

PENETRON® Concrete Proofing

PENETRON® TUNNEL HANDBOK



PENETRON® ADMIX Shotcrete BOTNIA Railway tunnels in Sweden

- A PENETRON® concrete proofing technology in tunnel projects
- B PENETRON® Slurry proofing of shotcrete linings
- C Tunnel construction with PENETRON® ADMIX shotcrete
- D Optimal RH & temperature conditions by PENETRON® tunnel proofing
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## A PENETRON® Slurry proofing of shotcrete linings

By construction of rock tunnels many efforts and different technical methods are used to make them water tight. Basically we talk about ground water contained in the rock cracks. The technical design to take care of this water, often with high hydrostatical pressure, offers a great variety and the design to be used are depending on the geological realities.

To avoid high water pressure from being built up outside the tunnel, this water normally is directed into drainage systems anchored in the rock roof and walls. Due to the tunnel construction system used, rest leakages can appear even into a membrane proofed tunnel. Membrane proofed or not, the tunnel inner roof is made of concrete and/or shotcrete linings.

Proofing of water leakages through this concrete layer can be complicated. The traditional method to eliminate water leaks is to collect the water in special designed drainpipes mounted to the concrete roof. Large roof leaking areas are often drained by anchoring a synthetic membrane or thick cell membrane or similar to the concrete or shotcrete roof and thereby collect the leak water and canalize to drainage. In traffic tunnels an additional fire protective reinforced shotcrete lining must be added inside those organic membranes – and such a construction need up to a 10" or 250 mm thick layer reducing the free load profile in a traffic tunnel with the same measurement.

### PENETRON® CONCRETE CAPILLARY PROOFING

PENETRON® expands the range of tunnel proofing alternatives. PENETRON® can be applied as slurry directly on the underside/inside of the rest leaking concrete based tunnel roof.

PENETRON® makes the concrete roof water tight. PENETRON® starts a crystalline water proofing process within the cracks, pores and capillaries in the concrete or shotcrete roof with the help of the leak water itself. A PENETRON® slurry sprayed directly on the roof concrete is not more than 1/12" or 2 mm thick and does not need any fire protection and thereby does not reduce the free load profile in a traffic tunnel. By making the concrete roof water proof itself PENETRON® canalizes the ground water into the already built in drainage system in the tunnel.

### PAES™ - PENETRON® ADMIX ENHANCED SHOTCRETE

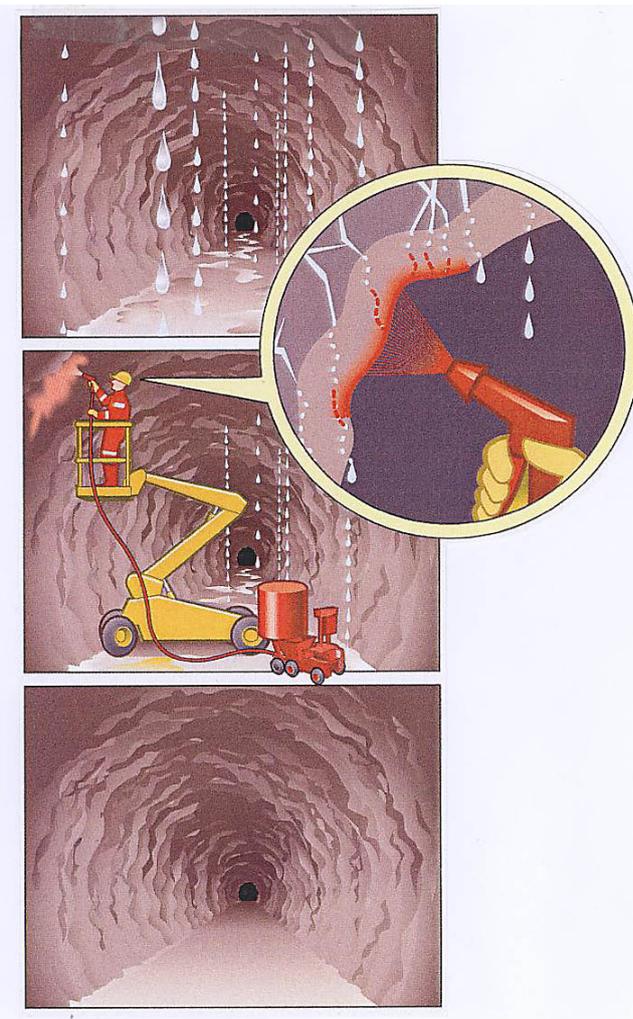
Adding PENETRON® ADMIX directly into the shotcrete by batching is a very interesting and effective water proofing alternative by new construction of tunnels or repair of leaking tunnels.

## B PENETRON® SLURRY APPLICATION

### TUNNEL ROOF/WALL SURFACE PREPARATION

The concrete surface or bedding to receive the PENETRON® SLURRY must be structurally sound and free from crystals of lime and rust areas, soil etc. Use high pressure water equipment up to 250 bar pressure or more with rotating nozzle.

By using high pressure cleaning the necessary complementary water saturation of the concrete is done in the same operation.



#### Mixing PENETRON® slurry:

1 bag 50 lbs/22,68 kg PENETRON® to 15 – 16 litres water. The correct volume of water is depending of the type of spray equipment that will be used.

#### Spray instructions:

Use a normal slurry spray equipment; remote controlled or manual.  
Spray flow: 2 – 5 litres/minute

#### Apply:

2, 5 – 3 kg PENETRON®/visible m<sup>2</sup>.  
On extreme rough surfaces partly even more. One visible m<sup>2</sup> must be multiplied by 1,3 – 2,0 to calculate the effective area.

Continuously spraying is recommended over the area to be PENETRON® treated. Apply the slurry in repeated thin layers to avoid slurry rills.

NB!

Carefully check that all parts of a rough roof and wall are covered with the Penetron® slurry. Eliminate spray shadows on rough surfaces by moving the spray nozzle in different directions.

The PAES™ methods can be used by repair of damaged tunnel roofs and walls with moderate to severe water problems.

The PAES™ can be used as a constructive shotcrete building method in combination with its unique water proofing abilities. The PAES™ methods can preferable be used at tunnel projects through lower ridges, METRO projects and similar.

With the PAES™ methods it is possible to create a form for self-supporting water proofing arch roof designed shotcrete tunnel lining sprayed in layer thickness up to 300 mm in a single spray operation.

## TUNNEL ROOF/WALL SURFACE PREPARATION

By repair of damaged concrete linings; the bedding or concrete surface to receive the PAES™ must be structurally sound and free from crystals of lime and rust areas, soil etc. Use high pressure water equipment up to 250 bar pressure or more with rotating nozzle. By using high pressure cleaning the necessary complementary water saturation of the concrete is done in the same operation.

Rock anchored steel reinforcement grid must be installed in the damaged parts of the tunnel roof, domes and similar. Technical & physical design is to be worked out together with the project construction engineers.

## APPLYING PENETRON® PAES

Shotcrete mix design including Penetron® ADMIX and PAES™ layer thickness is to be decided together with the project construction engineers.



PENETRON® ADMIX ENHANCED SHOTCRETE – PAES™ APPLIED IN RAILWAY TUNNEL PROJECT IN SWEDEN

## D Optimal RH & temperature conditions by PENETRON® tunnel proofing

### HUMIDITY AND TEMPERATURE CONDITIONS

Air climate, temperature and humidity in underground constructions, tunnels or similar can vary a lot depending on where the project is geographically situated, type of project and so on.

Concrete and rock bedding temperature vary too but is more stable.

The best climate conditions for the PENETRON® to start and fulfil the crystalline building up process within the concrete either as a PENETRON® slurry treated concrete or a PAES™ layer on a rock or a concrete bedding are:

<u>TEMPERATURE:</u>	6 – 20° CENTIGRADE
<u>RELATIVE HUMIDITY – RH:</u>	40 – 80%

If possible it is recommended to keep the air climate within this recommendation. If not possible to control the air climate, PENETRON® will do the crystalline proofing as well but:

With a RH > 80% in the tunnel air, the crystalline forming process slows down and by reaching RH = 98% it stops because the air cannot carry more water vapour.

The crystalline process continues when the RH decrease.

With a RH < 40% the crystalline forming process will possibly speed up at the beginning and that must not always be positive.

The most important factor is the RH percentage. A much higher air temperature can carry more water vapour by weight and combined with a very low RH percentage in the air there is risk to dry out the PENETRON® process.

Under such circumstances a water saturation of the treated area 2 to 4 times a day during the first 4 – 6 days after application is recommended.

## E PENETRON® ADMIX – COMPATIBILITY WITH OTHER COMMONLY USED CONCRETE OR SHOTCRETE ADDITIVES

PENETRON® ADMIX is compatible with commonly used additives made and delivered by well known companies like GRACE, BASF, SIKA, MAPEI and others. Alkaline free accelerators co-operates very well with PENETRON® ADMIX. The use of high quality accelerator additive results in lower hydration temperatures which together with PENETRON® ADMIX gives you the best available water proofing shotcrete combination.

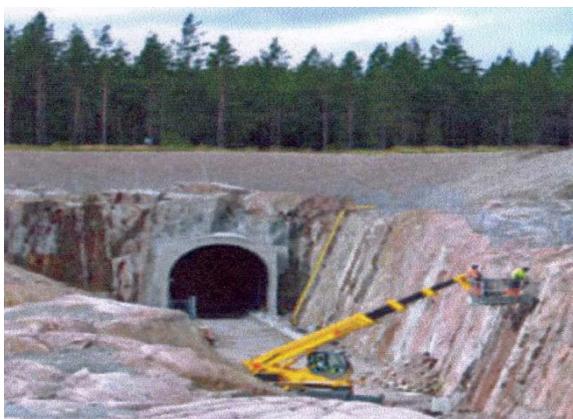
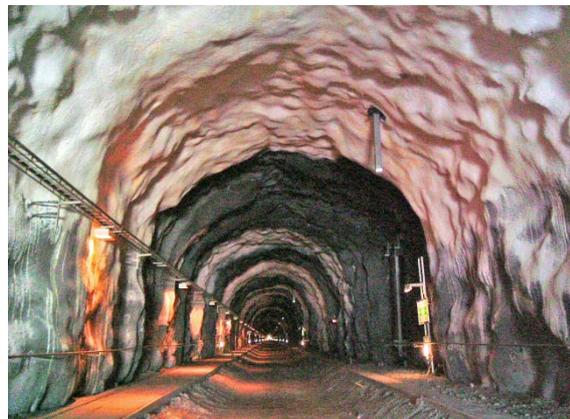
**NB!** Additives containing sodium- or potassium water glass must not be used together with PENETRON® ADMIX

## F REFERENCE PROJECTS

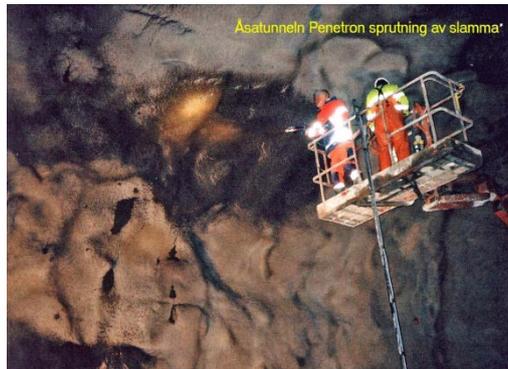
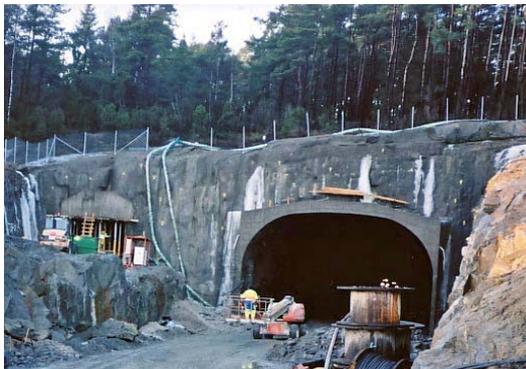
Some tunnel projects in Sweden:

### BOTNIABANAN RAILWAY PROJECT

2001 – 2008 over 50000 M<sup>2</sup> tunnel roof in 8 different tunnels



PENETRON® AND PENETRON® WHITE SLURRY PROOFED TUNNEL ROOFS



SWEDISH WEST COAST RAILWAY ÅSA TUNNEL 4000 M<sup>2</sup> SLURRY PROOFED ROOF AREA

## PAES™ - PENETRON® ADMIX ENHANCED SHOTCRETE TUNNEL PROJECTS

NEW E18 HIGHWAY WEST FOR STOCKHOLM UNDER CONSTRUCTION.

- DOUBLE TWIN HIGHWAY TUNNELS – 11000 M<sup>3</sup> PENETRON® SHOTCRETE CONSTRUCTION IN A ONE-SPRAY OPERATION DIRECTLY ON THE ROCK ROOF BEDDING.





4540 meter - BANVERKET SWEDEN – ÅDALSBANAN/  
KROKSBERGSTUNNELN A NEW RAILWAY TUNNEL USING  
**PAES, PENETRON® ADMIX SHOTCRETE**

Some tunnel projects in Finland:

**E18 Helsingfors – Åbo Motorväg, Finland**

- 51 km motorväg + lokala vägar
- 76 broar, 7 tunnlar (5,2 km dubbeltunnel)
- Betalning: tillgänglighet
- Kund: FINNRA
- Byggstart: 2005
- I drift: 2008
- Koncession till 2029
- Total finansiering: € 330 M
- Skanskas ägarandel: 41%
- Partners: Laing, Lemminkäinen



**SKANSKA** Infrastructure Development Enhancing life through partnership

E18 - HIGHWAY HELSINKI - ÅBO PROJECT IN FINLAND UNDER CONSTRUCTION.  
51 KM HIGHWAY + LOCAL ROADS  
7 TWIN TUNNELS

Thousands m<sup>3</sup> of PAES™ in a 100 mm thick lining operation estimated to reduce the total tunnel proofing costs by over 50% compared to commonly used methods.

The highway will open for traffic 2010

Around the globe:

- Moscow Subway, Russia
- Washington DC Subway, USA
- Second Hanna Highway Tunnels, Japan
- St. Petersburg Subway, Russia
- Prague Subway, Czech Republic
- Torino METRO, Italy
- Budapest METRO, Donau tunnels
- São Paulo METRO, Brazil - YELLOW LINE, GREEN LINE under expansion
- Caracas Venezuela & Santiago de Chile METRO under construction
- China METRO tunnels and stations in 7 different cities
- Stockholm Sweden CITY HIGHWAY TUNNELS 2000-2005 SÖDRA LÄNKEN
- Coast to Coast Railway Sweden, Gnosjö-tunnel - 2002

- .....and many more tunnel projects around the globe.....