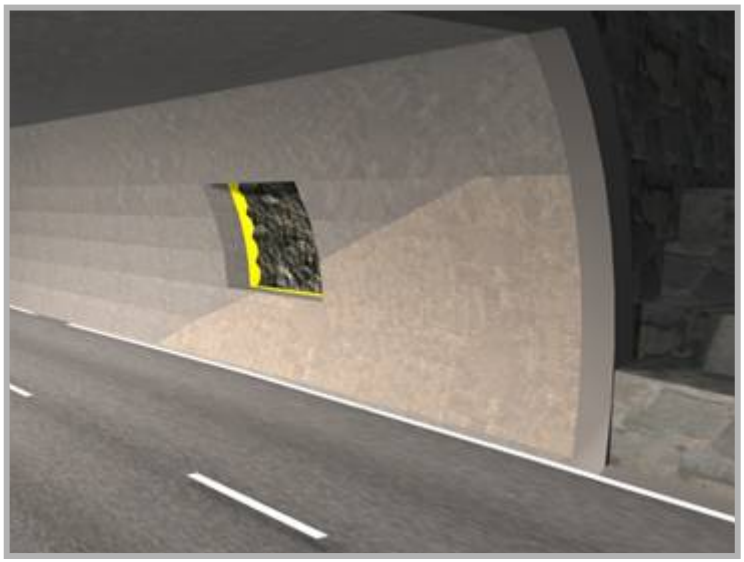
- Efficient to mount (industrialized process)
- Easy to replace just parts of it
- Easy access for inspection



Technical solutions_ inner lining

The experience from the Nordic countries is that pre-fab concrete element has the best durability in high-traffic tunnels and is also the most used.

In low-traffic tunnels other solutions like PE-foam or different membranes in combination with sprayed concrete is the most used solution



Technical solutions_ inner lining

- PE-foam combined with mesh reinforcement and sprayed concrete
  - **Experience: Used a lot in Norway and Iceland. Good results on water and frost protection. Test results for fire protection, show acceptable values (min 8cm concrete). Good durability. Low cost. Flexibility in geometry.**

Pre-fabricated concrete and PE foam

Södra Länken, Stockholm.Concrete roof, bare walls. Foto: Mikael Ullén

Technical solutions_ inner lining

- Pre-fabricated concrete elements with isolation
  - **Experience: Used a lot in Sweden and Norway on high traffic tunnels. Good results on water and frost protection. Good results on durability and cleaning. Expensive. Not very flexible regards to geometry.**

- Metal sandwich panels
  - **Experience: Most used in the Faroe islands and Norway. Some in Denmark. Good results on water and frost protection. Not to good on durability. Not very flexible regards to geometry.**

Technical solutions_ inner lining

- Spayed membrane combined with mesh reinforcement and sprayed concrete
  - **Experience: Used some in Finland and Sweden. Low cost. Hard to get a sustainable solution.**
- Mounted membrane combined with mesh reinforcement and sprayed concrete
  - **Experience: Used some in Norway and Sweden. Good results on water and frost protection (when 8cm concrete). Test results for fire protection, show acceptable values. Hard to keep clean. Flexibility in geometry.**

Mesh reinforcement combined with membran and sprayed concrete

Pre-fabricated concrete elements combined with metal panels in the roof

Example from Södra Länken, Stockholm Sweden.

Concrete roof, sprayed concrete walls:

Experience: Hard to keep white roof clean. Expensive to mount the heavy concrete roof elements. They have also experienced some problems with water and building up of ice.

Foto: Mikael Ullén

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Example Kopparberget , Finland

Sprayed Polyurethane on rock surface.

Mesh reinforcement in the roof, and sprayed concrete with polypropylene fiber in roof and walls.

Experience from this tunnel:

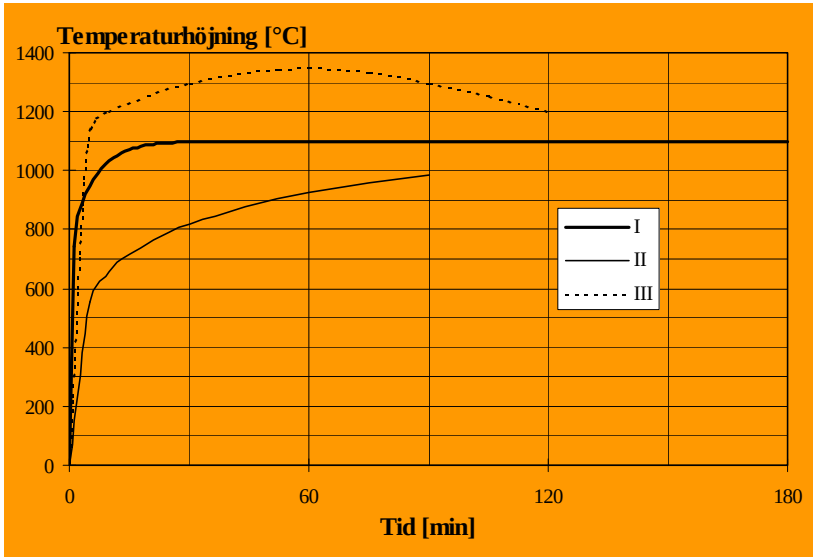
- The polyurethane forms ”pockets” of water
- Cracks gives leakages
- Doesn’t protect against frost, because of to much water “stored” in the construction
- Problem with corrosion

Fire safety requirements for inner linings

The big tunnel fires in Europe contributed to put an extra focus on fire safety in tunnels. To find and test non-flammable and fire resistant materials has been a prioritized area for all Nordic countries, and the result has been used in this report.

The construction should not

- **contribute to a fire**
- **spread a fire**
- **continue after the source is neutralized**
- **develop smoke or toxic gasses**



Dimensioning time/temperature curves

Cost-benefit evaluation

Traditionally it is only the investment cost that is taken under consideration, when an inner lining solution is selected, but this is only a part of the total cost in the lifetime of the construction. The solution that is selected, will influence on the cost for operation and maintenance during the whole lifetime of the construction

LCC

- Investment cost
- Maintenance cost
- Operation costs
- Cost for traffic and accidents

$$N = \sum_i \frac{a_i}{(1+r)^n}$$

Example

LCC cost for

Metal sandwich panels

- 600kr/m2
- 12-15 years lifetime

Pre-fabricated concrete elements

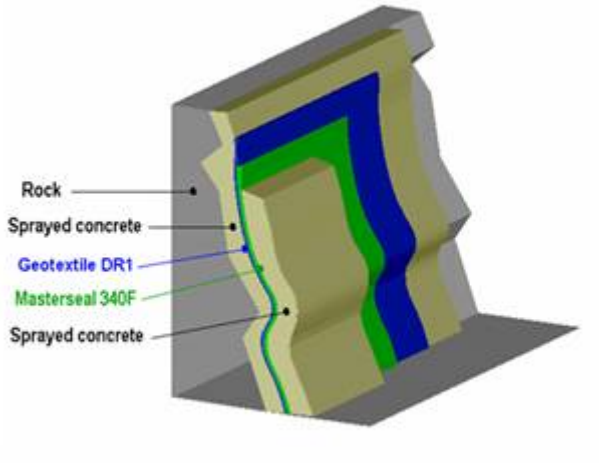
- 1000kr/m2
- 30 – 50 years lifetime

New solutions and materials

Many of the Nordic countries run different tests on new inner lining solutions

It is experienced that durability and lifetime of the construction is strongly influenced by the level of cleaning. Material, structure of the surface and shape/design of the inner lining can often be a challenge for the cleaning of the tunnel. It is complex to find good solutions, and necessary to test thoroughly

- Sprayed membranes
- Photo catalytic concrete
- Light concrete elements
- Composite panels
- Metal sandwich panels
- Sprayed rockwool
- Isolation material



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We do not have the perfect solution yet
Research and development is needed
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