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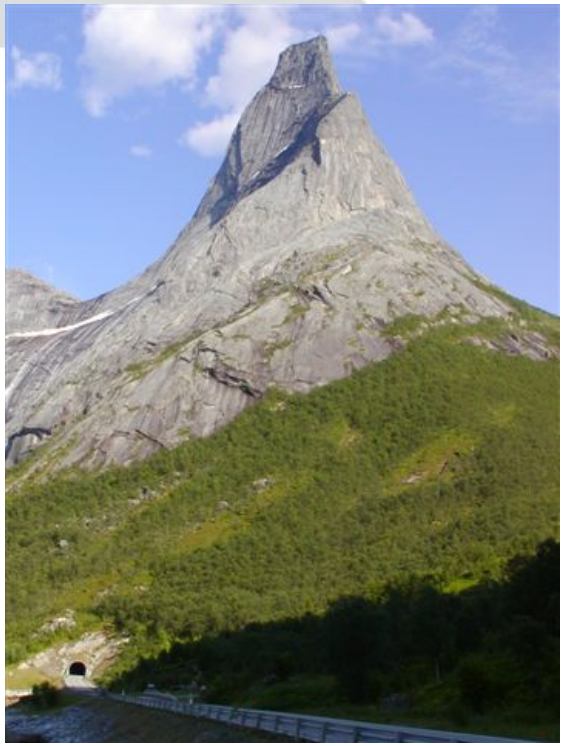
Norwegian
Public Roads Administration

Introduction to- and experiences with Norwegian Tunneling

By Mrs Ruth G Haug

Norwegian road tunneling



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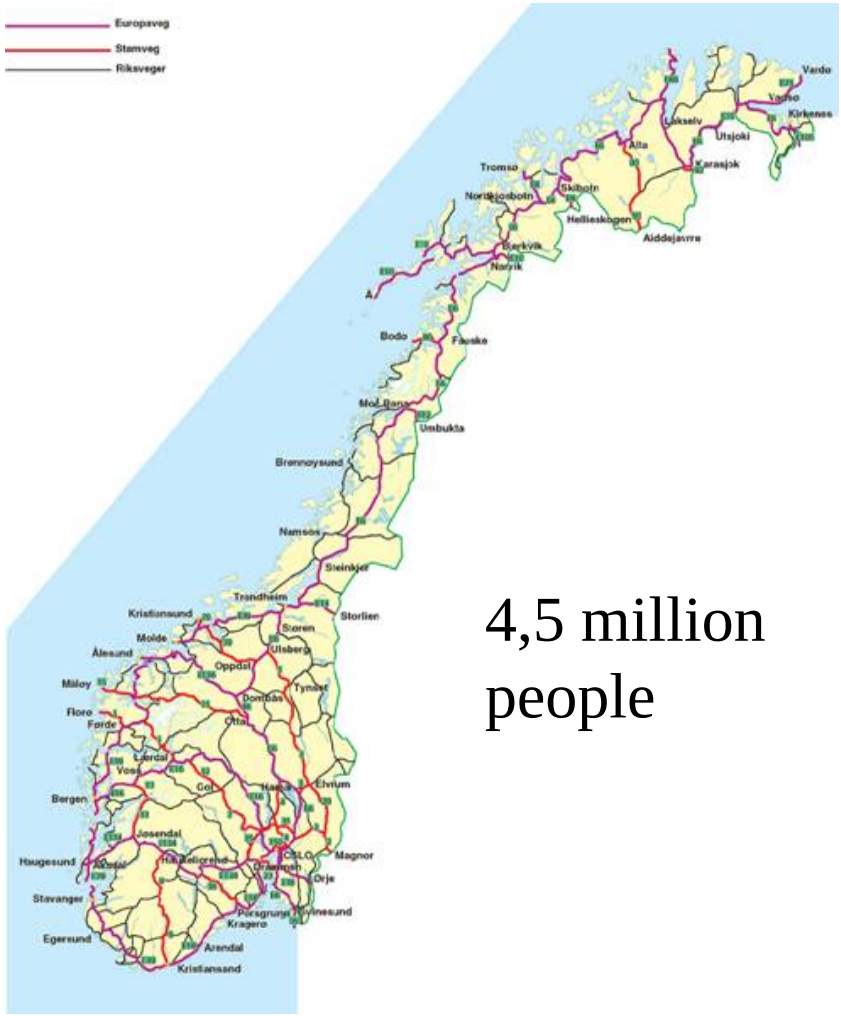
Norwegian tunneling

- Road tunnels- 962
- Rail road tunnels- 780
- Hydro power many!

  200 as rock cavern
- Oil & gas storage many!
- Military purposes – amount unknown



4,5 million people

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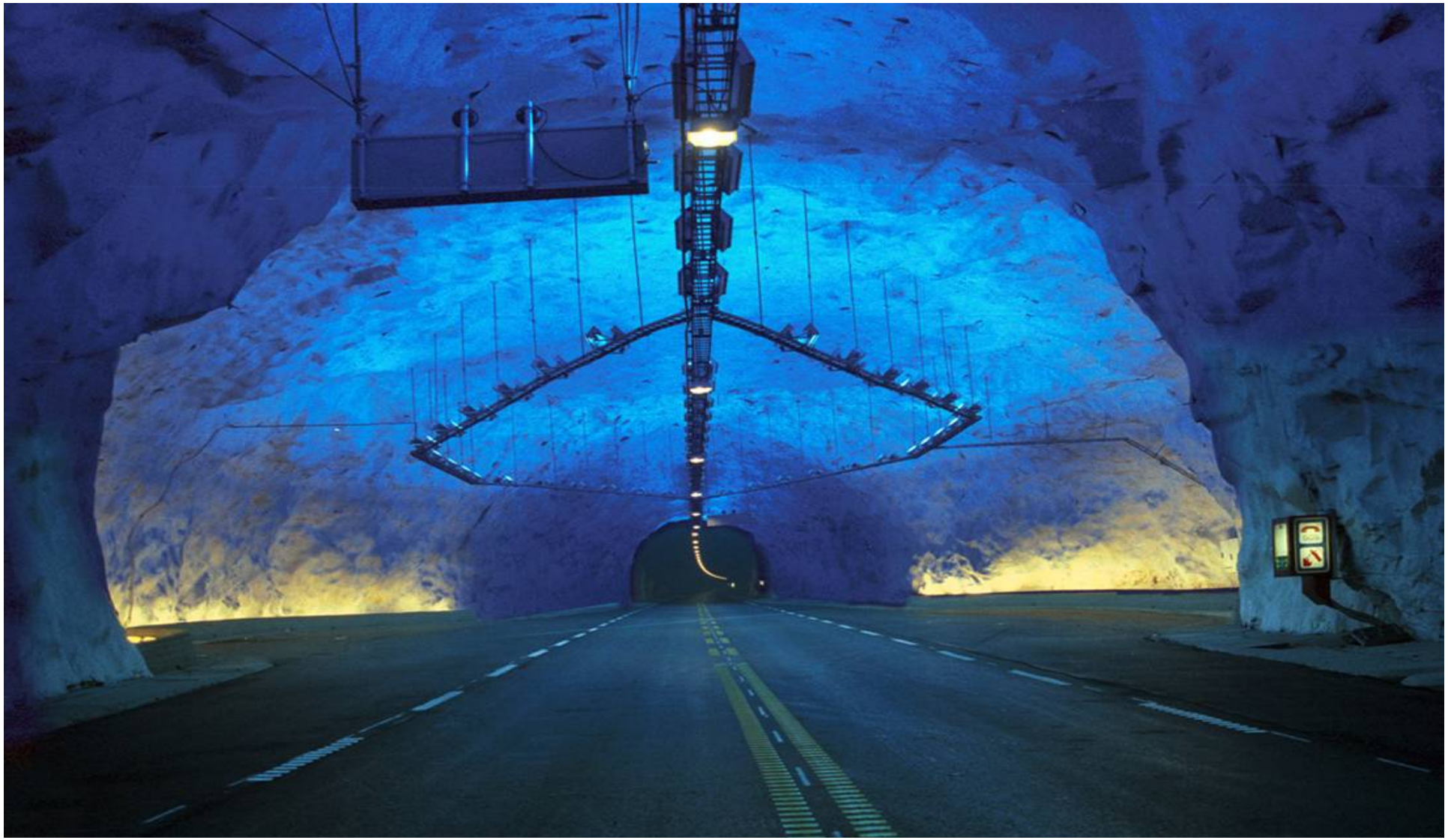
Tunnelstatistikk

	Riksveg (TERN)		Fylkesveg		Totalt	
Lengdeklasse	Antall	Lengde i km	Antall	Lengde i km	Antall	Lengde i km
Under 100m	118 (16)	7,3 (0,9)	29	1,7	147	9,0
100-499m	323 (92)	81,1 (23,4)	72	17,5	395	98,5
500-999m	150 (57)	104,3 (39,9)	31	23,1	181	127,5
1000-3000m	155 (45)	269,1 (75,9)	19	27,6	174	296,7
Over 3000m	60 (17)	310,2 (93,1)	4	16,3	64	326,5
Totalt	806 (227)	772 (233,2)	155	86,2	961	858,2

Public roads in total: 93.000 km

Longest Tunnel:
The Lærdal tunnel 24505 m

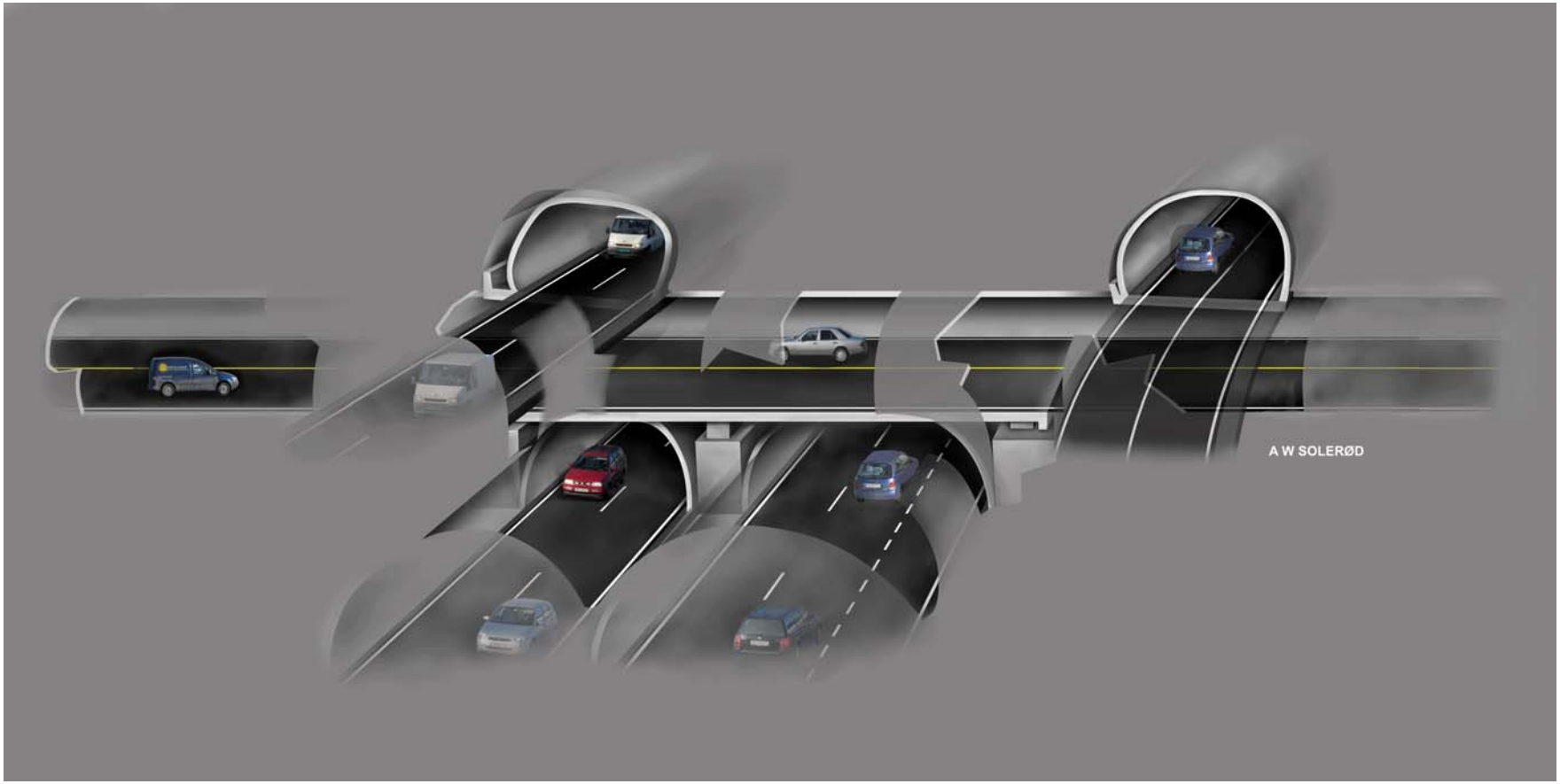


Longest Sub Sea Tunnel:
Bømlafjord tunnel 7860 m

Bjørvika in Oslo

- Clearing the way for the new water front

Bjørvika immersed Tunnel



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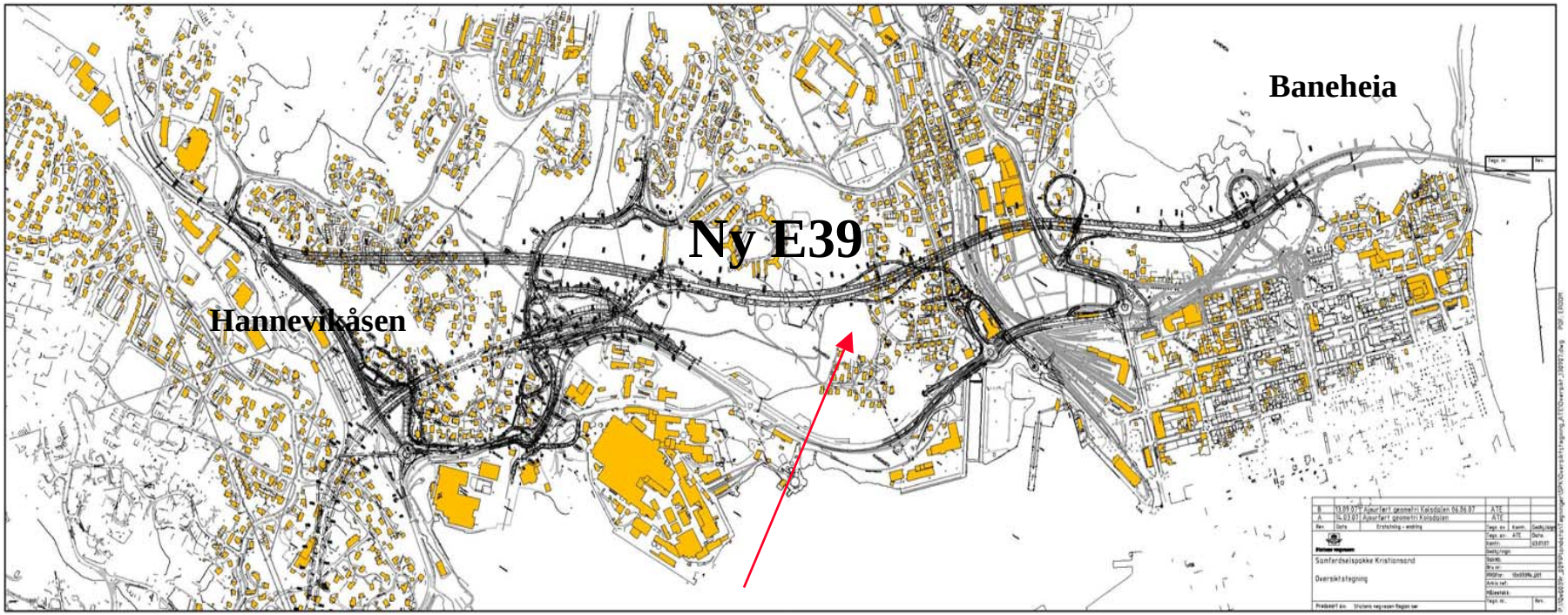
Contruction, Grønnlia tunnelen

E39- a complicated urban challange



Kryss for :

Næring

Havn

Jernbane

Tunnels for safety…..

Constructed tunnel
- fauna passageway

Key information, road tunnels in Norway

- 962 tunnels, total length 858 km
- Mostly short tunnels: < 1 km
  longest tunnel 24,5 km
- Deepest tunnel, -287 m bsl
- Varying traffic density:
  (Annual average daily traffic)
  AADT < 1000 for 50 %
  AADT > 5000 for 20 %
  Oslo tunnels up to 100 000
- 28 sub-sea tunnels, steep gradient

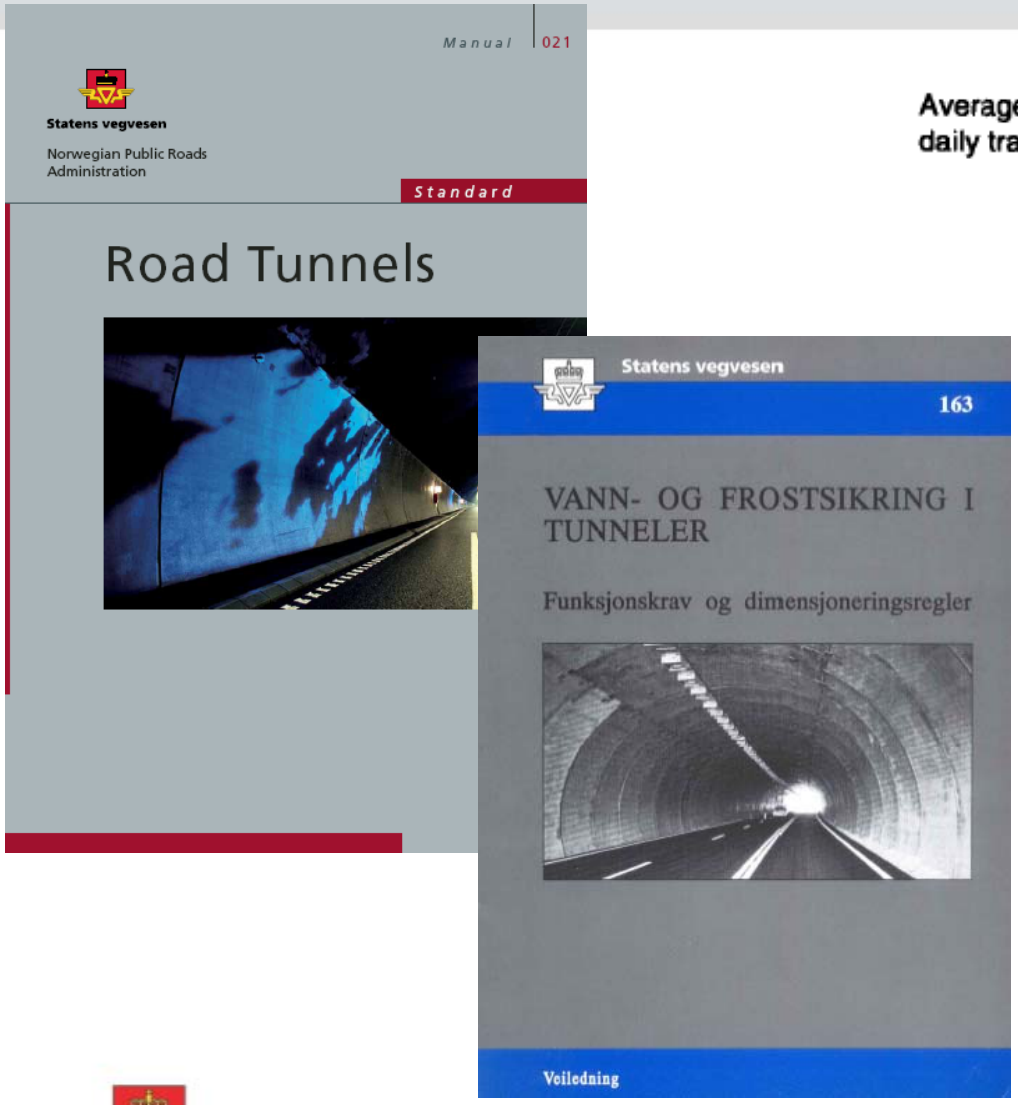
Tunnelling technology

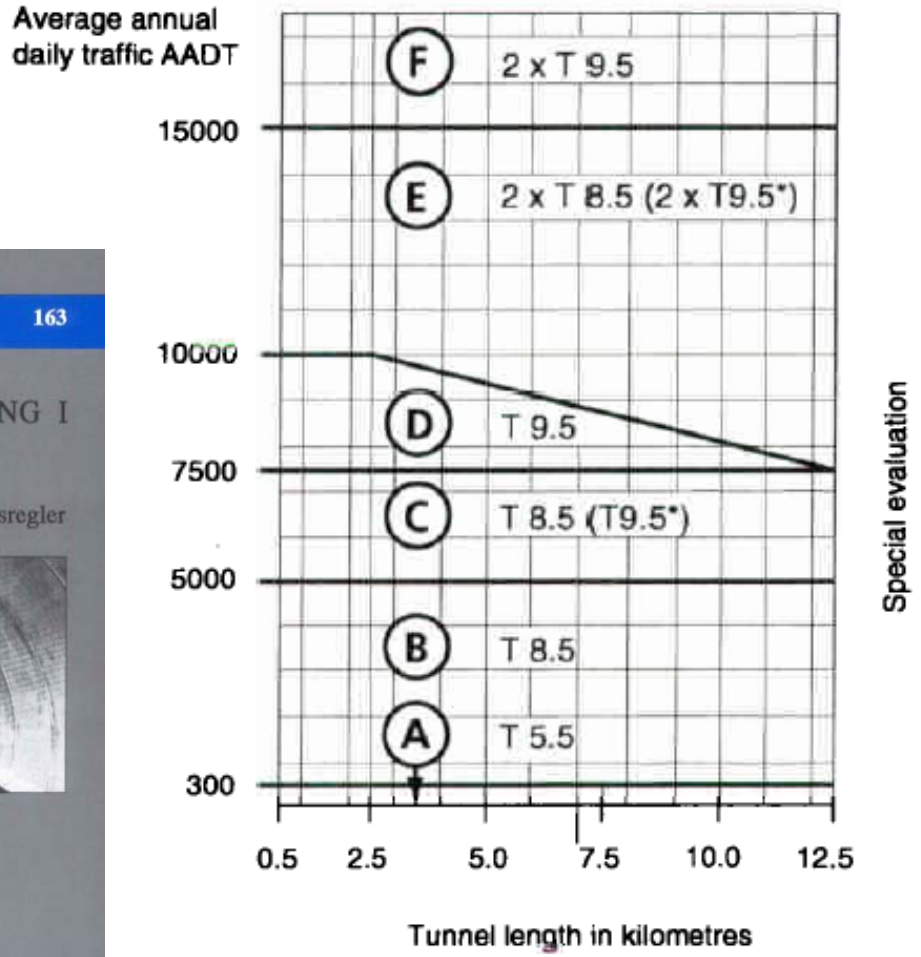
- Hard rock tunneling
- The rock is the building material
- Drained concept
- Drill and blast
- Pregrouting
- Support methods: rock bolting and shotcrete
- Steel reinforced shotcrete arches
- Spiling or cast concrete only in dangerous weakness zones
- Water and frost protection

NPRA , a brief introduction to Norwegian tunnel technology

- NPRA has a Tunnel Technology department
- Main objectives of work related to tunnels;
- Guidelines
- Research and development
- Preinvestigations
- Plan, build and operate tunnels
- Cooperate with and develop the national tunnel experts
- International relations

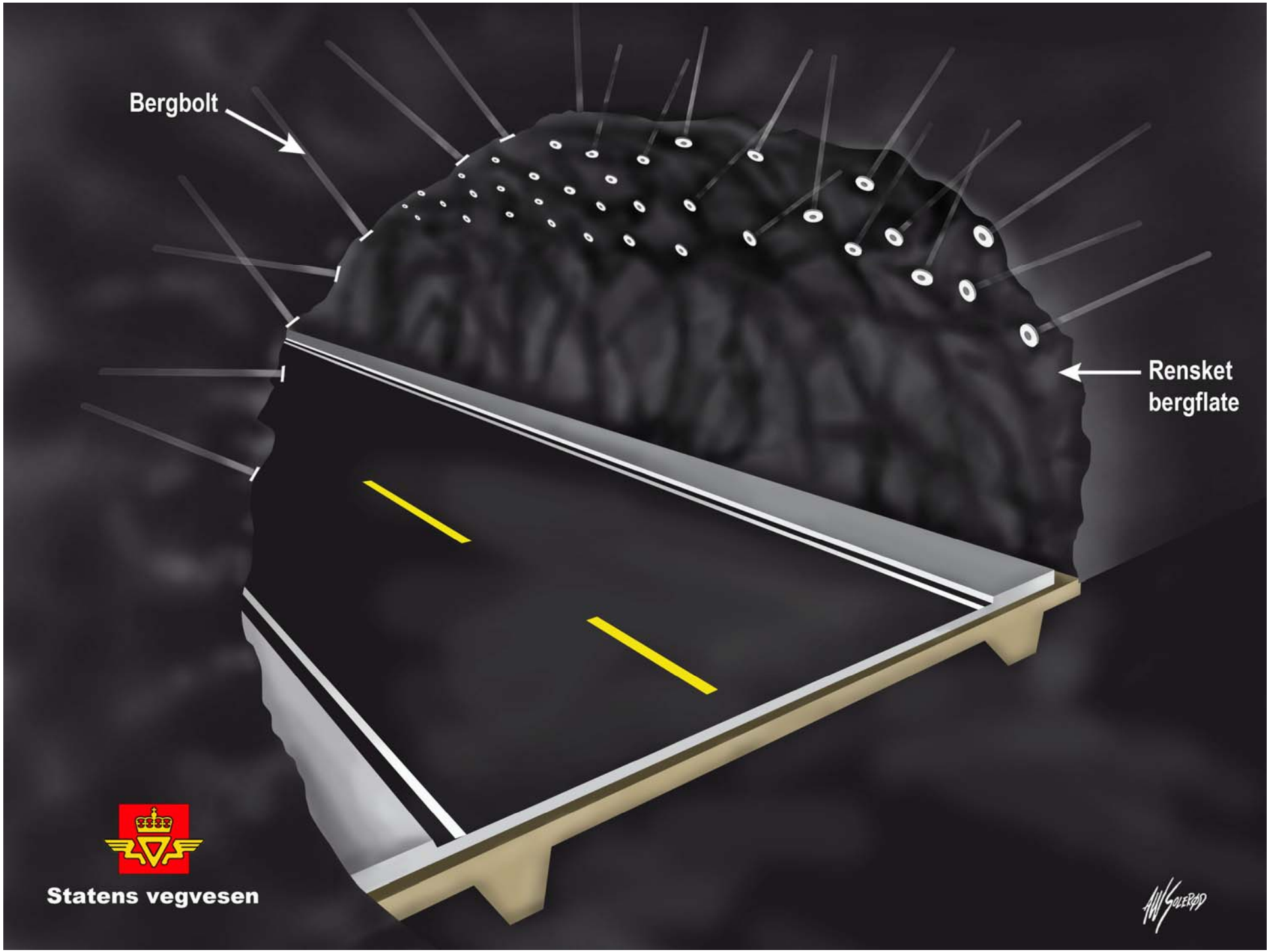
Tunnel Guidelines

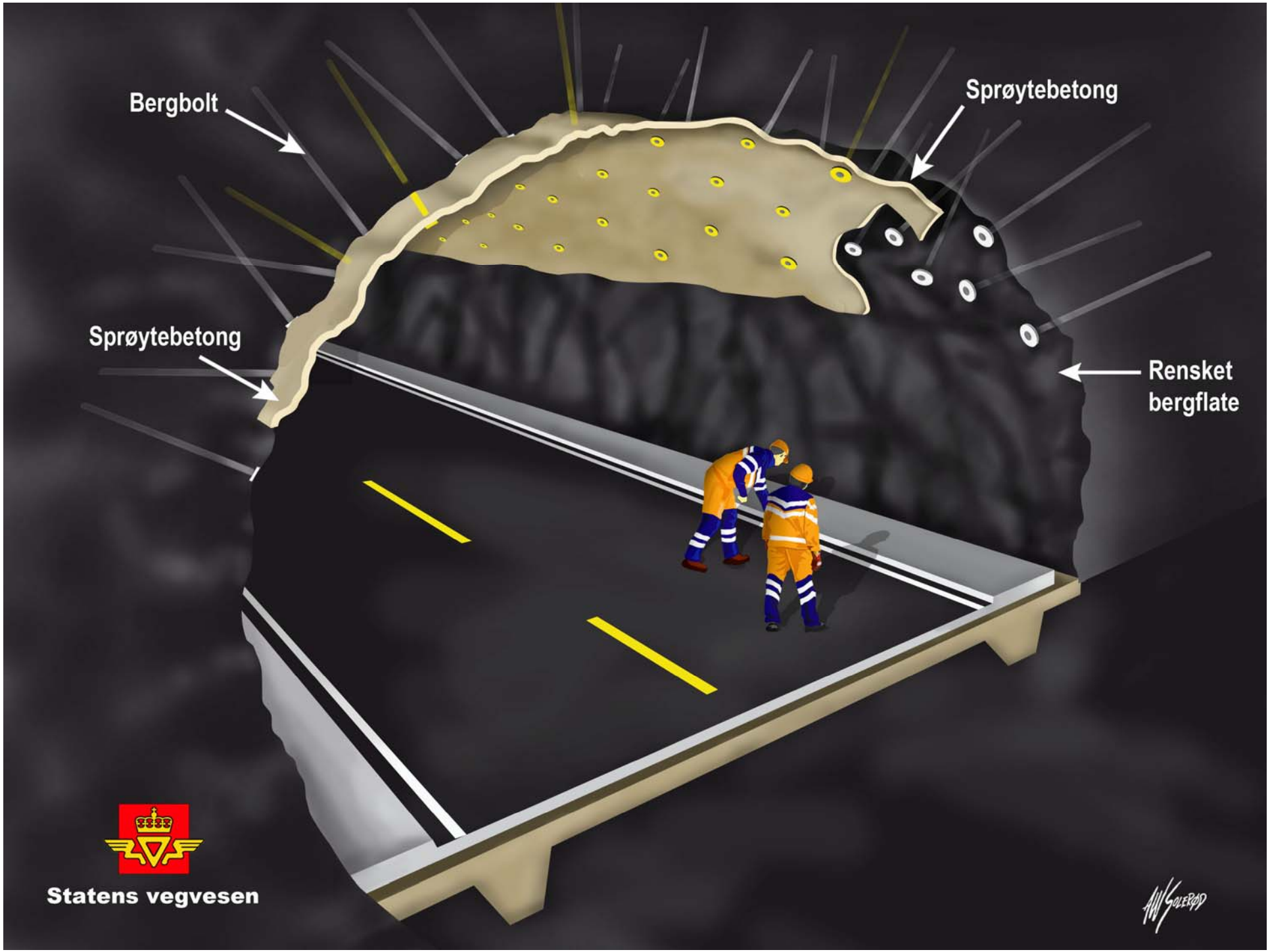


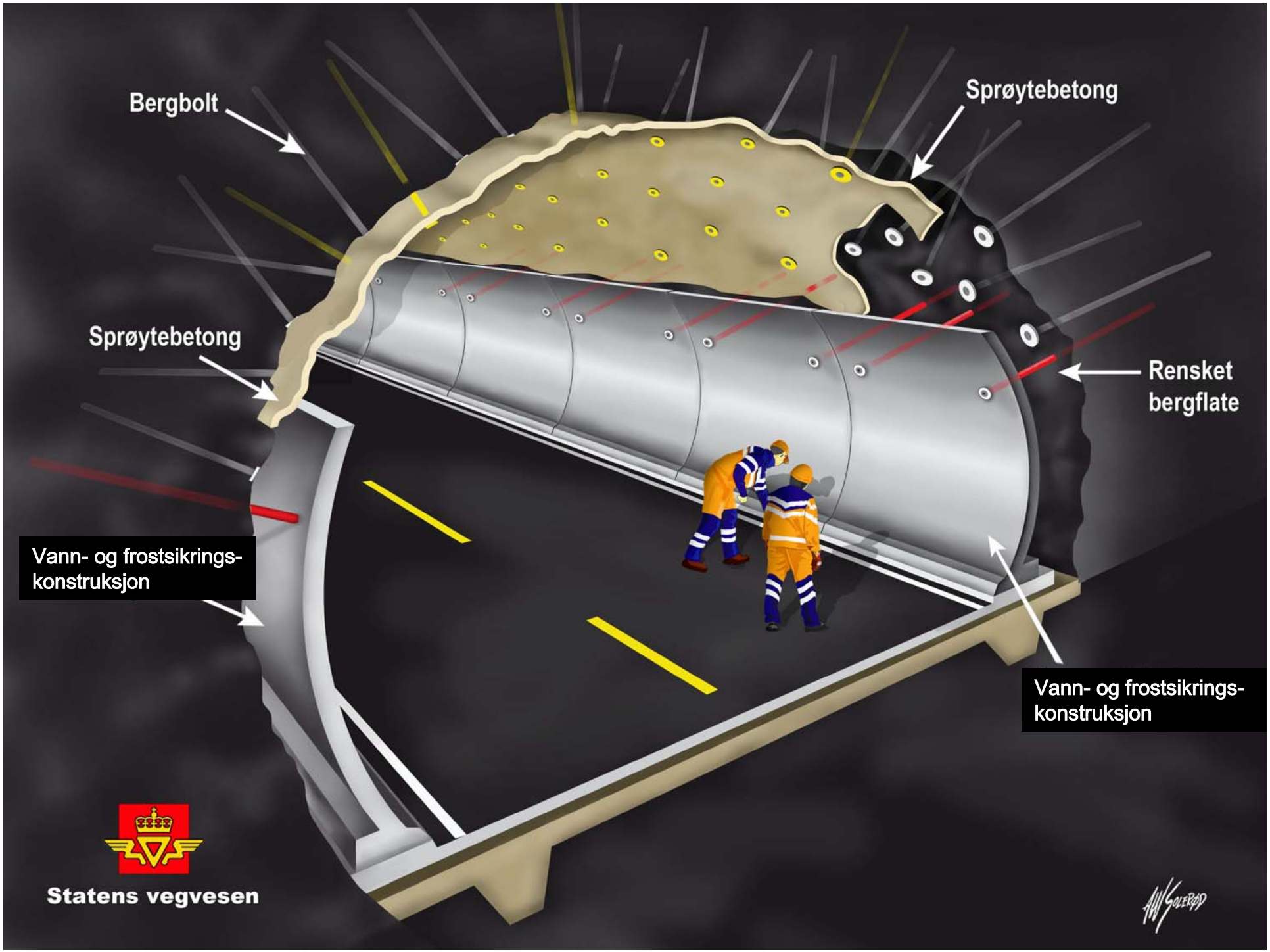


Construction

- Tunnel round
  - **Predrilling 4 holes à 24 m to inspect rock and check for water**
  - **If water-pregrouting with sement**
  - When dry-new round
  - Drill and blast 5 m
  - Mucking
  - Rock control and manual insepction
  - Rock support , rockbolts and shotcrete


Bergbolt
Rensket bergflate
Statens vegvesen


Bergbolt
Sprøytebetong
Sprøytebetong
Rensket bergflate
Statens vegvesen


Bergbolt
Sprøytebetong
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Rensket bergflate
Vann- og frostsikrings-konstruksjon
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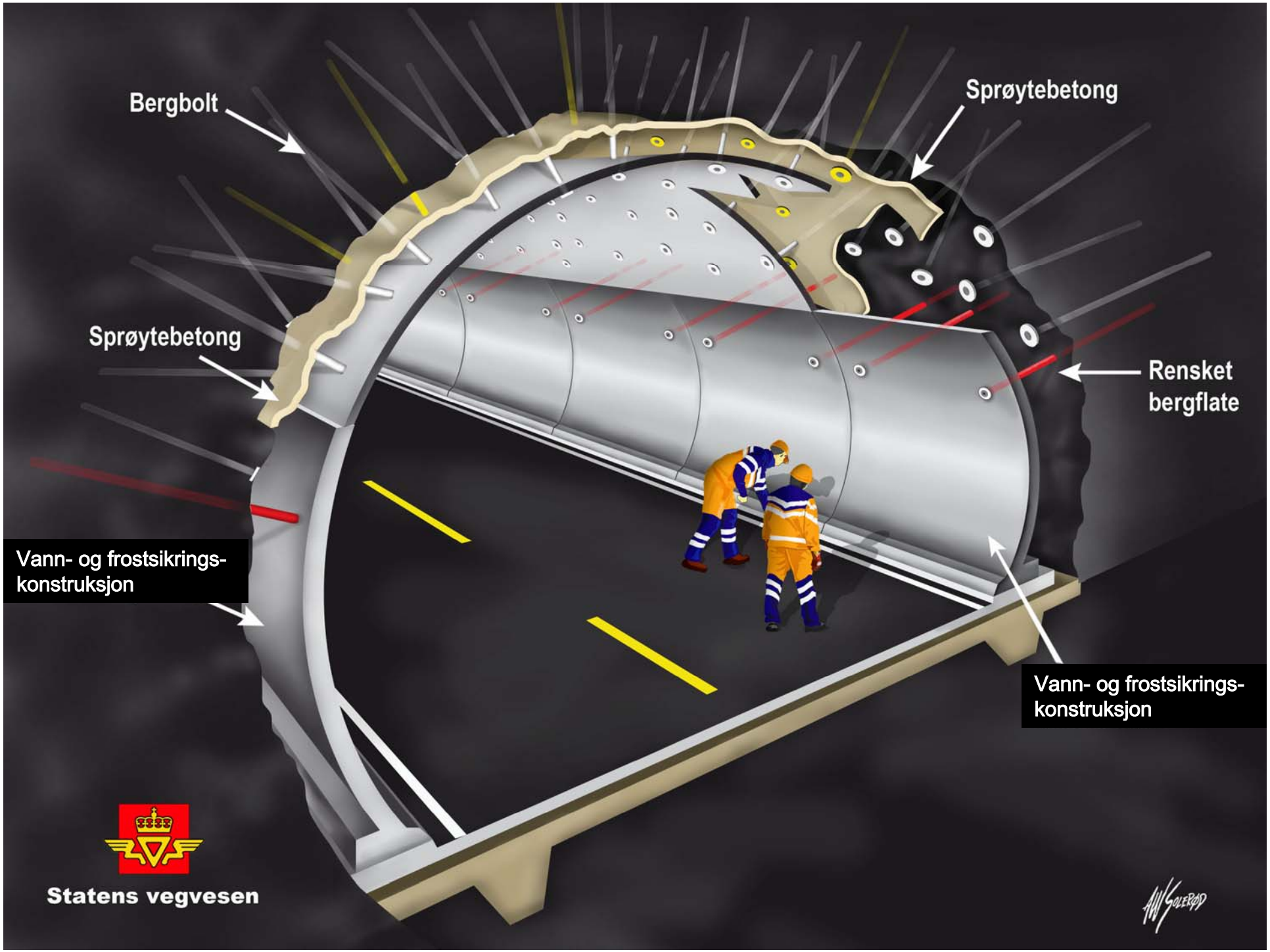
Statens vegvesen


Bergbolt
Sprøytebetong
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Armerte sprøytebetongbuer

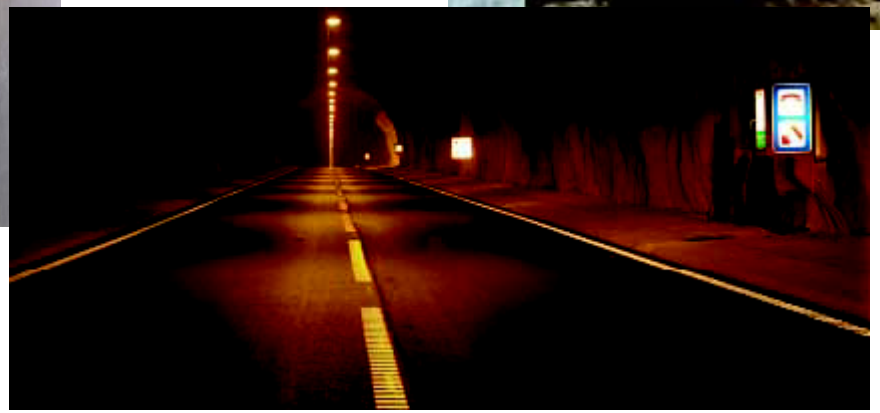
Norwegian Sub Sea Tunnels

Eiksundsambandet

Veg Eiksund-Eika

- 28 sub-sea tunnels from 1983 to 2008
- Traffic density between 100 – 7000 AADT
- Lenght between 1650 m - 7250 m
- Depht under sealevel between 56 m – 287 m
- Gradients between 7% - 10%
- Rock cover from 18-50 m

Many solutions for water and frost protection…

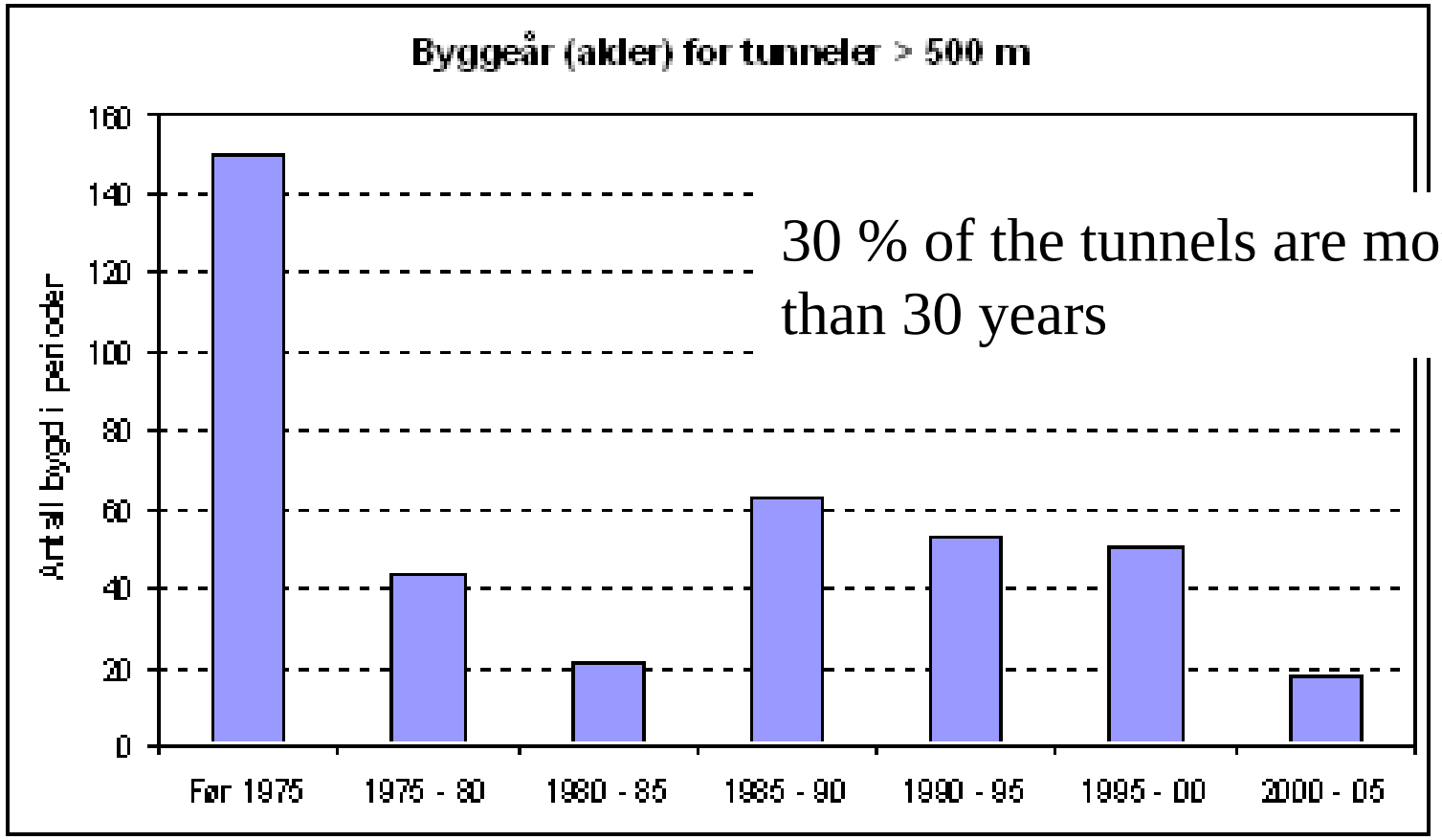


Tunnel linings

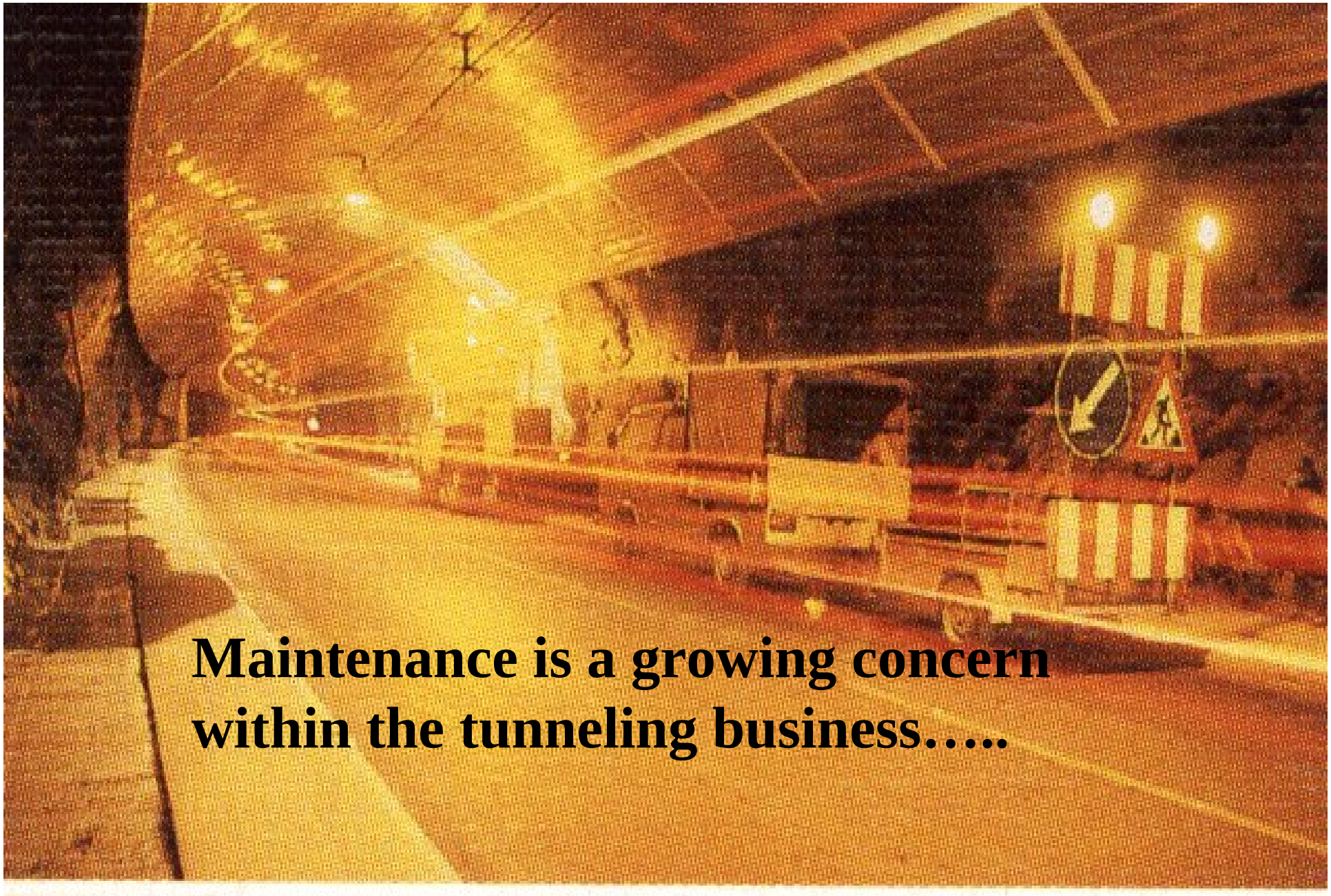
Protecting the tunnel space from water and ice.
Drained concept: lead water into drainage system

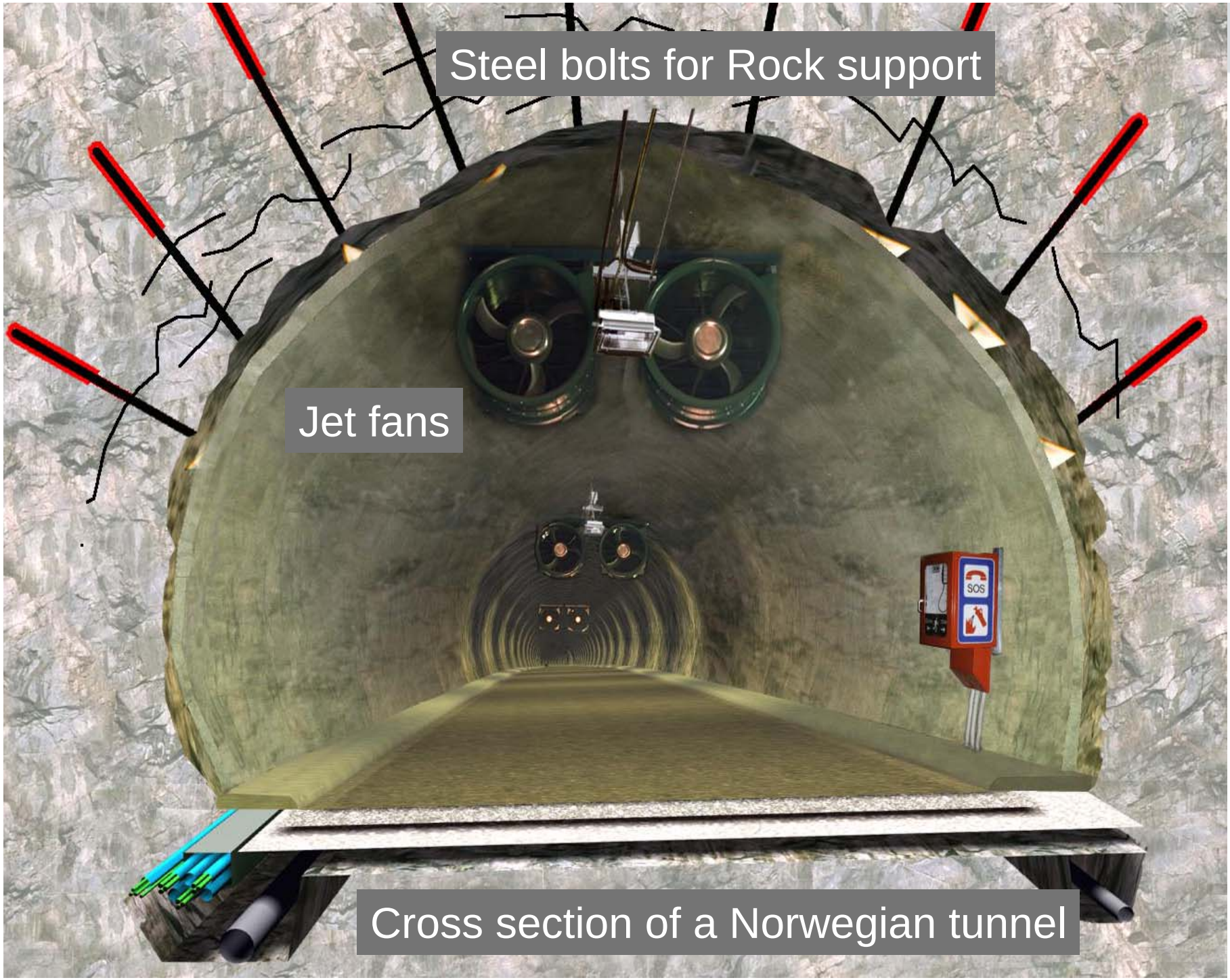
- Pre-cast concrete elements (AADT > 10000). Membrane for water protection. Frost insulation
- PE-foam for water and frost protection. Fire protected: shotcrete with PP-fiber. (1980-)
- Aluminium or steel linings. Membrane for water protection. Frost insulation
- Membrane lining (low-traffic tunnels)
- Combined solutions including concrete elements in walls (3.5 m), or concrete barriers

Age of short and long tunnels



30 % of the tunnels are more than 30 years


Maintenance is a growing concern
within the tunneling business…..


Steel bolts for Rock support
Jet fans
SOS
Cross section of a Norwegian tunnel

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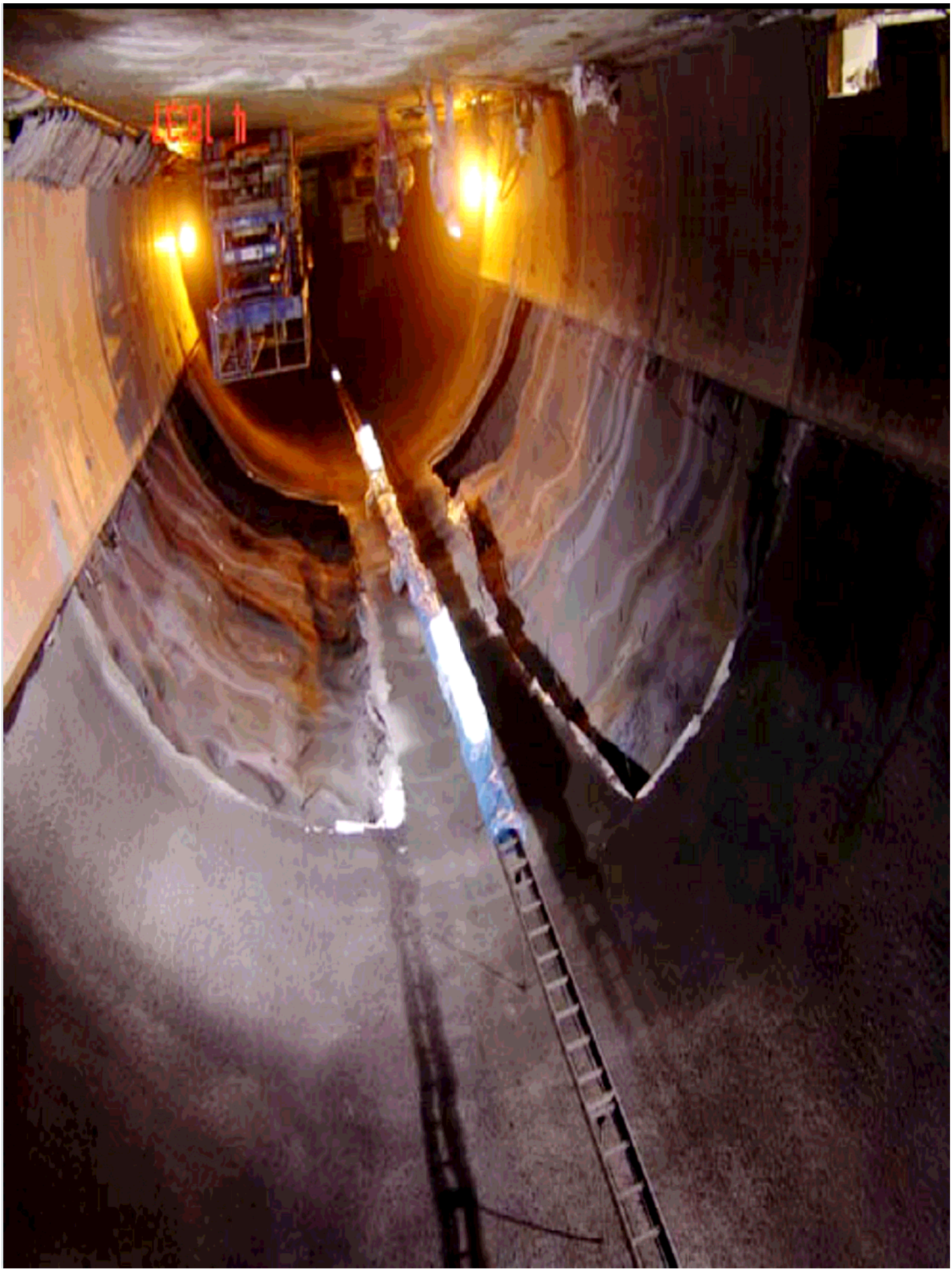
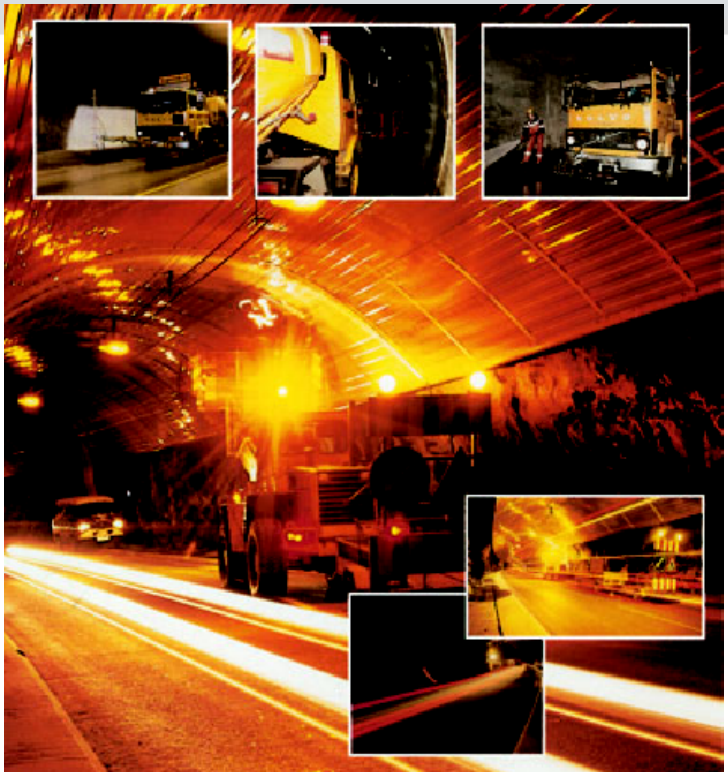


Rehabilitation


Is-svuller

Maintenance...Life cycle cost..



There is a growing concern and awareness for future quality, safety and cost related to maintenance, hence the relation between planningphase, construction and maintenance is put on the agenda.

Tunnel Fires in Norway

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Runehamar Test Tunnel

For full scale fire testing

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Hanekleiv Tunnel, dec. 2006

- Collapse of the tunnel roof (250 m^3) along 25 m tunnel length
- Collapse caused by swelling clay, deep weathered rocks combined with insufficient rock support
- Seven tunnels in the area were closed for repairs and rehabilitation until july 2007

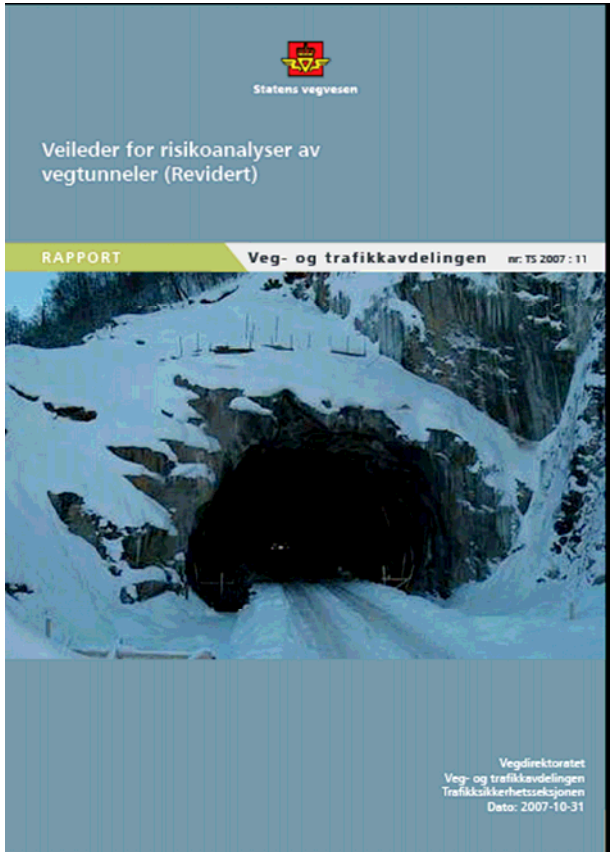
Future tunneling in Norway

- Tunnel strategy
- Risk analysis
- Geology, NS 3480
- Systematic approach

  q-method
- Documentation, traceable

Safety Documentations

- As a consequence of new EU directives tunnels should be able to document safety at all stages.
- Before construction can start
- Before opening
- During operation



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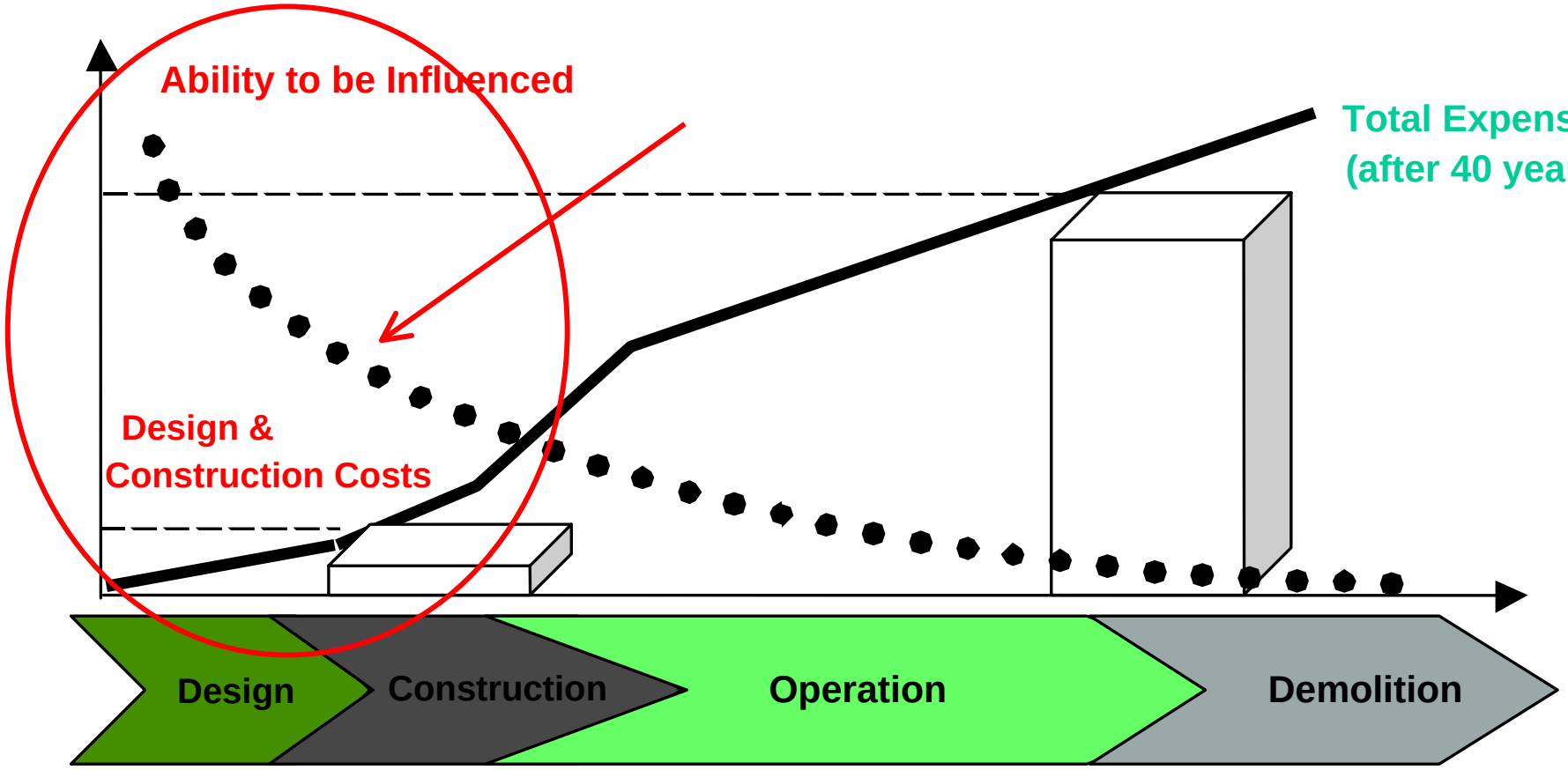
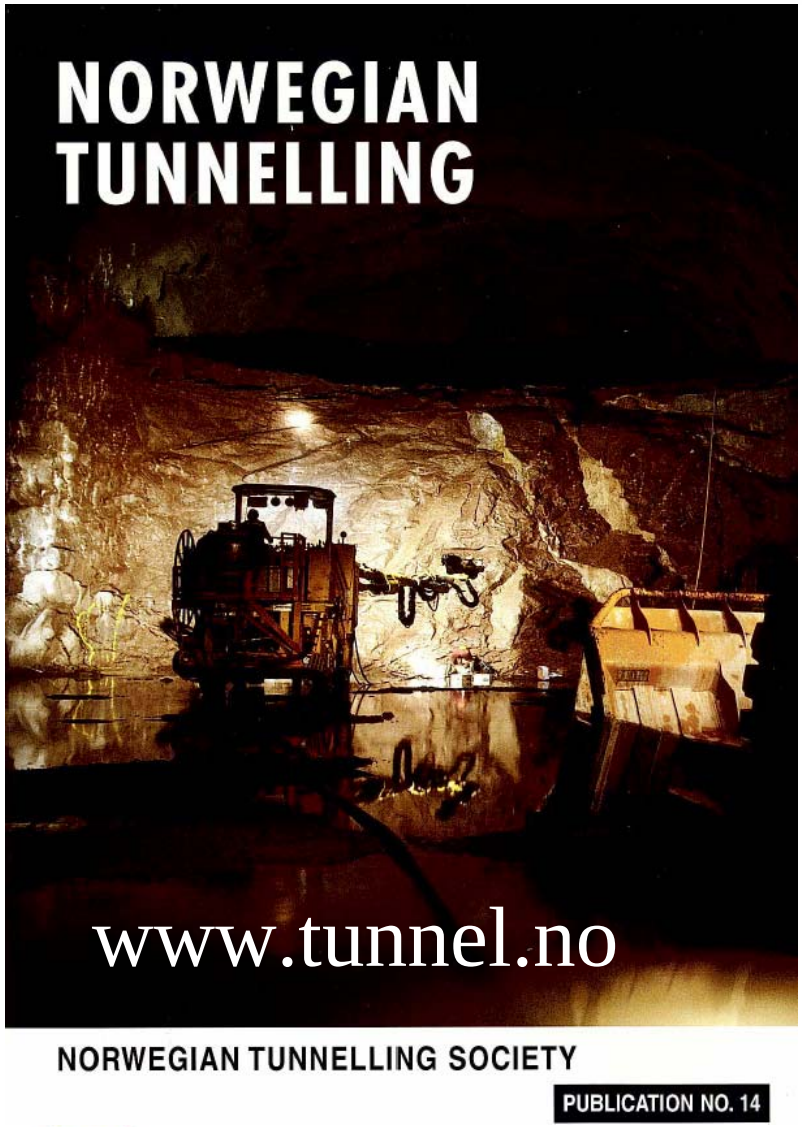
Plan for the future



Life cycle cost and timeframe

- From idea to construction 5-10-30 years
- Construction 2-4 years
- **Maintenance and operation 50-100-?? Years**
- **In Oslo, 3% of the road network is tunnels, but it takes 30% of the maintenance budget**
- **The more tunnels- the maintenance cost will increase**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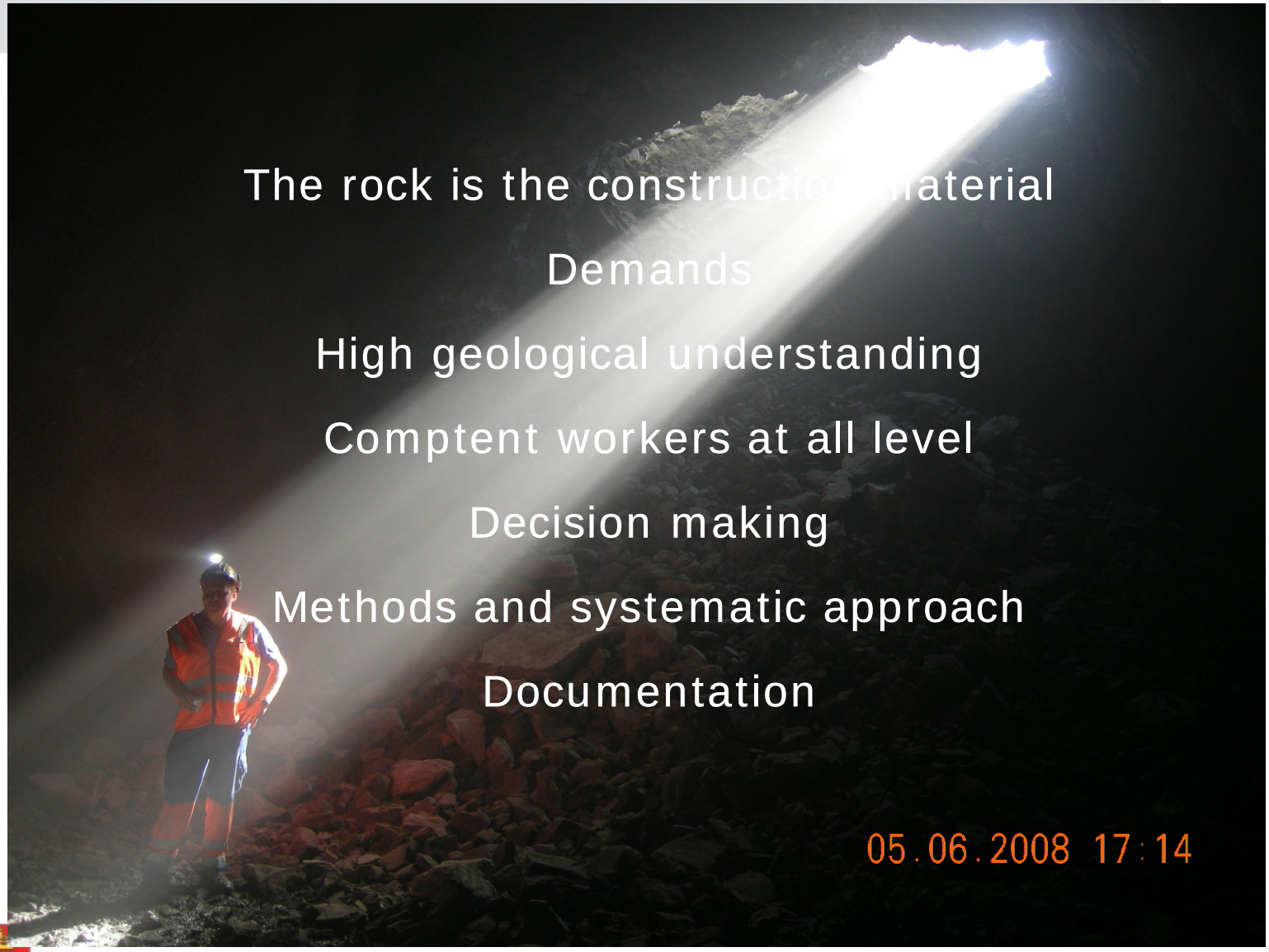
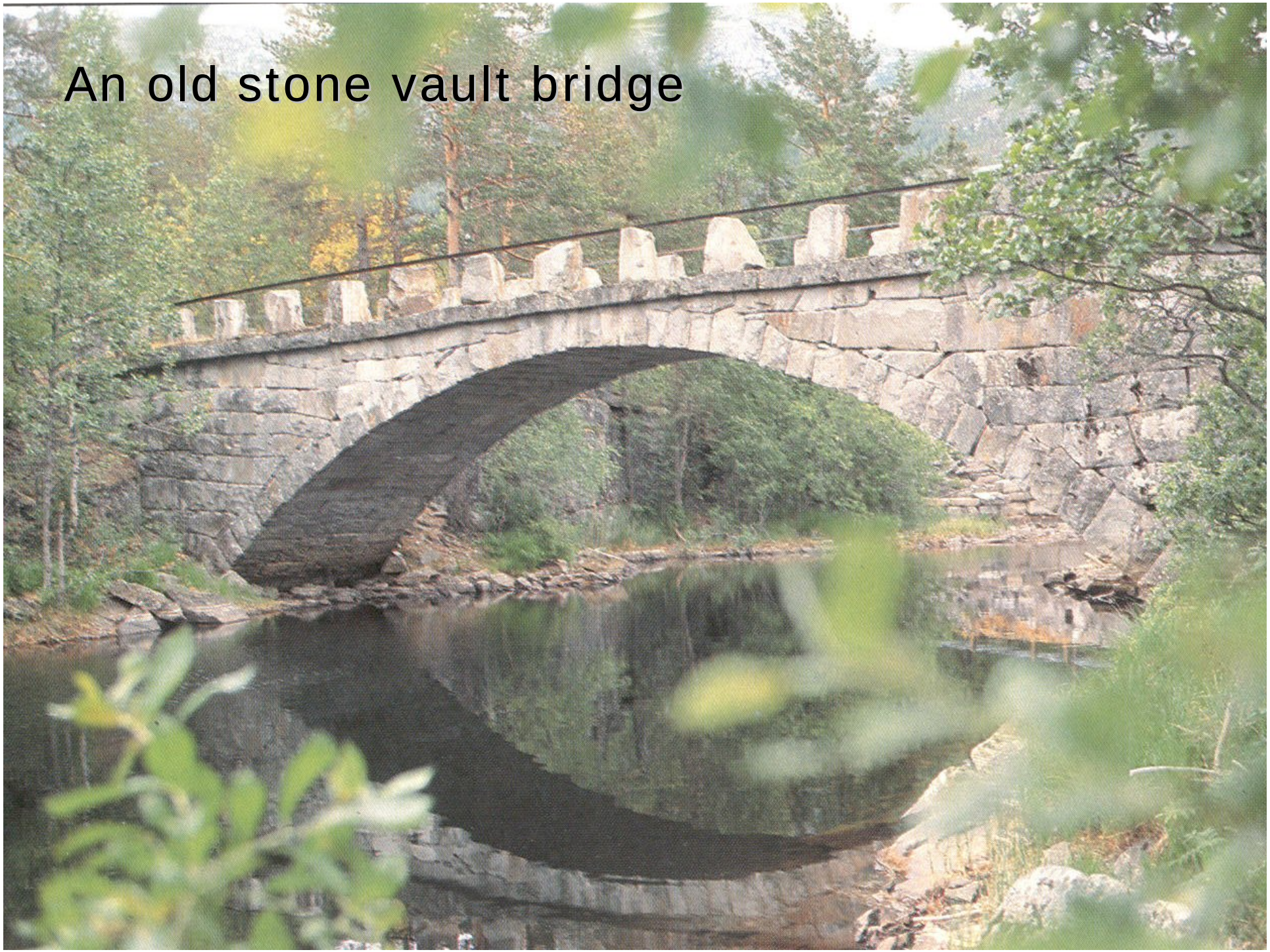
NORWEGIAN ROAD TUNNELLING
GEOLOGY OF NORWAY
NORWEGIAN TUNNELLING TODAY
NORWEGIAN TUNNELLING
AS REVIEWED BY
TUNNELS & TUNNELLING
NORWEGIAN SUBSEA TUNNELLING
Vardø
Lengde
NORWEGIAN UNDERGROUND STORAGE
NORWEGIAN URBAN TUNNELLING
NORWEGIAN TBM TUNNELLING
WATER CONTROL IN NORWEGIAN TUNNELLING
NORWEGIAN SOIL AND ROCK
NORWEGIAN TUNNELLING SOCIETY

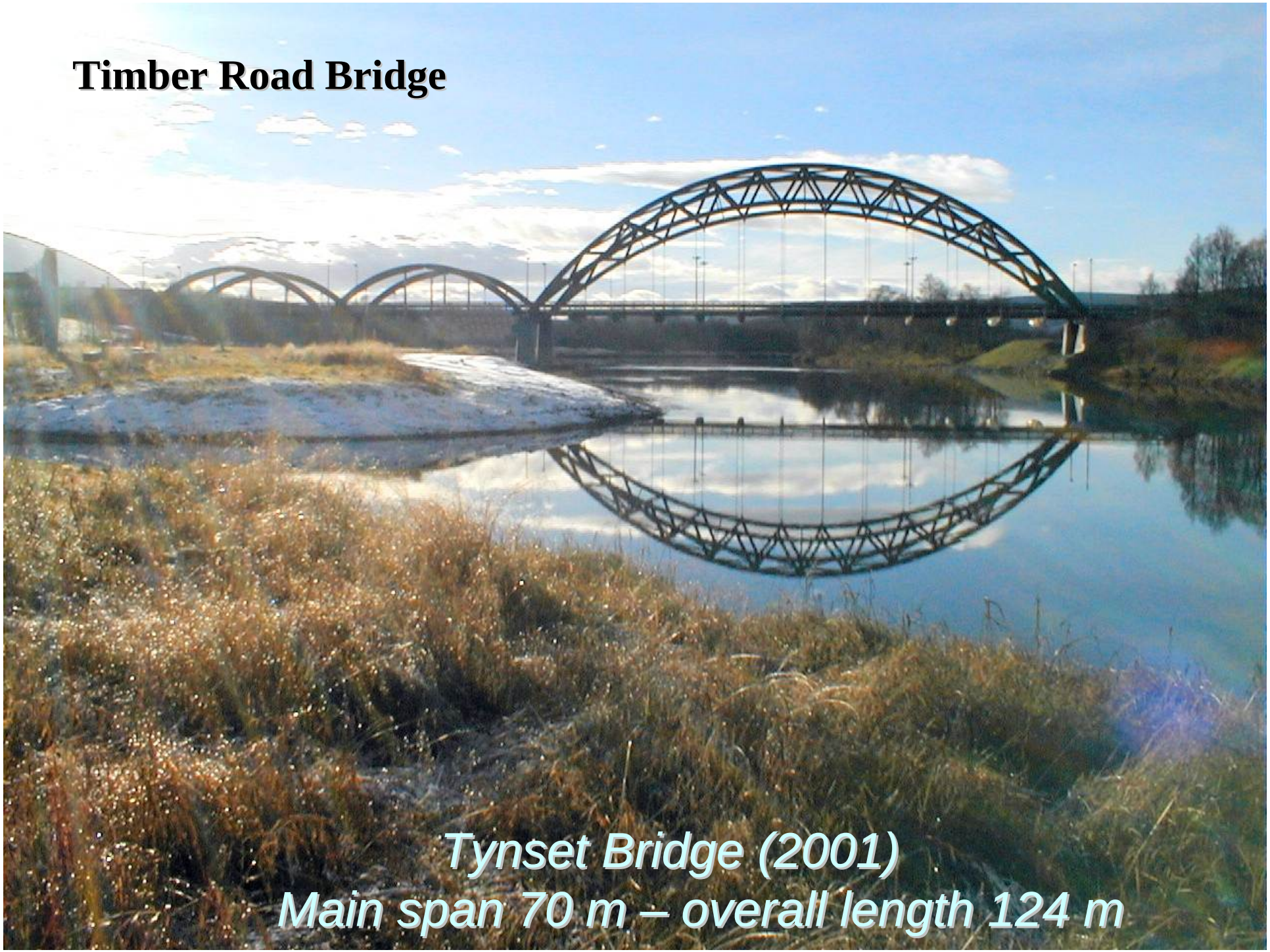

The rock is the construction material
Demands
High geological understanding
Comptent workers at all level
Decision making
Methods and systematic approach
Documentation
05.06.2008 17:14


An old stone vault bridge

Steel Arch Bridge

Karmsund Bridge (1955)
Total length 691 m

Timber Road Bridge



Tynset Bridge (2001)
Main span 70 m – overall length 124 m

Trollstigen

Trollstigen før

Steinsdalsfossen

Torghatten