SIKA AT WORK
THE HALLANDSÅS RIDGE RAILWAY, SWEDEN

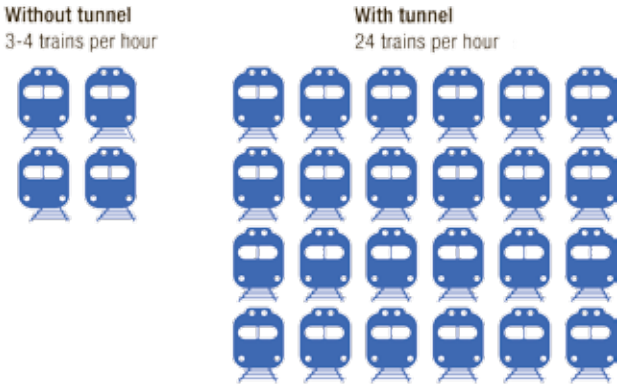
WATERPROOFING IN VARYING GEOLOGY AND HIGH GROUNDWATER PRESSURE

BUILDING TRUST

PROJECT DESCRIPTION

The Hallandsås Tunnel
The 8.7 km long Hallandsås tunnel is the core piece of the west-link railway in Sweden. Due to the varying geology and high groundwater pressure the construction of the tunnel is complicated. The tunnel is scheduled to open for traffic in 2015.

Why build a tunnel?
The current railway line over the Hallandsås ridge comprises a single-line track that was completed in 1885. Due to its climbs and tight bends, the section over the ridge has always been a problem. Hallandsås restricts capacity and creates delays along the entire west coast of Sweden.
In the 1980s, when the Swedish Government decided to expand and regenerate the Swedish rail network, the suggestion was also put forward for a tunnel to solve the problem of low traffic capacity on the stretch of track beyond Hallandsås. In 1991, the Swedish Government decided to construct an 8,7 km long tunnel between Båstad and Förslöv.
A tunnel through the Hallandsås ridge increases capacity from the current rate of 4 trains per hour to 24, and the goods trains weight capacity will be double.



History
The construction of the tunnel suffered many serious setbacks in the period from 1992 to 1997. The first TBM (tunnel boring machine) used was not suitable to the demanding conditions in the ridge and switch was made to traditional drill and blast techniques. This time there were problems with water flowing into the tunnel which caused wells to run dry and the project's environmental permit to be exceeded.

A chemical sealant was then used to make the tunnel watertight. When it became apparent that toxic acrylamide leaked to the surrounding environment the work was stopped. The tunnel was then sealed and decontaminated and the ridge was given a clean bill of health. Completion of the project required, among other things, a resolution by the Swedish Government and Parliament, a construction permit and a new environmental permit. This was completed in 2004.

Contractors
When the Swedish government decided to complete the Hallandsås Tunnel in 2001, the Swedish-French consortium Skanska-Vinci HB was selected as the general contractor. Skanska has considerable experience of traditional tunnel construction in Sweden and previous knowledge of Hallandsås. The French company Vinci is one of the world´s largest construction companies and has considerable experience of tunnel excavation under very difficult conditions. The Skanska-Vinci consortium ensures that skills required in project Hallandsås correspond to those needed to surmount the challenge.
The total cost of the project is estimated to SEK 10.5 billion in 2008 monetary value.

Tunnel construction in a complex geological environment
The two parallel tubes that make Hallandsås Tunnel are connected by 19 cross tunnels. Approximately two thirds of the tunnel remained when the new TBM (named Åsa) started up in the autumn of 2005. The new piece of equipment was a shielded TBM especially adapted to the geological conditions found in the Hallandsås Tunnel. The varying quality of the rock, featuring alternate layers of hard, disintegrated and water-bearing rock, makes it difficult to construct a tunnel. The TBM installs a waterproof pipe as it bores through the rock to prevent groundwater from leaking into the tunnel. The method is known as lining and it consists of 2.2 meter long concrete rings, each containing eight sections, segments, which weigh 12 tons a piece.
The segments, which are more than 40.000, have been manufactured in the Skanska-Vinci factory in Åstorp. The tunnel tube must have a technical life time of at least 120 years and cope with the high water pressure and rock pressure in the ridge. This put high requirements on the properties and quality of the segments.

In the 19 cross tunnels connecting the two parallel single-line tunnels evacuation is made in event of any stoppages or accidents in the railway tunnels. The cross tunnels are constructed with a distance of 500 meters and they have fire doors at both entrances which convert them into fire cells.
The approx. 22 meter long cross tunnels are constructed using traditional drill and blast method from the east tube. These are carried out at the same time as the west tunnel is being constructed.

Waterproofing with membrane in insitu tunnels.
The major parts of the tunnels are segment lined tunnel (approx. 65%) drilled by TBM meanwhile the rest is done by traditional drilling, blasting and shotcrete application. However, since there is a high water inflow in some sections in the non-segment lining these sections have been concrete lined insitu with a membrane for waterproofing of the construction. The installed membrane is divided in compartments by waterstops and with injection devices.

The tunnel runs through varying geology and high groundwater pressure. The water pressure is 15 bars in some parts of the tunnel which means 150 m of groundwater above.

Environment and control
Executing a major infrastructure project without affecting the environment is impossible. However, the goal is to minimize the impact. The Hallandsås project has learned from earlier incidents during the tunnel construction and environmental initiatives are now a central part of the construction work. Several internal and external control systems are in place to look after the water, chemicals and ecology.

QUICK FACTS
PROJECT PARTICIPANTS

The tunnel construction – year by year

1885 - Railway over the Hallandsås ridge is inaugurated
1975 - SJ (Swedish railway) conducts the first tunnel investigation
1991 - The Swedish Parliament approves the construction of the tunnel.
1992 - Contractor Kraftbyggarna is selected as the contractor for the project.
1993 - The TBM Hallborr becomes stuck. Kraftbyggarna changed to more traditional method of drilling and blasting.
1995 - Contractor Kraftbyggarna is withdrawn from the project
1996 - Skanska takes over as the new contractor.
1997 - The regulation of the Water right Court was exceeded. Acrylamide (Rhoca Gil) is used to seal the tunnels. High levels of acrylamide are registered in seepage water. The leakage triggers a crisis in the immediate surroundings of the tunnels.
1999 - The government decides that Banverket (the Swedish Railway Authority, today Trafikverket, the Swedish Transport Administration) will investigate whether work on the tunnel is to be continued.
2001 - The Skanska-Vinci HB consortium is appointed general contractor for the continued construction work on the tunnel.
2005 - Preparation of the TBM Åsa is initiated in the autumn.
2008 - The TBM Åsa breaks through the midway point in the east tunnel.
2010 - The TBM Åsa makes its breakthrough in the eastern tunnel.
2011 - The work on the 19 cross tunnels is started. The cross tunnels are linking the two tunnel tubes at approximately every 500 meter and act as escape routes among other things. The segment factory in Åstorp is closing after have been producing more than 40.000 segments.
2013 - The TBM Åsa makes break through in the western tunnel 4 sep 2013.
2014 - The Skanska-Vinci contract will be completed, followed by the track installation.
2015 - The first train will pass through the Hallandsås Tunnel.

QUICK FACTS

Building time and cost
Construction began: 1992. Restart 2003.
Traffic to commence: 2015
Cost: A total of SEK 10.5 billion in 2008 monetary value.

Facts about the main tunnels
Main tunnel length: 2 x 8.7 km
Inside diameter lining: 9.04 meters
Total amount of cross tunnels: 19

Facts about the TBM Åsa
Length with back-up: 250 m
Total weight: 3 200 tons
Weight drill head: 218 tons
Number of people in a TBM-shift: 16
Cost: about SEK 500 million

Facts about lining
Total amount of segments: about 40 000
Produced by Skanska-Vinci and Sydsten (ready-mix supplier)
Eight segments in each lining ring
Weight of one segment: 12 tons
Thickness: 54 cm
Length: 2.2 meters
Concrete: 180 000 m^3

PROJECT PARTICIPANTS

Owner
Trafikverket (The Swedish Transport Administration)

Tunnel Contractor
Skanska-Vinci HB

Applicator membrane/waterproofing
Renesco a.s

REQUIREMENTS AND SIKA SOLUTIONS



The tunnel is designed for a technical life time of 120 years, which put high requirements on the tunnel construction. Sika has continuously been involved in technical discussions about waterproofing, injection, shotcrete, concrete, etc.

Waterproofing - membrane
Since the ridge has a high groundwater level the construction of the waterproofing is made with "watertight full-around seal" or holding the head of water. This means that the construction has no influence on the water table.
The TPO membrane (FPO, Flexible Polyolefin) system is installed on an inner-lining or on shotcrete with a surface evenness of 10:1 to provide adequate support. The system consists of geotextile fixed with discs which the membrane is welded to and divided into compartments to limit occurring leakages. The size of the compartments (in square meter) depends on construction type and they are created with waterstops with integrated injection channels. In some parts protection sheet is installed as well to create a compartment and protection of the membrane. The system has been used in tunnel sections where there are no segments installed and with water leakages higher than the requirements.

Waterproofing - connection between segments and membrane in cross tunnels
Connection between membrane and segment has always been a challenge with flange construction in order to create a waterproofed connection. After investigation of reports, tests on-site and references the Sika joint tape sealing system was used to have a waterproofed system in the cross tunnels.

In the cross tunnels the joint tape (FPO, Flexible Polyolefin) was glued by epoxy adhesive directly on the backside of the segment. Afterwards, the waterproofing membrane was welded to the joint tape to create a waterproofed system. The joint tape has also been used to create compartments on the wet side of the cross tunnels. The system has been supplemented with swelling profiles/paste, injection hoses and by grouting to secure the waterproofing system.

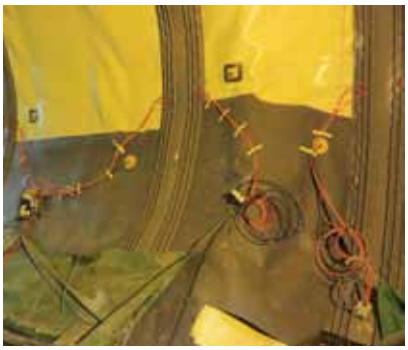



SIKA PRODUCTS

Rock grouting
A lot of information about the ridge was received from the drilling with the TBM in the first tunnel, the eastern tunnel. To increase the efficiency of the TBM in the second tunnel, the western tunnel, pre-grouting of the rock with a cement based injection grout was made from caverns created at cross tunnel 5 and 6. Cross tunnel 5 and 6 are located in the area called Lyadalen which has approximately 840 m of very poor rock. Grouting was made in both directions (250 m) from the cavern to secure the rock and minimize the water inflow by a high reduction factor, from 250-350 l/s and 100 m to less than 50 l/s and 100 m.
The Swedish Transport Administration was specifying the requirements on the grout (injection cement suspension) which were discussed and tested. The requirements on the grout were defined by rheology properties (yield stress and viscosity), penetration ability (filter properties) and stability. All discussions were open between The Swedish Transport Administration, Skanska-Vinci and Sika (in cooperation with Cementa-Heidelberg) to share knowledge, save time and to find the optimal solution.
Sika (in cooperation with Cementa) could after testing at Cementa Research provide a grout solution that fulfilled the requirements of The Swedish Transport Administration. The pre-grouting of the rock shortened the lead time with approximately 6 months.

Segments
The segment factory in Åstorp produced more than 40 000 segments in order to complete the segment lining through the Hallandsås. In total 180 000 m³ of concrete was used to manufacture the segments during a 6 year period. The factory was run by Skanska-Vinci and Sydsten was supplying the concrete. The factory closed down in early 2011 when the last segment was produced. Sika was involved in an early stage to develop admixtures to fulfill the high requirements on rheology and cure time.

Shotcrete
Shotcrete was used to fill out cavities and create surface evenness for membrane application. Sika fulfilled the requirements on the shotcrete accelerator which were high efficiency, high strength development of the concrete, safe working, avoid work interruptions and support/deliveries on short notice.



Waterproofing
- Sikaplan® WT 2200-32HL2
- Sikaplan® WT Protection sheet-25HE
- Sikaplan® Felt PP 1000-J B2
- Sikaplan® W Tundrain Type A
- All kinds of membrane accessories
- Sika® Waterbar WT AF-600/34 MP
- Sikaplan® WT Tape 200
- Sikadur®-31 CF Normal
- SikaSwell® products
- X-Plug (mechanical plug)

Grouting and Injection
- Sika® Injektering 30 (injection cement)
- Sika® iFlow-1 (dispersing admixture)
- Sika® iAcc-1 (accelerator)
- Sika®-SP40
- Sika® Intraplast-A
- SikaFuko® VT-1, VT-2 and Eco-1
- Sikadur®-52
- Sika® Injection-201 CE
- Sika Injection-306
- All kinds of injection accessories

Shotcrete
- Sigunit®-T&M

Concrete segments
- Sikament® 20 HE Åstorp
- Sikament® EVO 26
- SikaAer®-S

Mortars and other products
- Sika FastFix®-4
- SikaQuick®-506 FG
- Sika®MonoTop®-910
- Antisol-E
- Sika®-2
- Sika® AnchorFix-1
- SikaTop®-71

THE HALLANDSÅS RIDGE RAILWAY

MORE INFORMATION:

Sika Sverige AB, a part of the global group Sika AG, is a leading supplier of specialty chemical products. Sika provides solutions, systems and products to the construction, building and manufacturing industries and is a leading supplier of materials that are used for sealing, bonding, damping, reinforcing and protecting.

Sika's product range consists of high quality concrete admixtures, mortars, sealing & bonding, damping and reinforcing materials, structural strengthening systems, industrial flooring as well as roofing and waterproofing systems.

SIKA SVERIGE AB
Box 8061
SE-163 08 Spånga
SWEDEN

Contact
Tel +46 8 621 89 00
Fax +46 8 621 89 89
www.sika.se, info@se.sika.com

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