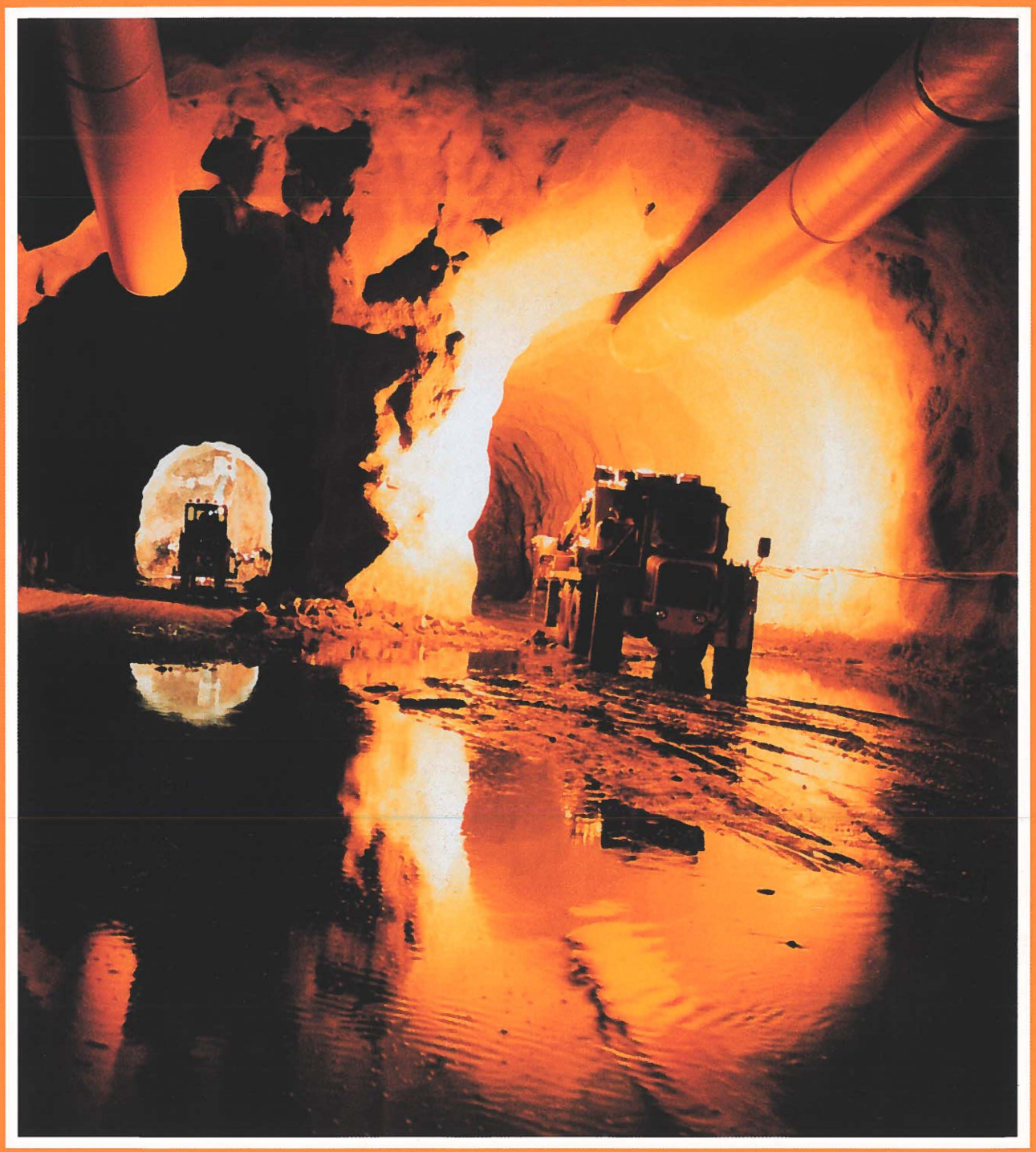
Underground Construction



Sweden in Focus

Second Edition

Cover illustration: Rock works under the Arlanda Airport, further described on pp 15-17.
(Photo: Arlanda Express)

Second edition of
Underground Construction - Sweden in Focus

Published by
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SveBeFo-Swedish Rock Engineering Research

Managing Editors
Annica Nordmark and Sven Gunnar Bergdahl

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Foreword

Dear Reader,

It is a great pleasure for us to present you with a second edition of Underground Construction Sweden in Focus. The first issue of this publication appeared in 1996, and many new tunnelling projects have been undertaken since then. We are pleased to update you accordingly.

From all the underground construction works carried out by Swedish contractors at home and abroad, we have chosen nine projects, one of which is in Iceland. All these projects have one important factor in common: they all required an imaginative engineering approach to solve specific problems.

Our aim has been to present these projects in a concise way, with several descriptive illustrations, in order to give the reader a clear impression of the current state of the art of underground rock construction in Sweden. For those seeking further information, we have given the names of persons involved in each project, who may be contacted for further technical details.

"Underground Construction" is produced jointly by BK (the Swedish Rock Construction Committee), and SveBeFo (the Swedish Rock Engineering Research Foundation), two organizations that together cover research and application of underground construction techniques. A list of their members is to be found on the last pages.

Stockholm, November 1999

The Editors

Annica Nordmark *Sven-Gunnar Bergdahl*

Acknowledgement

This publication is based on contributions from the following companies and organizations (in order of appearence)

National Swedish Road Administration, Stockholm Division
Swedish Nuclear Fuel and Waste Management Company SKB
Käppala Association
NCC International AB
LKAB
NCC Civil Engineering
PEAB Berg AB
Skanska International Civil Engineering AB
Sycon Energikonsult AB
Swedish Rock Engineering Research - SveBeFo

UNDERGROUND CONSTRUCTION
Sweden in Focus

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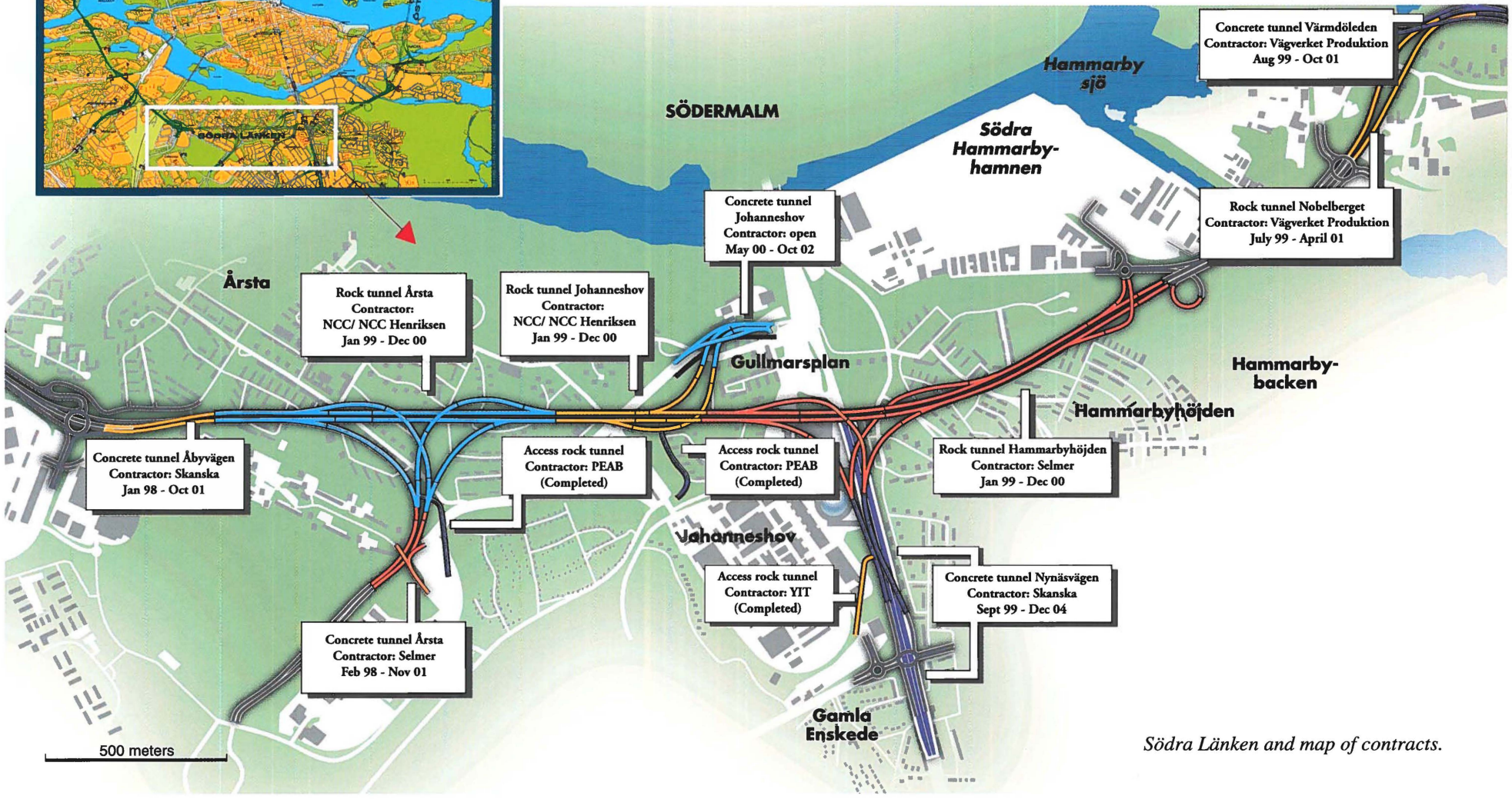
List of Members of BK and Principals of SveBeFo 34

In brief: ITA International Tunnelling Association and
EFEE European Federation of Explosives Engineers *(inside back cover)*

Acknowledgements *(opposite page)*



Essingeleden and the first sections of Norra Länken are the only parts of the Ring Road that exist already, and constitute the western part of the Ring Road.



Södra Länken and map of contracts.

Södra Länken - the Largest Road Tunnel System Ever Built in Sweden

Facts

Client and Owner: National Swedish Road Administration
Contractors (underground works): see opposite page
Consultants (design stage): SLK Consortium (Scandiaconsult, Golder Grundteknik, Vattenfall Hydropower, Bergab)
Construction period: 1998-2004

The southern parts of Stockholm are today badly affected by through-traffic, which totals 40-90, 000 vehicles per day. Noise, congestion and air pollution are a considerable nuisance for people living in these areas. To improve their living conditions and environment, a 6 km motorway is being constructed in an underground system comprising 16.6 km of rock-tunnels, including access tunnels. This means excavating about 2 million m^3 of rock. Because of the scheme's complexity, involving many underground interchanges along the route, great efforts have been made to ensure safe driving conditions with clear orientation for tunnel users.

In 1992, three of the largest political parties in Sweden decided that a ring-road should be constructed around Stockholm in order to re-route through-traffic heading north and south of the city, in particular through the sensitive areas of the Old Town. The project was to have been financed by road tolls on all access roads to Stockholm City. After that, strong opposed political and public opinion put the project to a standstill.

However, the traffic problems in south Stockholm were widely recognized, and in January 1998, a decision was finally taken to build just the southern link - Södra Länken - running south-east of the city. This project is being financed by the government and the City of Stockholm. When the other links of the Ring will be built is something that remains to be decided in the future.

Project description in brief

The project comprises two parallel three-lane road tunnels and a number of access tunnels. Three of the five main junctions will be located underground, and will connect the tunnels with the surface road system.

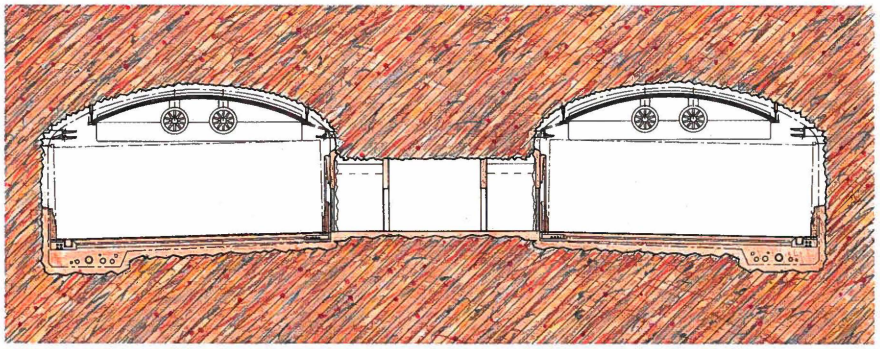
The cross-sectional area of the access tunnels will be 48 m^2 and that of the main tunnels will be 100 m^2.

The tunnels are designed with an insulated ceiling to prevent leaking water from freezing. Instead, leakages will be conducted down the walls in

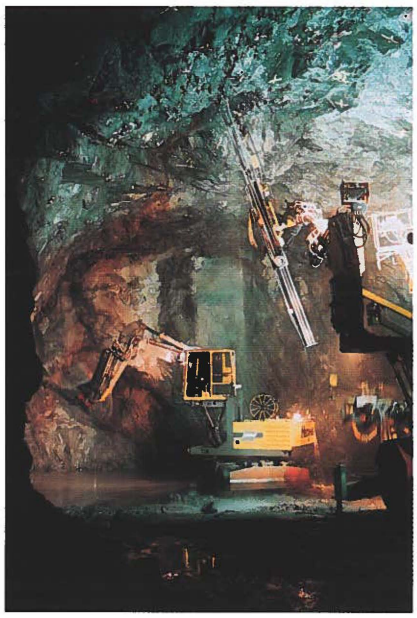


Drill rig in operation with roof bolting (Photo: Mikael Ullén)

Right: Illustration of a section where there are three carriageways in each tube, as well as an emergency evacuation passage running between the two tubes. Such passages are constructed every 100 metres.



Mechanized scaling preceeding roof bolting (Photo: Mikael Ullén).



electrically heated pipes to a drainage system under the tunnel floor. The drainage pipes will be covered with shotcrete to prevent freezing.

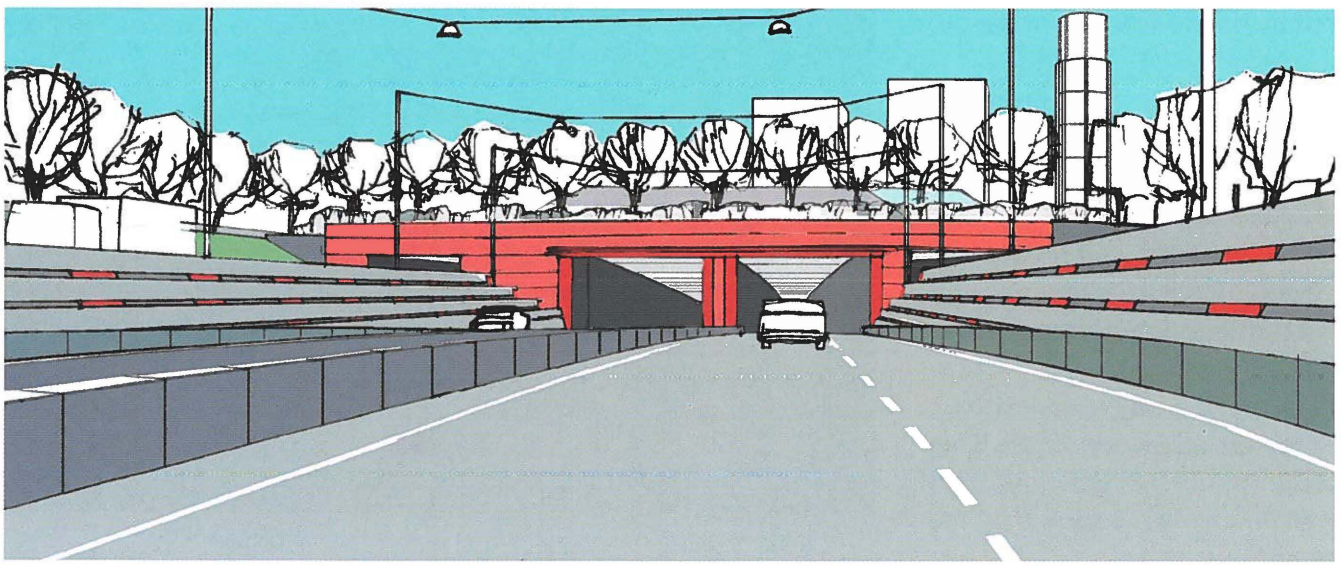
Rock reinforcement will be carried out using bolts and shotcreting. A high standard is being set for sealing the tunnels to reduce the groundwater leakage to a minimum. The most stringent demands only allow a leakage of 1-2 litres of water per minute and per 100 m. In some parts of the tunnels a larger leakage is permitted. The groundwater level will be checked continuously in a number of wells along the tunnel routes and in adjacent areas.

Environmental and quality aspects

Very stringent limits have been put on the acceptable level of disturbance to the environment by noise and vibration, and also on the existing roads that may be used for transporting building materials, machinery, excavated rock, etc. For instance, the transport of excavated rock will be steered clear of traffic peaks during the day, and the material will be divided between different crushing plants in the Stockholm area. Handling of chemicals and pollution of the ground will also be strictly controlled.

In addition, all personnel connected with the project are being educated about the scheme's environmental aspects, and taught how best to inform people living in areas adjacent to the construction sites. A Quality Assurance plan following ISO 9001 has been set up, as well as an Environmental Assurance Plan in accordance with ISO 14001.

Eastern view of the tunnel openings on the Åbyvägen interchange at Årsta. This part of the tunnel system (between Årsta and Gullmarsplan) has a total length of 10.3 km including ramps, emergency tunnels and operational space. Total excavated rock volume for this part is 760, 000 m³, equivalent to 76, 000 1orry loads. Estimated rock reinforcement requirements are 4, 000 tonnes of grouting cement, 40, 000 rock bolts, and 20,000 m³ of concrete for rock walls of less good quality.



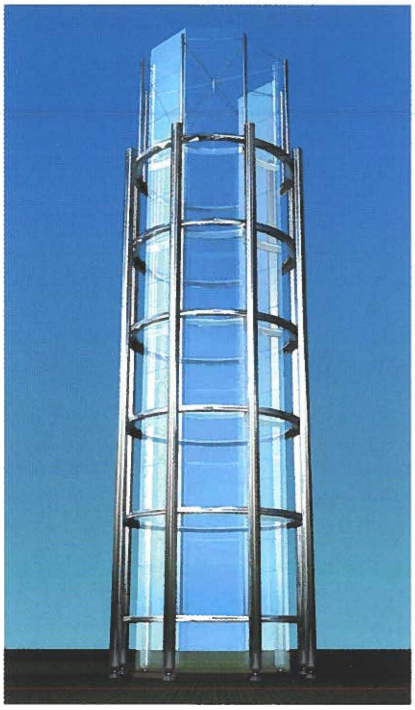
Geological and other conditions

As is widely known, the city of Stockholm is built on sound granitic rock. But inevitably such rock is not without weaknesses, and the project will encounter zones of less solid rock with high permeability. Another special challenge will be posed by the number of crossings with existing service tunnels. There will also be sections with very little rock cover, or none at all. Particular care must be taken with blasting due to the large number of people living in these areas.

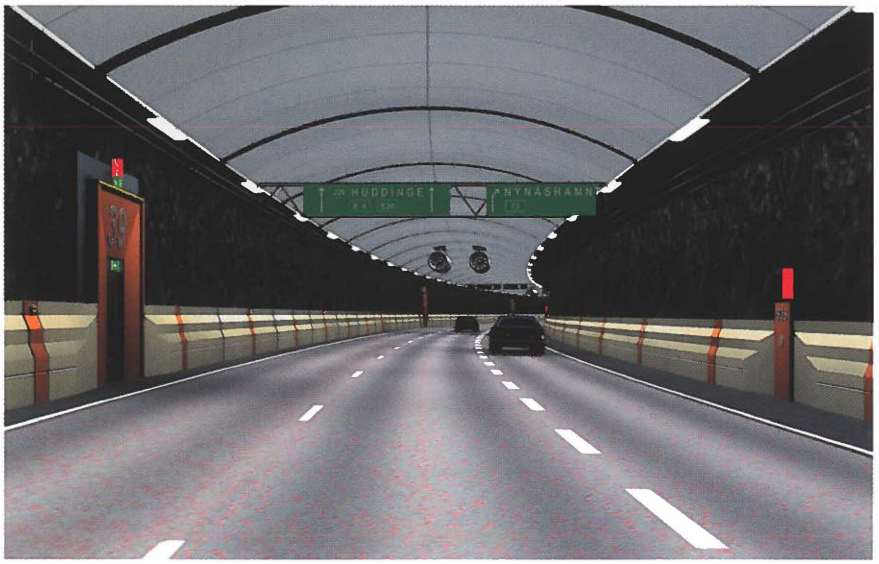
Orientation and safety

A full-scale demonstration model of the interior of the tunnels was built in 1995 by the client, the National Swedish Road Administration. The ceilings in the tunnels and the road surface will be light-coloured, and the tunnel lighting will simulate daylight as closely as possible. Artistic designs and special colours on the tunnel walls and road signs will help safe driving by providing drivers with easily recognisable orientation points, especially at the road junctions and tunnel exits. It is estimated that traffic accidents will decrease by about 25% in this new road tunnel system compared with today's road system on the surface.

A 24-hour CCTV surveillance system will be installed, and two high ventilation-towers will take care of exhaust gases from all the tunnels. There will be 29 emergency exits.



Model of the 20 m high ventilation towers in steel and glass.



Interior of the tunnels showing their light-coloured ceilings and driving lanes.

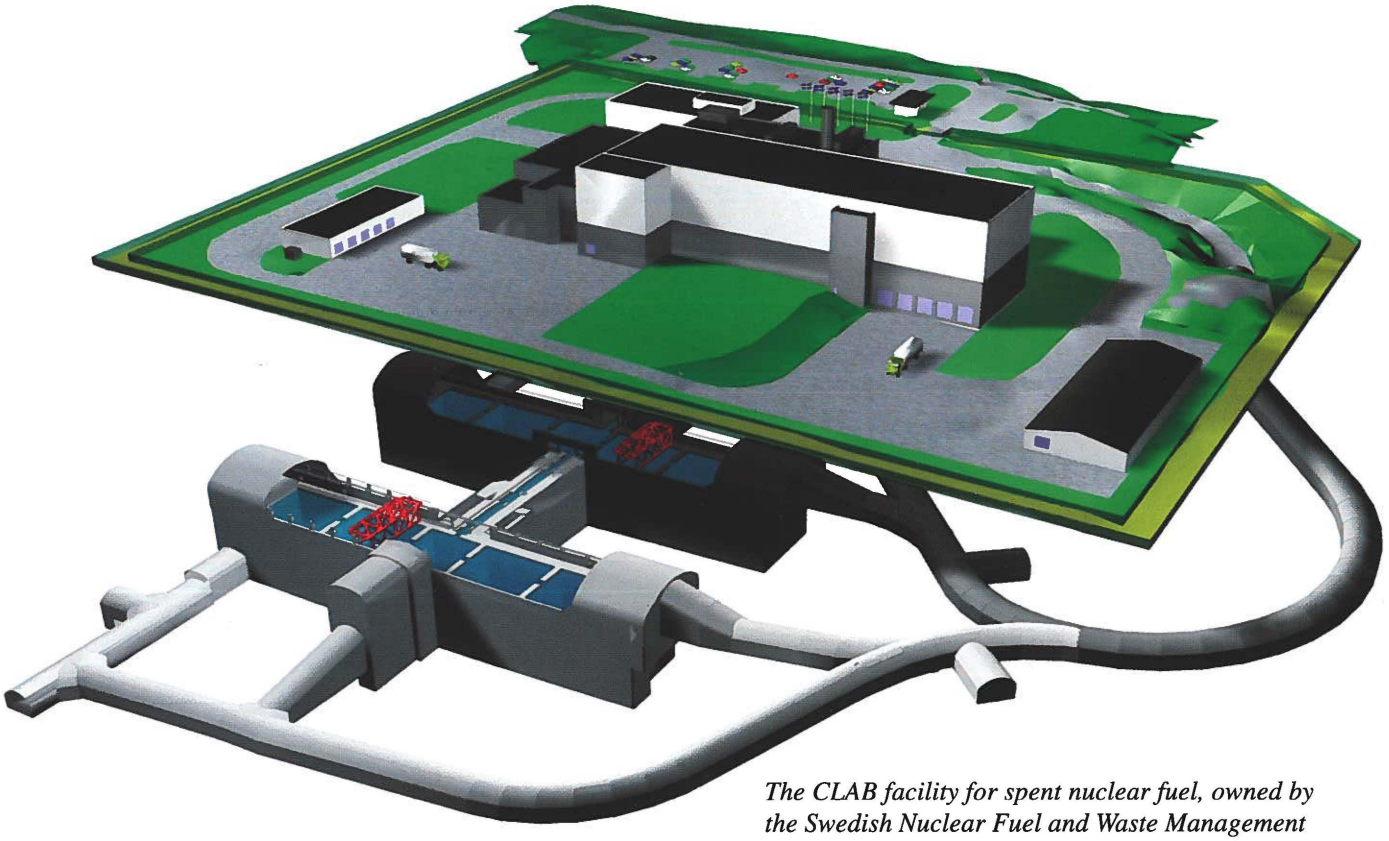
Financing and time schedule

Estimated cost for Södra Länken is SEK 6,500 million, of which 5,680 million will be provided by government funding and about 827 million by the City of Stockholm. If there are cost overruns, the government will cover 75% and the City 25%. Operation of the completed Link will be financially supported by the government to the tune of SEK 15 million annually. In respect of costs, it should be mentioned that this project has not only suffered political delays but has already cost millions because of the destruction of machinery by so-called 'ecological activists'.

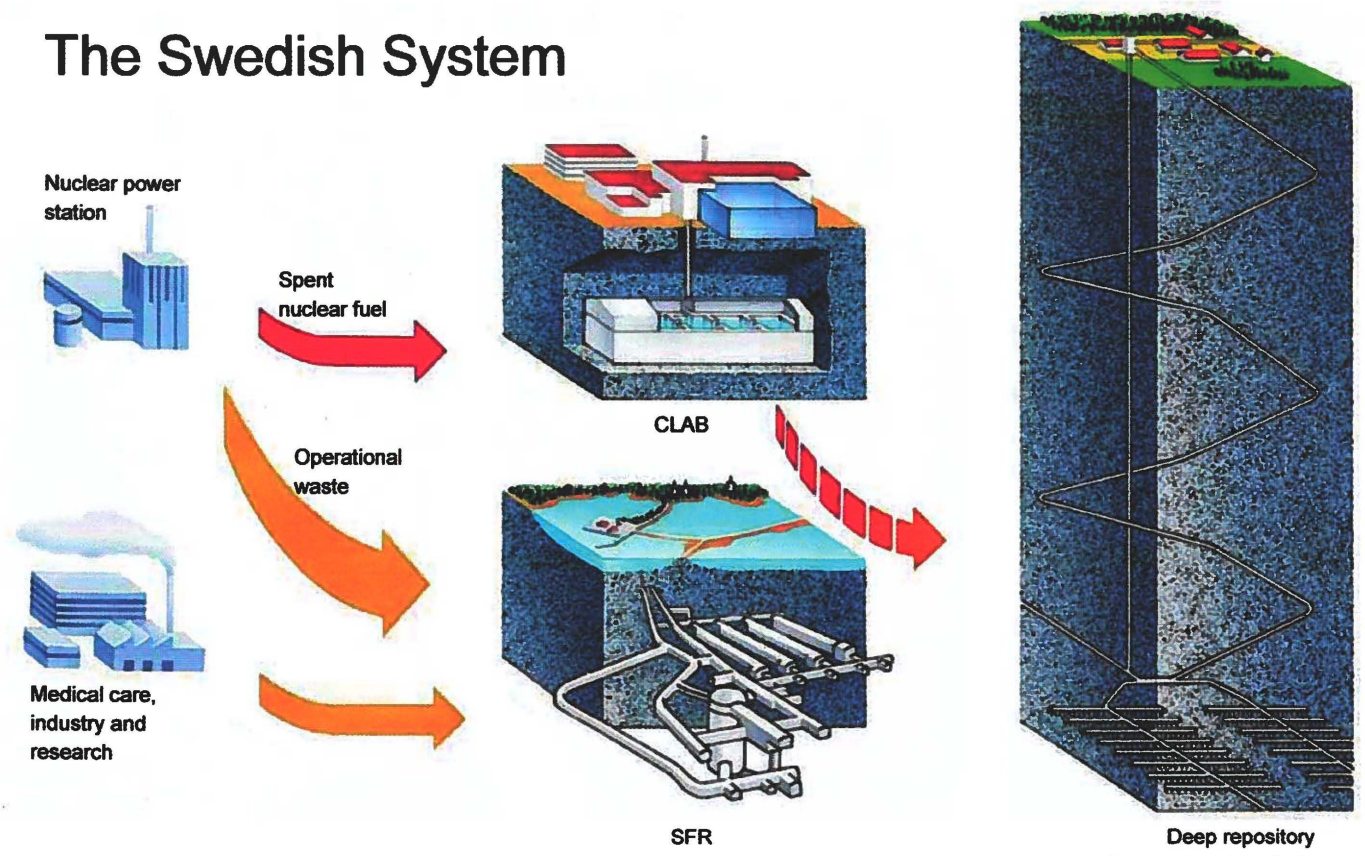
Construction started in the autumn of 1998. Rock works should be finalized in the year 2002, and inauguration of the whole Link is scheduled for 2004.

For further information, please contact:

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The CLAB facility for spent nuclear fuel, owned by the Swedish Nuclear Fuel and Waste Management Co (SKB).



The complete Swedish nuclear power concept.

CLAB Stage 2 - a Challenge in Controlled Rock Construction

Facts

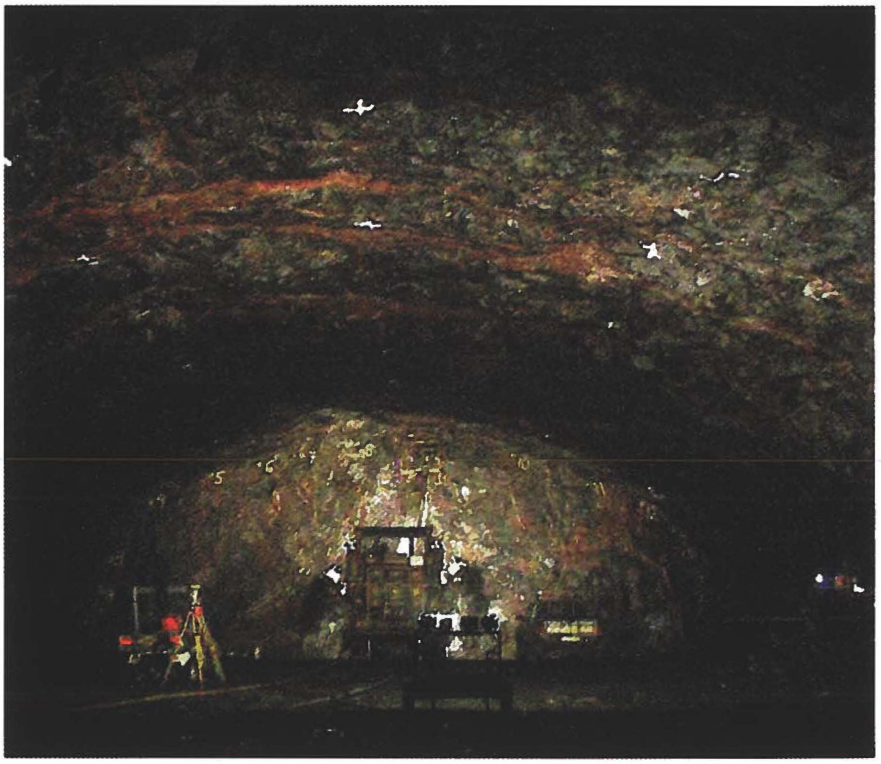
Owner:
Swedish Nuclear Fuel and Waste Management Co (SKB)
Contractor:
Skanska Sverige AB
Consultant: SwedPower AB (rock engineering)
Construction period: 1998-2003

The safe disposal of nuclear waste and spent fuel is a vital requirement for the future of our society. The central interim storage facility for spent nuclear fuel on the east coast of Sweden, known as the CLAB plant, was put into operation in 1985. But as the existing storage is scheduled to be fully utilised by the year 2004, the Swedish Nuclear Fuel and Waste Management Co (SKB) decided to build another rock-cavern storage at the same location. The fact that this addition is very close to the existing cavern where some 3,000 tonnes of spent fuel is currently stored, meant that very specific and stringent safety measures had to be enforced during all stages of construction of the new rock-cavern.

This article does not deal with the technical aspects of the construction work, but focusses on the rigorous and essential procedures needed to ensure that the highest possible safety standards are being maintained, both for the existing facility and the environment.

In order to obtain the necessary permits from various authorities before the project could start, a number of Legislative Acts had to be examined. These included the Nuclear Activities Act, the Management of Natural Resources Act, the Environmental Protection Act, and the Water Act.

In addition, a detailed project description had to be submitted to more than 30 authorities for their consideration. This description focussed particularly on blasting procedures and their impact on the immediate environment.



	Length	*Width*	*Height*	*Area m²*	*Volume m³*
Cavern No.2	120	21	27	530	70,000
Canal tunnel	40	10	22	190	9,000
Transport tunnel	400	8	5	37	16,000
Total					95,000

Dimensions of the CLAB storage addition (CLAB stage 2).

Quality assurance

Because of the sensitive nature of the project, its quality and safety aspects have been - and will continue to be - the major issues throughout the construction and operation of the new storage facility. With this in mind, the owner SKB has drawn up several detailed documents for Quality Assurance (see figure).

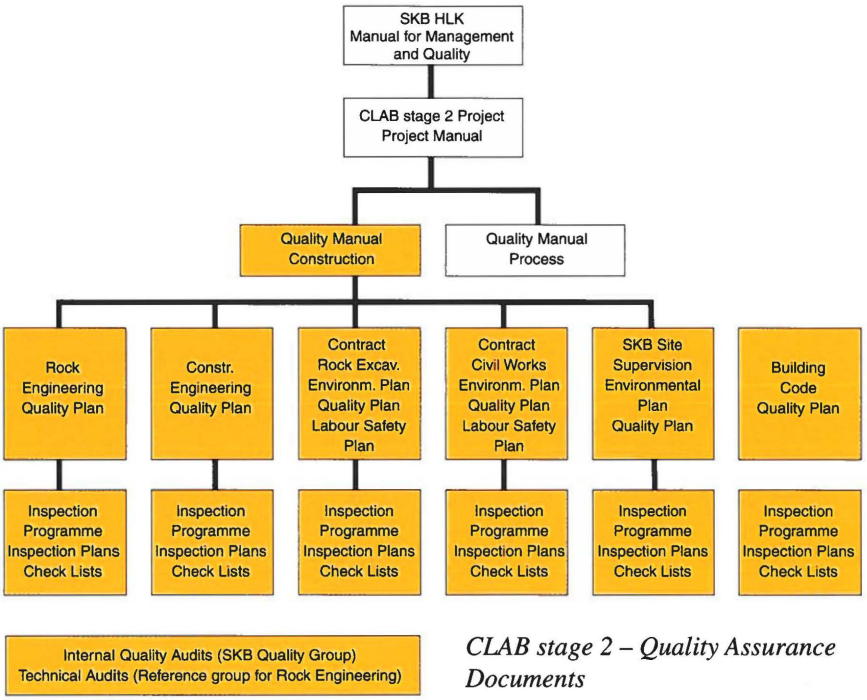
The maxim underlying the effort to meet the strict safety demands, is "not only to make sure that what is done is done right, but also to make sure that it is the right things that are being done".

Preparatory studies in-situ

A number of studies were undertaken to accompany the various permit applications. The following study topics are particularly relevant to the blasting operations:

- Bedrock geology
- Environmental impact
- Rock mechanics investigations of stability conditions, and possible impact on the existing rock storage (e.g. by rock stress measurements)
- Rock mechanics investigation of blasting-induced dynamic loads on the existing rock storage
- Proposed programme for vibration and deformation measurements
- Proposed procedures regarding quality assurance of rock caverns and structures

One of the most important authorities in the evaluation of these and other reports has been the Swedish Nuclear Power Inspectorate, which has also provided many observations of value for the project's progress.



CLAB stage 2 – Quality Assurance Documents

Risk analyses

A number of risk analyses are being carried out, including:

- Overall analyses by the project management to identify all risks that could prove hazardous to the implementation of the project within the scheduled timetable and budget.
- Detailed analyses of all incidents during rock construction that could lead to functional damage in the existing and new storage caverns.
- Conventionally executed risk analysis, which is carried out frequently in connection with the site inspection preceding the rock works.

Education

In a highly sensitive project of this type, it is vitally important that all personnel - whatever the form of their participation – are made fully aware of all the project's pre-requisites. They must also be thoroughly informed about all the regulations governing the construction work, and understand them completely.

Concluding remarks

Looking further ahead and after about 30-40 years in the intermediate storage at CLAB, the spent fuel will be encapsulated in copper canisters and moved to a deep repository also in rock excavated about 500 m below surface. Extensive investigations to find a suitable location to dispose of the spent nuclear fuel for its final storage are at present being undertaken in Sweden.

In the limited space available here, it has only been possible to give a very brief overview of some aspects of the CLAB stage 2 project. We therefore invite interested readers to contact us if they would like further information.

For further information, please contact:

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Extension of the Käppala Sewage Treatment Plant

Facts (for reconstruction)

Client and Owner:
Käppala Association
Building and Rock Consultant:
J&W Bygg & Anläggning AB
Construction period:
1994-2001

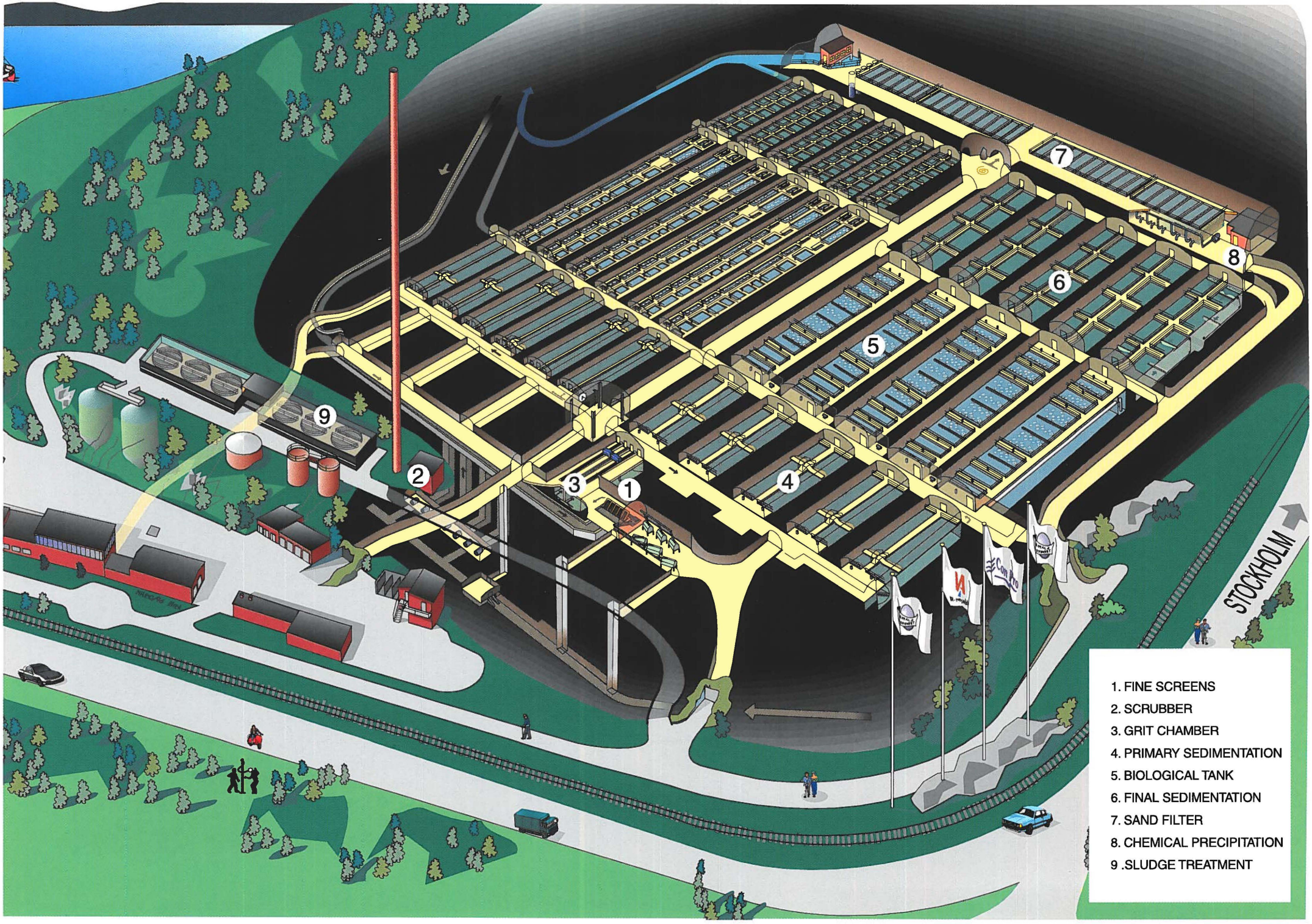
Käppla is one of the world's most effective sewage treatment plants. Eleven municipalities in the Stockholm county forming the Käppala Association are today served by this plant, which is designed for a population of 500,000.
Because of an estimated increase in population during the coming decades and the need to improve treatment processes further, it has been deemed necesssary to extend the plant's capacity. By the year 2020, it is expected to serve a population of 700,000.

The Swedish Parliament has decided that all large sewage treatment plants around the Swedish coast, from the Swedish/Norwegian border to the town of Gävle on the Baltic Sea, must reduce the Nitrogen content of waste-water by at least 50%. About 70 sewage treatment plants will be rebuilt and many billions SEK will be invested in modernizing and extending these plants.

The Käppala plant
Construction of the tunnel network, totalling 60 km, started in 1958, and the Käppala installation has been in operation since 1969. Since 1994, extensive structural alterations and extensions have been made to the Käppala plant. They have involved an almost three-fold increase in rock cavern volumes, from 250,000 m^3 to 700,000 m^3 of excavated rock.

"Our aim a cleaner archipelago Käppala 2001". Stockholm is a city surrounded by water, with the archipelago just round the corner. The picture is taken from Käppala.




1. FINE SCREENS
2. SCRUBBER
3. GRIT CHAMBER
4. PRIMARY SEDIMENTATION
5. BIOLOGICAL TANK
6. FINAL SEDIMENTATION
7. SAND FILTER
8. CHEMICAL PRECIPITATION
9 .SLUDGE TREATMENT
STOCKHOLM

The four major improvements are:

- increased capacity (and plant volume)
- decrease of Nitrogen content
- improved working environment
- better ventilation installations to prevent odour in and outside the plant

To purify the outlet air, a so-called scrubber has been installed, and a 150 m high chimney has been built. Improved safety measures, new sprinkler systems and gas extinguishing systems have also been installed. The heat in the incoming sewage water is utilized to heat the premises, making the plant practically self-supporting in this regard.

Recycling

In the operation of the plant large amounts of sludge are produced. The sewage comes principally from households, offices and the food industry. Consequently, the amount of heavy metals is very low, so the sludge can be treated, turned into biosolid and in this way returned to its natural cycle.

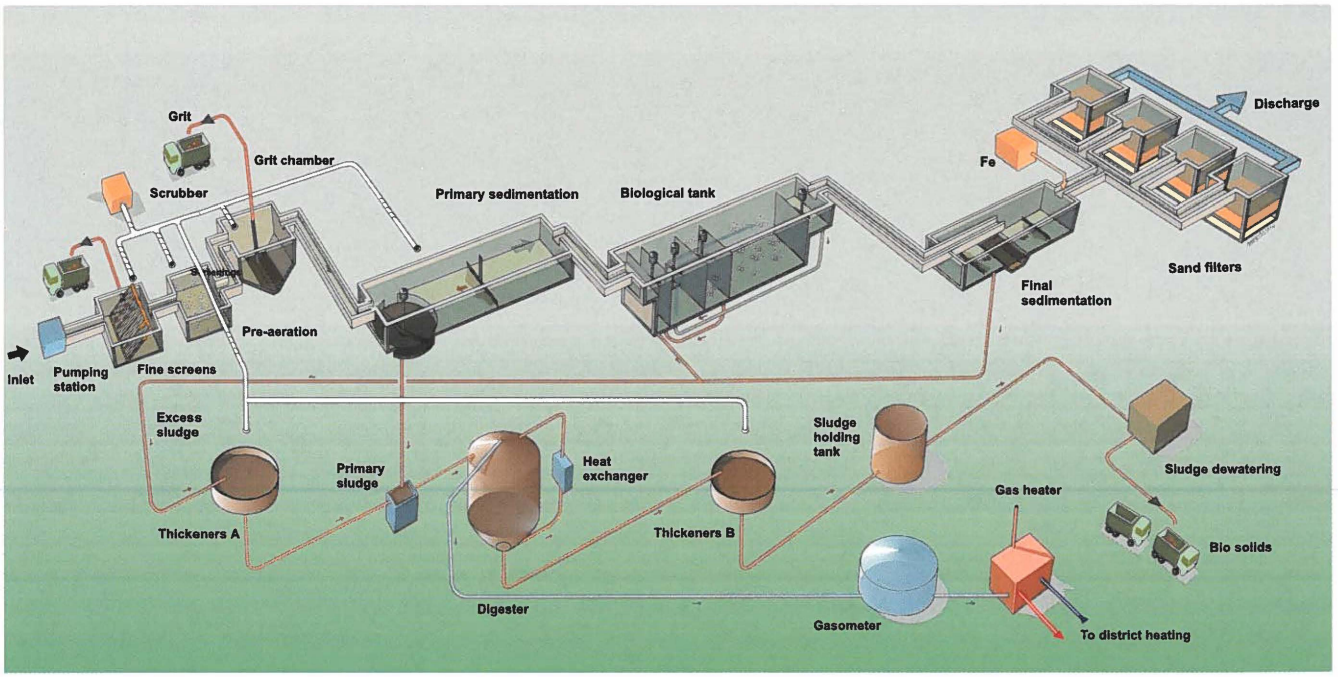
Costs and financing

The total costs of the entire extension, including modernization of the old part, are estimated at SEK 1 200 million /USD 150 million (January 96). Operating costs are expected to rise from USD 5 million to USD 6.5 million in the year 2000. All customers connected to the Käppala plant

The member municipalities of the Käppala Association, and the 60 km tunnel system to Käppala.



pay water charges which cover sewage treatment charges. For house-holds, this charge is today about USD 0.15 per 100 litres of water. One fifth of this is used for sewage treatment.



The processes in sewage treatment are pre-treatment, mechanical separation, bilogical and chemical treatment, filtration and sludge treatment. The treatment of about 150,000 m³ of sewage a day (or 50 million m³/year) with a plant throughput of about 20 hours, requires very large-volume structures.

For further information, please contact:

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Fax: +46 8 766 67 01
E-mail: tp@kappala.se
Website: www.kappala.se





Drilling and blasting right under the Arlanda Airport Terminals with minimum disturbance of airport operations. All categories of personnel contributed greatly to the successful completion of a complicated excavation job. (Photos: Linus Levinson)

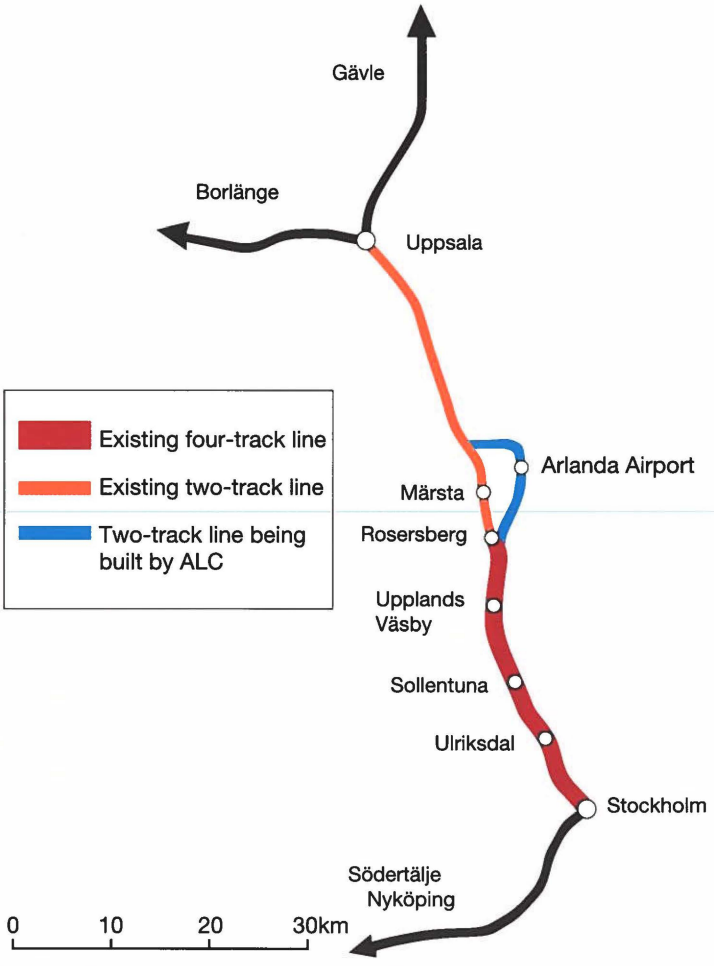
The Arlanda Link Express Railway: Stockholm-Arlanda Airport

Facts

Client: A-Train AB
Owner: A-Banan Projekt AB
Contractor:
NCC/Siab (Banbrytarna)
Consultant:
Swedpower, Tyréns,
NCC Teknik
Construction period:
1995-1999

At the end of 1999, an express railway from Stockholm and a loop from the main line between Stockholm and Uppsala will carry passengers to the airport terminals. There will be three stations under the airport, two of them serving shuttle trains leaving Stockholm city every ten or fifteen minutes. The trains will run non-stop at a speed of up to 200 km/hr, and complete the journey within twenty minutes.
As part of the project, 8,860 m of tunnels have been driven, and in total, 820,000 m³ of rock have been excavated.

The Arlanda Link is Sweden's first major infrastructure project, built mainly with private finance. It is a so-called BTO (build-transfer-operate) project. The rock excavations were carried out by the Swedish contractors NCC and Siab in a joint enterprise "Banbrytarna". Another new company, A-banan Projekt AB, owned by the National Civil Aviation Administration and the Swedish Railway Administration, was established to represent the Government's interests. Organization at the work site was set up during the autumn 1995, and by the start of 1996 production was in full swing, three shifts a day on four fronts. In late summer 1997, the rock excavation was completed and installation works started.



Arlanda Airport is situated 39 km north of Stockholm city. The map illustrates the additional connection to the main railway line between Stockholm, Uppsala and Northern Sweden.

Geological conditions

Technically, the Arlanda Link is among the most interesting underground projects ever undertaken in Sweden. The rock overburden varies between 5 and 15 m and in the central areas under the airport terminals the bedrock consists of mica schist of varying strength. Rock quality was classified according to Barton's Q-values, and the quality varied between Q=1 and Q=40, with an average of Q=7 in the mica schist.

Heavy loads from the terminal buildings in combination with weak rock and shallow rock overburden (mostly 8-10 m with a minimum of 5 m), put stringent demands on excavation techniques and rock reinforcement procedures.

Ambitious control programme

The extensive programme for control of rock movement and deformation during excavation has provided comprehensive knowledge of the behaviour of the rock mass before, during and after passage of the tunnel front. Rock movements were monitored by three independent systems:

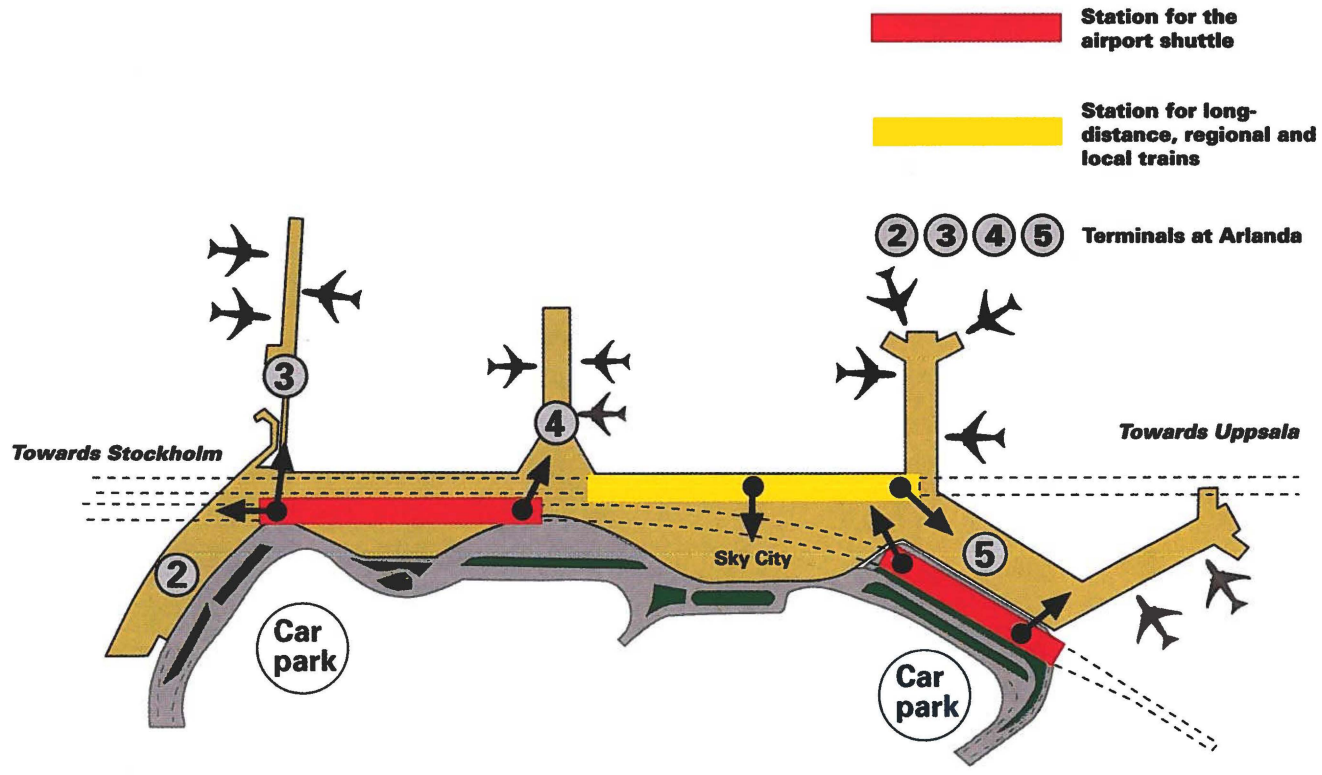
a) Convergence measurements
b) Precision levelling
c) Extensometers

Measurements were carried out at a total of 420 locations, and in addition, crack width changes were checked at about 30 locations in the airline terminals and the buildings of Sky City. With the advance of the tunnel fronts, continous measurement of ground vibrations took place at 10-20 locations. When a blasting round induced vibrations close to the maximum permitted peak particle velocity (ppv), the firing sequence was modified for the next round. Normally, the drill hole depth was 5.2 m, but in the most sensitive areas, the hole depth was reduced to 2.5-3 m. This was necessary for only about 10 % of the rounds, which was less than had been predicted after studying the results of core drilling and rock classification. An explanation is that the mica schist absorbed more of the vibration energy than was calculated.

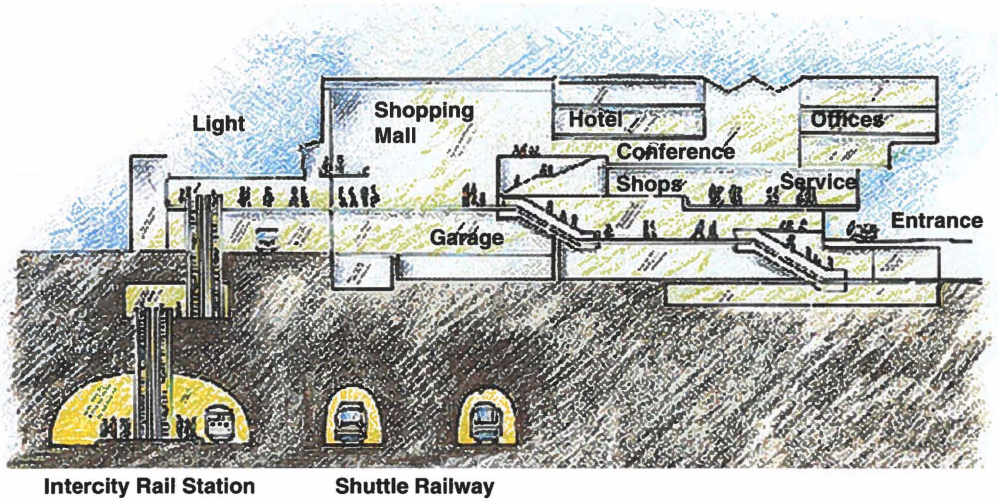
Grouting methods

All the terminal buildings are founded on rock while the major parts of runways 1 and 2 are founded on clay. Maximum allowed subsidence of the runways was 1 cm. Groundwater balance was of utmost importance, and the maximum inflow in the tunnels was set to 5 litres per minute per 100 m of tunnel.

All rock tunnels and caverns



Plan view of the airline terminals and their connection with the underground railway stations.



Cross section through the railway station and the Sky City facilities.

were pre-grouted. With regard to the shallow rock overburden and the sensitivity of terminal buildings etc., low grouting pressures were used. In some cases, the low pressures gave poor results with too much leakage, so the grouting pressure sometimes had to be increased to as much as 6 MPa. The structures on the surface were closely monitored and no severe damage was observed.

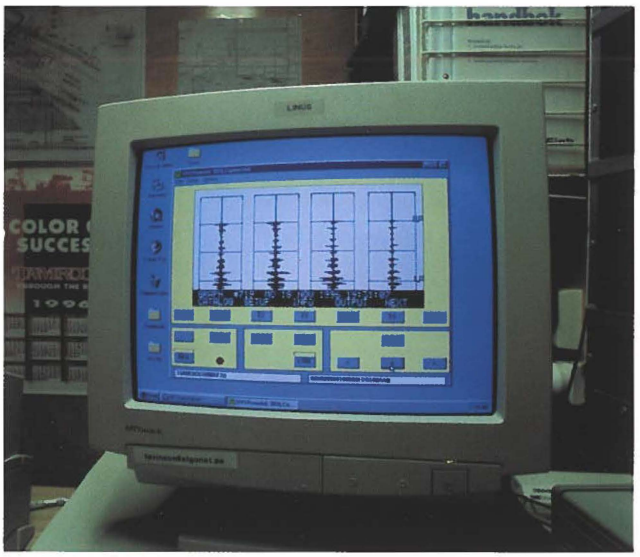
In some areas, curtain grouting was carried out with a "split spacing" technique. A row of 20 m long, 64 mm diameter curtain holes were drilled and grouted. The curtain extended 4 m beyond the tunnel contour. Then, a second row of holes, placed between the first ones were drilled and tested with water pressure. If the leakage was too high, these holes were also grouted, and a third row of holes were drilled before further water pressure testing. The process was repeated until water leakage was less than 5 litres per minute per 100 m of tunnel.

Where contact grouting was used, the cast concrete and the rock were secured with temporary rock bolts dimensioned for 0.5 MPa grouting pressure.

Rock reinforcement

It was decided to carry out permanent rock reinforcement close to the tunnel fronts. Four "reinforcement classes" were defined, based on observed Q-values. Engineering geologists followed the construction work round the clock, mapping and classifying every round. After mucking out and scaling, shotcreting and bolting were carried out according to the programme worked out by the geologists. Scaling was fully mechanized, and so reinforcement became an integrated part of tunnel driving. The system was highly appreciated by all personnel, as it meant that the tunnelling crews could work under a secured roof.

Recording of blasting vibrations during construction. (Photo: Linus Levinson)



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Web-site: www.ncc.se

Progress of the KUJ 2000 Project in the Kiruna Mine

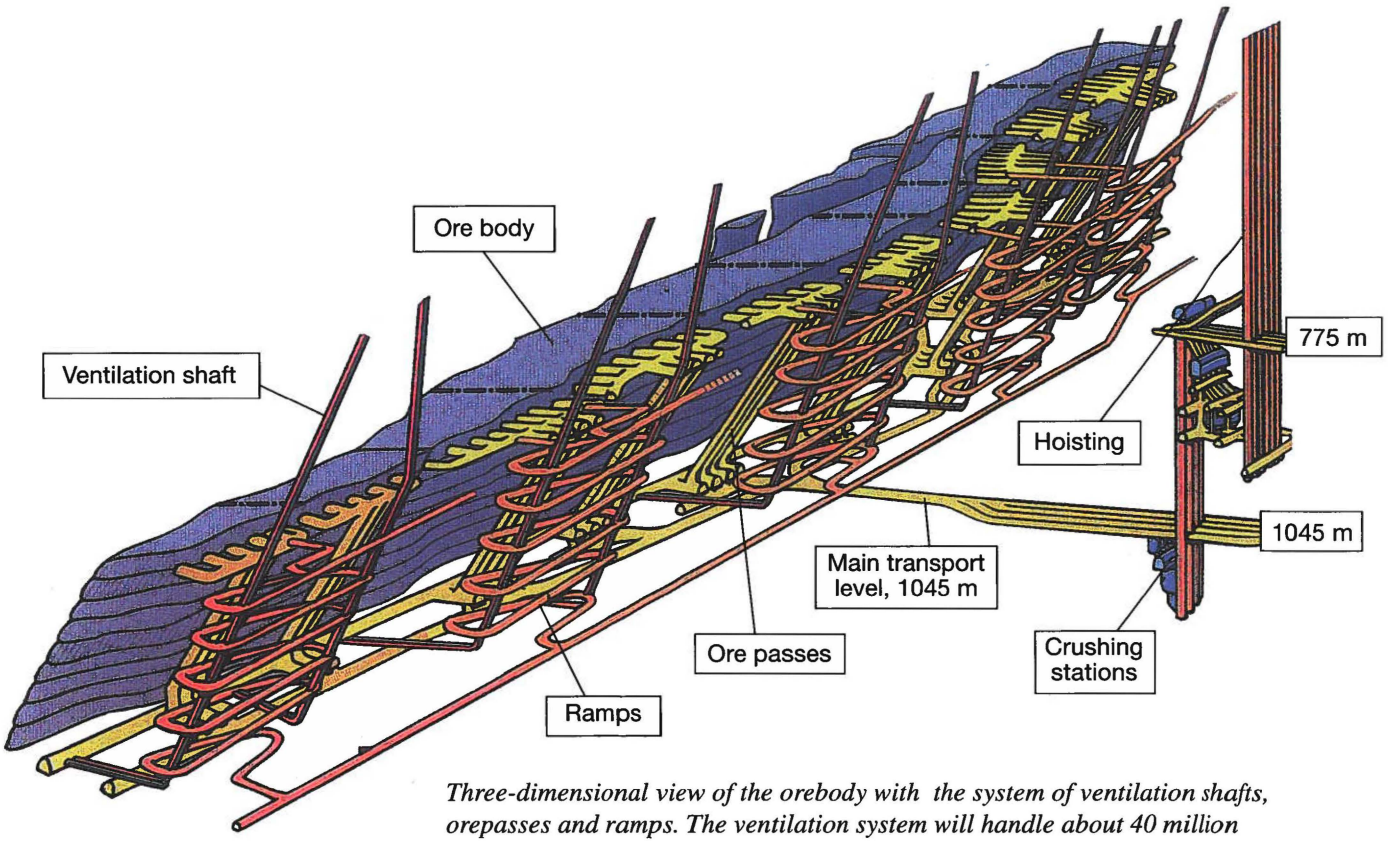
Facts

Owner: LKAB
Contractor:
NCC AB Anläggning
Construction period:
1994-2001

In the first edition of "Sweden in Focus" (1996), we published an article on the KUJ 2000 Project at the Kiruna iron-ore mine. It has proceeded according to plan, after the new haulage level was inaugurated by the King of Sweden on August 28, 1997 in the presence of about 300 international guests.
As a part of KUJ 2000, the biggest raise-boring project in the world is now well under way in the mine. A total of 20,000 m of ventilation raises and 10,000 m of orepasses will be driven. Work started in 1994 and will be completed in 2001.

The automation and remote control systems for the iron-ore production are now in operation. The production drilling rigs work automatically and one operator supervises three rigs from the central control room at 775 m level. Each rig drills one fan-shaped pattern of blast holes in eight hours. It is then moved 3 m along the drift by miners in the production area, after which it is again put into automatic mode. The system allows four operators to drill blast holes producing about 7.5 million tonnes of ore per year.

The first LHD machine equipped for automatic and remotely controlled loading and transport operations has also



Three-dimensional view of the orebody with the system of ventilation shafts, orepasses and ramps. The ventilation system will handle about 40 million tonnes of air per year.

been installed in the mine for testing. When the system is fully installed, one operator will supervise three loaders, producing over 1 million tonnes of ore per year.

For fresh air supply to the ten production blocks in the mine, an extensive system of ventilation raises is being driven. The length of the raises varies between 250 and 450 m. Boring is carried out with a 350 mm diameter pilot hole which is reamed to 3 m. Maximum deviation of the pilot hole is 1 %. Average bit life for the pilot hole bit is 180 m and cutter life for the reamer is about 350 m. Four raise-boring rigs are in operation, each one producing 5 m of completed raise per 20 hours working day.

The orepasses are bored in two steps, 125 to 170 m long, also with 3 m diameter. The inclination is 60 degrees for orepasses as well as ventilation raises. Since the orepasses are subjected to hard wear during operation, the rock is reinforced with cable bolting and cement grouting. This work is carried out from a raise climber running on guides bolted to the hanging wall of the raise.



Full face boring of a 450 m deep ventilation raise from the surface. The administration building is in the background.

The table below illustrates the extent of rationalization during 25 years.

	1975	1998	KUJ 2000 completed
Crude ore production	21.1 Mt	21.8 Mt	
Drifting	65,700 m	14,400 m	
Drilled m production	2.2 Million	0.8 Million	
Hole diameter (production)	51 mm	115 mm	
Drill rigs (production)	30	7	6
Drill rigs (drifting)	34	5	3
Loaders	80	8	8

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Electric Power Going Underground

Facts

Client: City of Solna
Project administration:
SCC Scandiaconsult AB
Design:
NCC, Tyréns,
Tenne Geoconsult AB
Contractor: NCC
Subcontractors:
Birka Services, Bergsäker,
BESAB, Billefält Transport

Solna is a town situated about 5 km north of the centre of the city of Stockholm. The Southern Bergshamra residential area lies within the recently established National City Park. The natural and cultural features of the park are to be preserved and also improved by taking measures to eliminate possible environmental problems.

During the years 1984-1989, a number of residential buildings were erected close to two existing 245 kV overhead power lines. The high price of land in Solna, with an area of 22 km^2. and a population of about 52,000, made the area attractive in spite of the power lines, built after a concession in 1947.

In the 1990s, the effect of magnetic fields on the health of people has been debated intensely. Even if it is difficult to prove statistically that the magnetic field around a power line can be the cause of disease, the public has been alarmed. Investigations have been carried out regarding the intensity of the magnetic field as a function of distance from the power line. In Solna, the alternative of replacing the overhead power line



Residential area close to 245 kV power line. The powerline poles dominate the view, and their removal will change the landscape considerably.



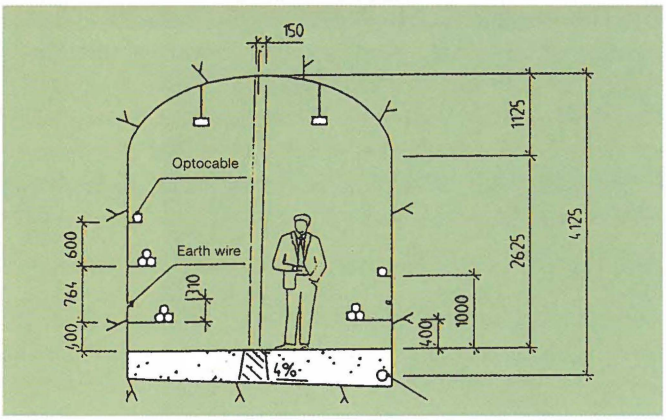
Tunnels were driven with conventional drilling and blasting. Closeness to buildings and roads required strict control of blast vibrations.

with cables installed in tunnels was considered. It was found that by placing the cables in tunnels with minimum 10 m overburden of rock, the magnetic field could be screened effectively. Of course, the tunnel alternative is considerably more expensive than an overhead power line, but besides the aesthethic advantage, removing the power line poles would free valuable space for other purposes.

When the local political decision to go ahead had been taken, tunnelling started in October 1997. From a point in central Bergshamra the tunnels run to the north, west and south. Total tunnel length is 1,780 m and excavated volume is 34,000 m^3. Excavation work was completed in October 1998.

The tunnels have been driven with conventional drilling and blasting. The cross section is about 18 m^2. Since there are two separate power lines entering the Stockholm area, the lines are separated by a vertical wall in the tunnels. This wall will withstand fire for one hour and shock waves corresponding to 1.5 kN/m^2. The cables are installed three by three in triangles, which makes the magnetic field harmless at a distance exceeding 10 m.

Terminals at the surface connect the cables with the overhead power lines via shafts 20-30 m deep. The shafts also serve as emergency exits and for ventilation and cooling of the cables.



Section of the tunnel with cables on racks at the side wall and a centric wall.

For further information, please contact:

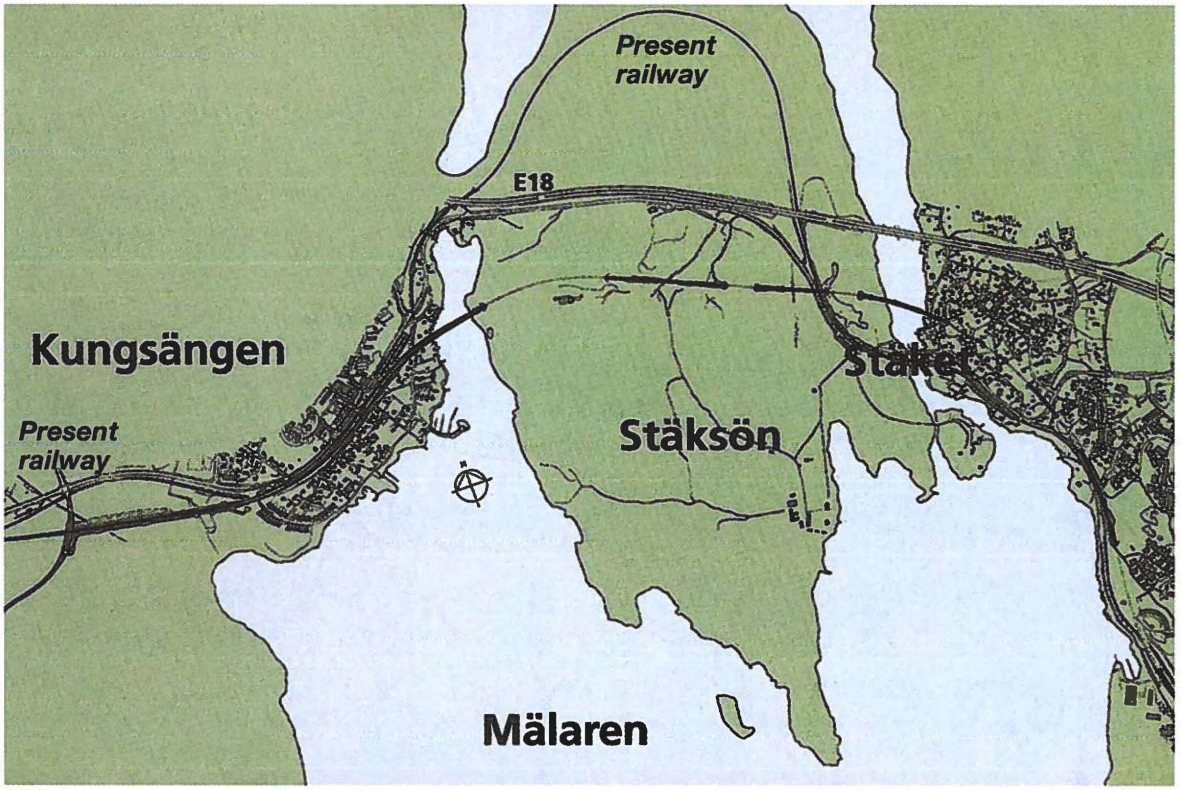
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Sophisticated Tunnelling Eliminates a Railway Bottleneck

The single-track railway between Kallhäll and Kungsängen stations north-west of Stockholm was built in 1876, with a pivot bridge over the narrow Stäket Sound. Only maintenance work has been carried out on this stretch of railway since it was constructed, while the rest of the main line around the northern side of Lake Mälaren is being rebuilt to modern standards for trains capable of speeds up to 200 km/hr. Installation of double tracks between Kallhäll and Kungsängen had been discussed for many years as this section is one of the most frequently used single-track railways in Sweden. In February 1997, the project was started. On completion, planned for the Spring of 2001, the new 7 km long twin-track railway will reduce travel time considerably for long-distance trains. It will also allow increased frequency for the many commuter trains running between Kungsängen and Stockholm.

Facts

Client and owner: Swedish National Rail Administration
Contractors:
Södertälje Väg & Bro AB, Swedish National Road Administration, Peab Berg AB, NCC Anläggning AB, Pihl & Son/Per Aarsleff
Construction period:
1997-2001



The new railway, including its tunnels and bridges, will be 1.7 km shorter than the existing single-track line.



The tunnel opening had to be located at a point with only 70 cm of rock overburden, so the contractor had to construct an about 3 m thick arch of reinforced concrete before starting the excavation. (Photo: Johan Bergstrand)

The new railway will pass through a densely populated area with many residential villas, and the project comprises six short rock tunnels and new bridges. The tunnels range from 70 to 480 m in length, and are being provided with concrete surface extensions to reduce the noise of trains. The rock- tunnelling work has been divided between five contractors, and in total there are nine contractors engaged on the project.

One of the tunnels is of special interest. It will be 350 m long, and is being driven underneath a number of villas, mostly with very little rock overburden. For the first 50 m (part 1), the overburden is 2-4 m; for the next 100 m (part 2) it is 0-2 m; and only for the remaining 200 m (part 3) is the overburden more than 4 m deep.

The tunnel has a cross-sectional area of 125 m^2, a width of 14 m, and a height of 12 m. It is being driven with a 43 m^2 pilot tunnel, which is then stoped out to the full area. Ahead of the tunnel front, 7 m long grouted bolts are installed with 60 cm c/c (centre to centre distance). For every 2 m of the pilot tunnel, three upholes are drilled in the roof to determine the depth of rock overburden. Stoping to the full area is carried out with 2.5 m long rounds. Reinforcement consists of shotcreting and systematic bolting in a 1.25 x 2.5 m pattern, and parts 1 and 2 of the tunnel will be lined finally with concrete.

Immediately above part 2 of the tunnel, there is a villa that had to be kept intact. This presented the contractor, Peab Berg AB, with a very intricate problem as the the building is situated right on top of the tunnel where there is practically no rock overburden. The following driving technique is being applied. Firstly, pre-grouting is carried out with 15 m long holes injected with low pressure. The surface is checked during grouting to see that no grout comes out of the ground, and then the pilot tunnel is driven with 1.5 m long rounds. Blasting vibrations are measured continuously, and after each round, up-holes are drilled to investigate the rock overburden. In order to construct a strong roof, a screen of 5 inch diameter pipes is installed ahead of the tunnel. Each pipe contains a drill bit that is left in the rock after drilling 15 m and then retracting



Looking up at the tunnel roof beneath the villa. The picture shows the 5 inch diameter pipe screen, wire mesh and shotcrete. The sewage pipes are visible just above the tunnel roof. (Photo: Johan Bergstrand)

the inner drill rod. The pipe consists of 3.5 m lengths welded together as drilling progresses, the pipe being perforated every 2 m for the cement grouting. The whole screen consists of 23 pipes with wire mesh and shotcrete, and after it is completed the tunnel is stoped to the full area with 1.5-2.5 m rounds. Before lining, the tunnel is reinforced with steel-fibre shotcrete and bolting in a 0.5-1.0 m pattern.

In addition to measuring blasting vibrations, there is close monitoring of deformation and ground subsidence by measurements every 10 m of tunnel. Construction has so far proceeded without major social problems, largely due to frequent contact with the public to keep people well informed. Technically, this is one of the most complex tunnel projects ever carried out in Sweden. Underground work started in August 1998, and is due for completion in January 2000.

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Highway under the North Atlantic

After 25 years of discussion, a report by the Economic Studies Unit of the University of Iceland concluded in 1992 that a tunnel under the 3-4 km wide Fjord of Hvalfjördur would be one of the most economically viable major road projects ever initiated in Iceland, and one which would generate large financial contributions to the national economy. When completed, it would considerably shorten driving distances between towns and villages in west Iceland, and also provide great benefits in terms of time and convenience for all drivers travelling to the west and north from the capital.

The Hvalfjördur tunnel project, with a total length of 5.7 km, is the result of years of extensive preparation both in Iceland and abroad, involving several groups of experts in the fields of engineering, transport and finance. The project was completed in 1998, eight months ahead of schedule.

Facts

Client:
Icelandic Public Roads Administration
Owner: 1998-2018 Spölur; 2018- Icelandic State
Contractor: Fossvírkí SF consortium (Skanska AB, Sweden, Ìstak hf, Iceland, and Phil & Sön, Denmark)
Construction period: Feb 1996-Sept 1998
Type of contract: Turnkey (design and build)

The Fjord of Hvalfjördur is 30 km long and 3-4 km wide. Before the tunnel project was implemented, driving distances between towns and villages on opposite sides of the fjord were considerable. The tunnel project comprises a 5,762 m long three-lane tunnel of which 5,484 m is driven in rock. The section of tunnel passing under the fjord is 3,750 m long, and there are 278 m concrete tunnels at both entrances.





View and route of the Hvalfjördur tunnel (blue)

Geological conditions and investigations

Iceland is situated on the Middle Atlantic Ridge between the earths North American and European tectonic plates. Every year, these plates are moving about 2 cm apart, and the successive joints are filled with volcanic basalt rock. As a consequence of these tectonic move-

ments, the rock mass is intersected by fault zones, one of which crosses Iceland from southwest to northeast and is located approximately 30 km from the Hvalfjördur tunnel.

Depending on when each fault occurred, it can reach all the way to the surface. The faults are sometimes non-permeable in relatively good rock, but they can also be associated with extensive crushed zones. In both cases the geological conditions for tunnel excavation can change very suddenly.

Throughout the whole construction period, the contractor undertook a number of wide-ranging seismic and geological surveys to assess the risk of leakage and the stability of the bedrock. Regular probe drilling at the front of the tunnel was also carried out.

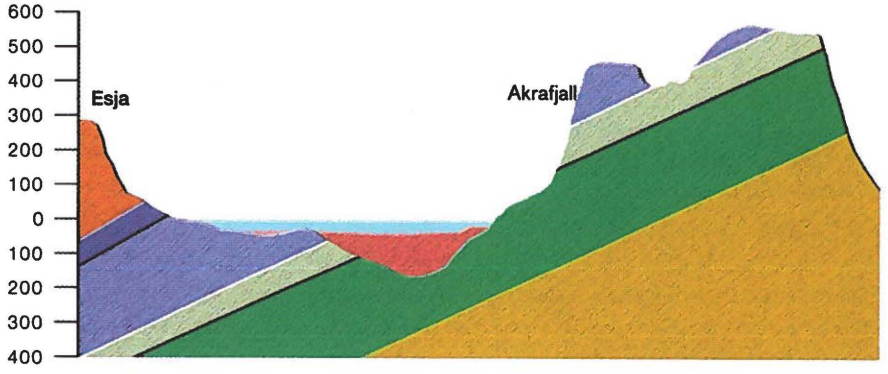
Construction details

In total, 380,000 m^3 of rock were excavated, 17,600 rock bolts were used, and 15,000 m^3 of shotcrete were placed. Only 370 tonnes of cement grout were required.

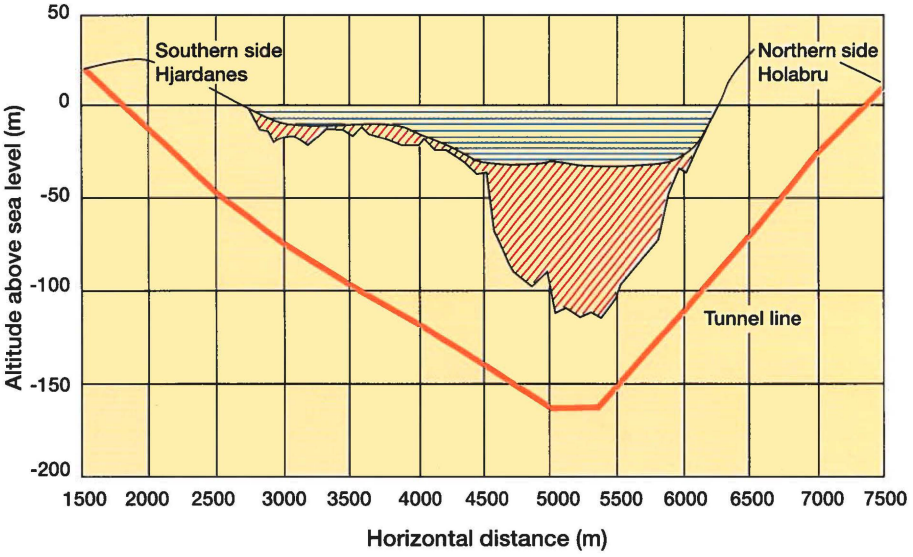
The lowest point of the tunnel is located at 165 m below sea level. At this point, there is a pumping station capable of storing one days leakage water. The maximum design leakage rate was 30 litres per minute per 100 m of tunnel, but the actual inflow of water to the completed tunnel is around 6 litres per minute per 100 m

Safety first

Very stringent safety standards were set for this project. All installations in the tunnel are monitored and controlled 24 hours a day from the northern exit, and there is FM radio reception throughout the length of



Geological composition. The diagram roughly shows the sloping rock strata on the shores and bed of the fjord.



Longitudinal section of the tunnel under Hvalfjördur.

	Present	Future
Reykjavik - Akranes	108 km	48 km
Reykjavik - Borgarnes	116 km	74 km
Reykjavik - Blönduós	286 km	244 km
Reykjavik - Stykkishólmur	215 km	173 km
Reykjavik - Akureyri	431 km	389 km

Comparative driving distances before and after implementation of the tunnel.

the tunnel. In addition the installations include:

- 32 jet-fans to supply fresh air and remove polluted air
- fire extinguishers every 250 m
- emergency telephones every 500 m
- turning points for vehicles every 500 m

If the pumps or the electrical systems were to fail, a back-up generator is available, and at the low point of the tunnel there is a reservoir capable of containing leakage for up to five days.

In addition, a contingency plan has been set up which clearly defines the role of every employee in the event of an accident or emergency.



At the steeper northern end of the tunnel there is a three-lane road, one lane of which is intended for slow-moving, heavy vehicles. At the southern end, where the gradient is less steep, there are two lanes. (Photo: Emil Thor)

Financing

The agreements on funding the Hvalfjördur tunnel are the first of their kind in the Nordic countries, and have attracted international attention. During construction, financing was the responsibility of the Fossvírkí consortium of contractors (see below). The total cost of the project was USD 70 million (Febr 1996). In brief, the bulk of the money was raised from foreign investors, with the remainder coming from domestic financial institutions and shareholders. The cost of research, planning and other preliminaries was met by loans from the Icelandic government.

The company, Spölur, is responsible for the first 20 years of tunnel operations, during which time all loans incurred by the project are expected to be repaid in full by collecting tolls. After that, the tunnel will be handed over to the Icelandic State which will thereafter be responsible for its operation.

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Construction of the World's First LRC Gas Storage Project Starts in Sweden

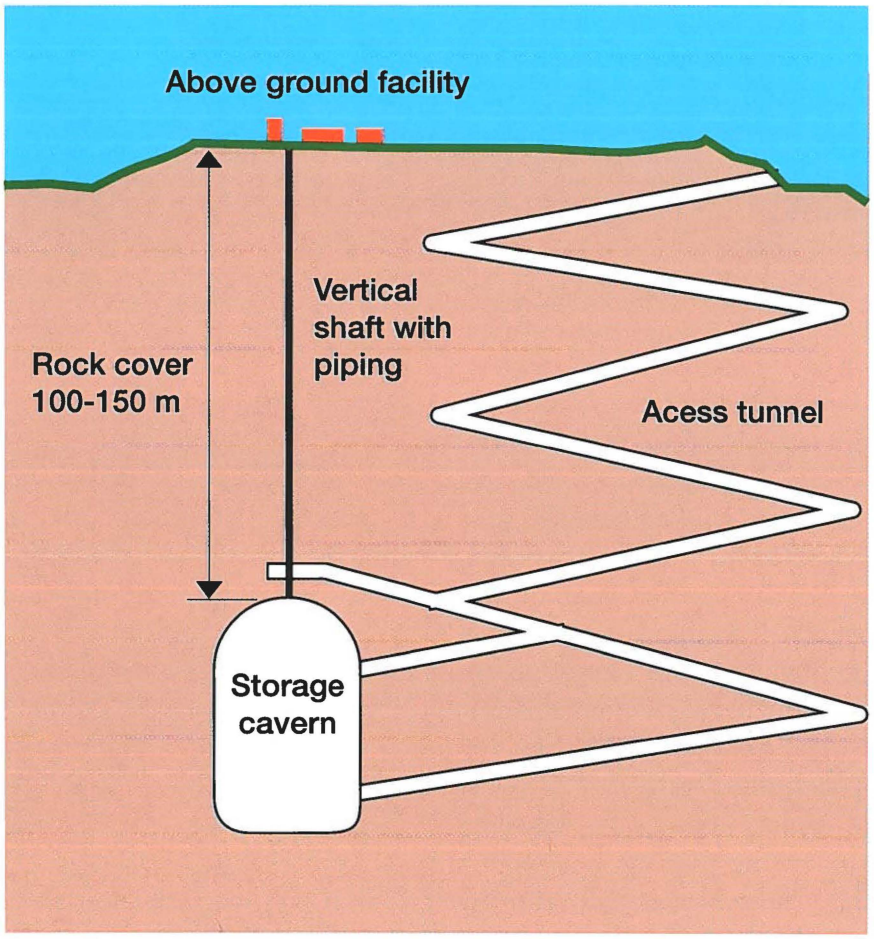
Facts

Client:
Sydkraft/Gaz de France
Owner:
SNL (Svensk Naturgas Lagring)
Contractors:
Skanska (rock works);
Elajo (mechanical installations);
(cavern-wall lining contract open)
Consultant:
Sycon Energikonsult AB
Construction period:
December 98-mid 2001

A method of storing natural gas in Lined Rock Caverns (LRC) has been developed in Sweden. Having started in the autumn of 1998, Sydkraft and Sydgas, Sweden, together with Gaz de France, are currently constructing a pilot plant outside the city of Halmstad on the west coast of Sweden. The project is an EU-supported joint venture between Sweden and France, which will demonstrate this new internationally challenging technique for storing natural gas in the future.

Since the mid 1980s when the first research and development work was carried out, the LRC method has been tested a number of times in rock caverns at the Grängesberg research station in Sweden. Further developments were made in the early 90s, resulting in an agreement with Gaz de France to co-operate in establishing the technical and economic potential of the concept. This joint exercise led to the current construction of the first pilot plant in the world.

After completion, the initial year will be devoted to testing the facility, after which it is intended that Sydgas will convert the project into a commercial storage operation.



The LRC concept involves storage of pressurized natural gas in excavated rock caverns, which are sealed with a gas-tight lining. A schematic illustration is shown above.

International markets

Natural gas is the cleanest of all fossil fuels. The EU Commission's Energy Department has predicted an 80% increase in the consumption of natural gas

within the EU between 1995 and 2005. To meet this demand, the Nordic countries are playing a central role, and the planned interconnected Nordic gas network is therefore considered of great strategic importance for all nations of the EU.

Before this development, Sweden had no economic or technically effective method of storing natural gas. But this first pilot plant is now being given priority treatment, and has received SEK 15 million from EU funds towards a total investment of SEK 200 million.

Storage of energy is vital for the gas industry, national economies and individual customers. Storage is also an important factor in a natural gas system. Many nations that rely on natural gas to provide part of their energy needs, normally have 15-20% of their annual consumption held in storage.

The LRC method will allow gas storages to be built at many different locations, thus making possible the introduction of gas energy in new territories. It also applies to international markets such as the US and Japan.

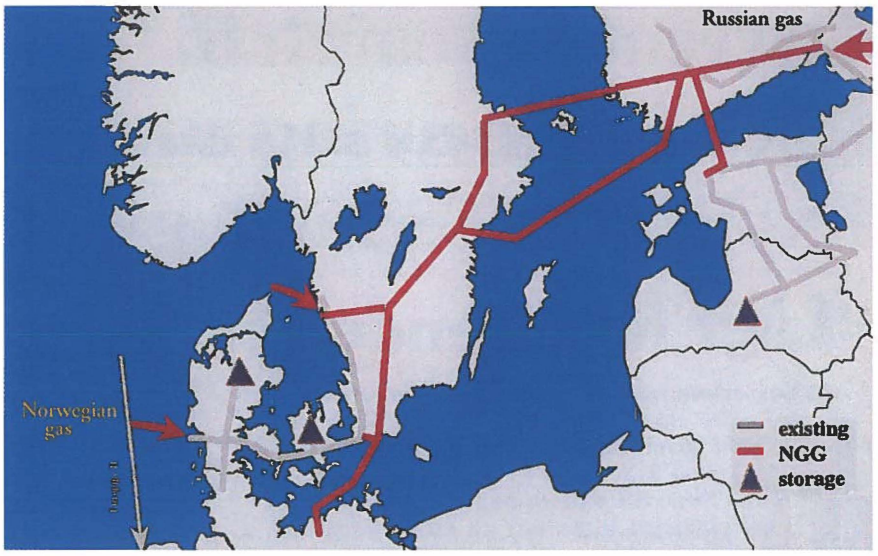
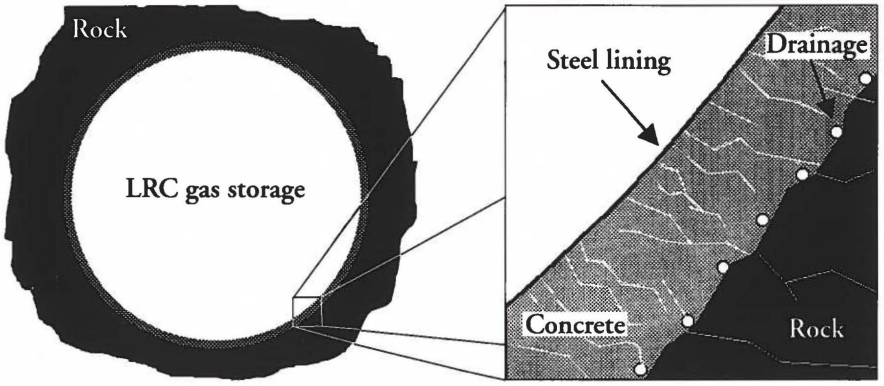


Illustration of a future gas-transportation network based on an investigation made by gas companies in the Nordic countries in co-operation with the EU. Total costs of such a scheme have been estimated at SEK 20-30 billion, and although private financial involvement is expected, the final decision to go ahead rests with the Swedish government, which must also take environmental consequences into account.

Horizontal cross-section through the storage, and an enlarged profile of the storage wall. The volume of the pilot plant will be 40,000 m³, while the full-scale project could consist of several rock caverns, each with a volume of 100,000 m³.



Construction method in brief

The surface-level section of the plant comprises the gas system, compressors, monitoring and control equipment. The sub-surface section includes an access tunnel down to the rock storage cavern, which enables excavation of the storage on two levels, as well as excavation of a tunnel above the cavern. Concrete linings will prevent gas leakage into the tunnels. A vertical shaft connecting the storage with the surface will accommodate pipes for the inflow and outflow of gas, and will also house the necessary instrumentation. The rock construction will include an access tunnel, a 95 m deep vertical shaft, a 40,000 m³ rock cavern, and drainage systems on the rock walls.

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Current Research in Rock Engineering and Explosives Technology at SveBeFo

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Looking towards the first decade of the new millennium we find some major underground projects under construction or planned, which require new techniques and approaches in response to the ever-increasing environmental concerns of our society. Deeper mining, geometrically complex road tunnels, rail tunnels in difficult geological conditions, gas storage under high pressure, and nuclear waste facilities are some of the projects being implemented.
All call for continuous research and development to enhance an economical, safe and environmentally sound technology for underground construction.

The Swedish construction industry works through SveBeFo - the Swedish Rock Engineering Research Foundation - to carry out technical and scientific research of common interest in the fields of rock construction and explosives technology. This research is financed jointly with government funds.

One of SveBeFo's main objectives is to promote collaboration between industry and university departments. The research programme is therefore to a great extent carried out under the direction of SveBeFo at the technical universities of Luleå, Stockholm (KTH) and Gothenburg (Chalmers), but also within companies and by inhouse researchers who specialise in rock blasting and explosives technology.

The main fields of research currently comprise:

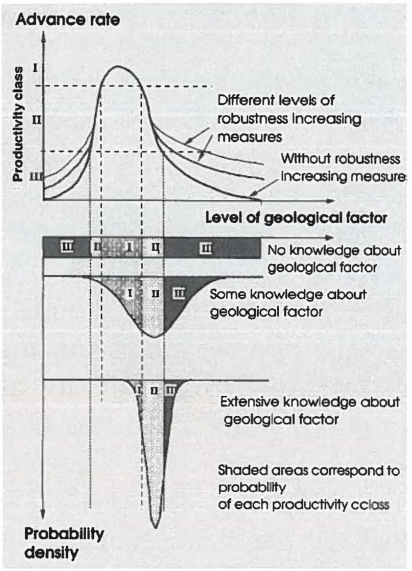
- Risk and decision analysis and environmental concern in underground design and construction
- Smooth blasting
- Rock fragmentation
- Rock reinforcement, function and durability
- Grouting techniques
- Explosives technology

The following gives a comprehensive view of SveBeFo's ongoing programme.

Statistical methods as an aid to better project decisions

Design for structures in rock is quite different from carrying out calculations for construction with building materials such as steel and concrete. The aspect of not knowing the final design or building material - the rock - until the tunnel is completed, entails special requirements in both project management and the design process.

In the management of the risks involved, reliability of the accessible geological information and prognoses plays an important role. There is a need though, for a more stringent assessment of risks, predictions and decisions.



The better the knowledge of the geology, the more accurate the estimation of advance rate.

Within SveBeFo's programme, existing tools are being evaluated and adapted to the special conditions that obtain in construction work in order to provide a more solid basis for decisions.

In one project, methods for time-cost calculations taking into account the robustness of different excavation methods are presented. Another project focuses on the communication and demands on geological information. It stresses the importance of always having the actual decision in mind when planning an investigation, and also knowing the reliability of the results.

There is also a study analysing the possibility of using statistical methods in rock mechanics calculations. The task is complicated, as the load situation is also difficult to describe.

Sealing rock tunnels

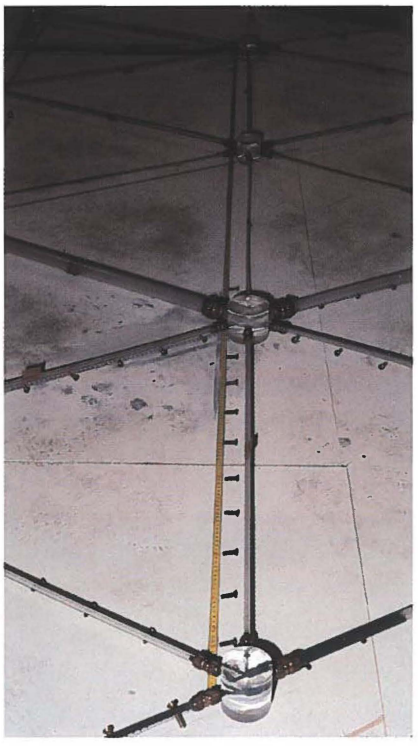
The sealing of rock tunnels is a topic that today interests not only rock engineers but also the general public. The requirements for sealing effectiveness are becoming very strict as a result of growing environmental consciousness, and because we are building close to existing facilities above and below ground.

Research into grouting technology for tunnels has been central to SveBeFo's research programme since the beginning of the '80s. Grout stability, as well as the mechanisms that affect flow and penetration, are being studied, the aim being a better control of the grouting process and results.

Sprayed concrete

The use of sprayed concrete (shotcrete) as a primary as well as final lining of rock tunnels is well established in Scandinavia, mostly performed with the wet process and steel fibre reinforcement. However, more knowledge is still needed to understand the interaction between rock and sprayed concrete as a basis for the design and efficient use of this material.

There are three projects currently under way, i.e. laboratory tests of fibre reinforced slabs to check failure modes as a basis for design calculations; field testing of newly sprayed concrete affected by shock waves from blasting; and long term testing of fibre reinforced sprayed concrete panels exposed to different environmental conditions, to investigate the corrosion of steel fibres in fractured parts of the panels.



A network of plastic tubes with diameters of 1.5 - 10 mm simulating penetration path-ways in a fracture plane.

Fibres in a sprayed concrete beam to be investigated with respect to corrosion.



Rock blasting

Cracks in the remaining rock

Even cautious blasting of contours damages the remaining rock, especially behind the bottom charges. This may cause problems with excessive rock handling, stability and maintenance.

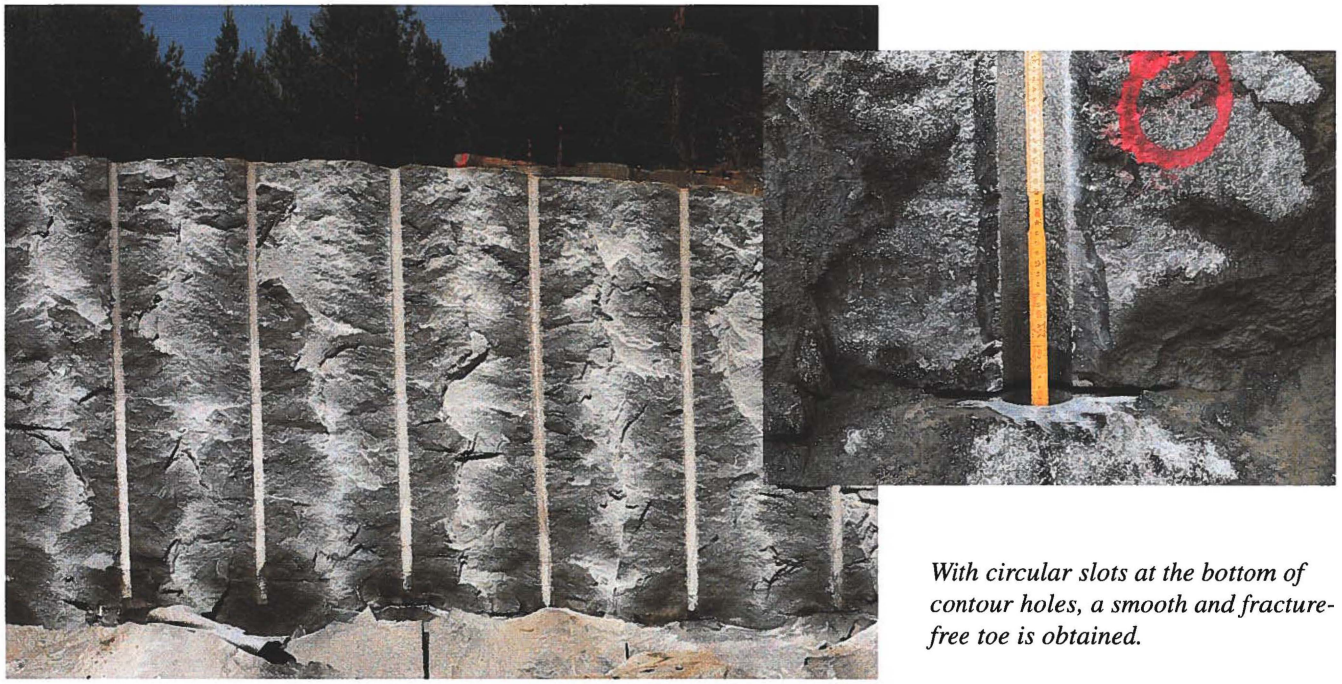
Through a unique series of tests in the Vånga granite quarry, SveBeFo has shown how factors like detonation pressure, decoupling and different firing times influence the blast generated cracks in the remaining rock.

The data have been compressed into a prediction formula being used to provide improved recommendations for smooth blasting.

Blasting with bottom slots

SveBeFo is taking part in an EU project: *'Abrasive Jet Cutting Operations in Quarrying, Mining and Civil Engineering'* aimed at extending the maintenance intervals of road cuts by lessening the blast damage.

To achieve this we use perimeter holes with disc shaped radial bottom slots whose charges are fired simultaneously by electronic detonators.



With circular slots at the bottom of contour holes, a smooth and fracture-free toe is obtained.

Our Swedish partners are Conjet, manufacturer of water jet equipment, and the National Swedish Road Administration, which has put a 130 m long road cut in Södertälje at our disposal.

The use of bottom slots made it possible to omit subdrilling as well as bottom charges.

The breakage was excellent and resulted in an extremely fine slope. At the toe, the bottom slots have created a continuous toe line fracture and virtually undamaged rock below.

Explosives technology

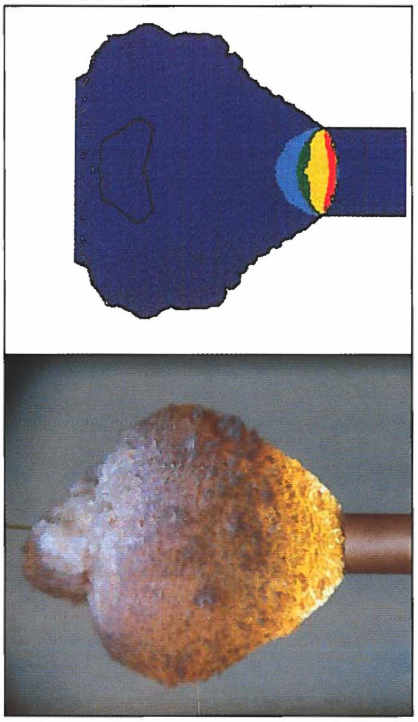
SveBeFo is making an important contribution to Swedish rock blasting technology through its explosives technology research. In co-operation with the Swedish Defence Research Agency (FOA) and the explosives manufacturers Dyno Nobel and Kimit, SveBeFo has developed burn models for emulsion explosives.

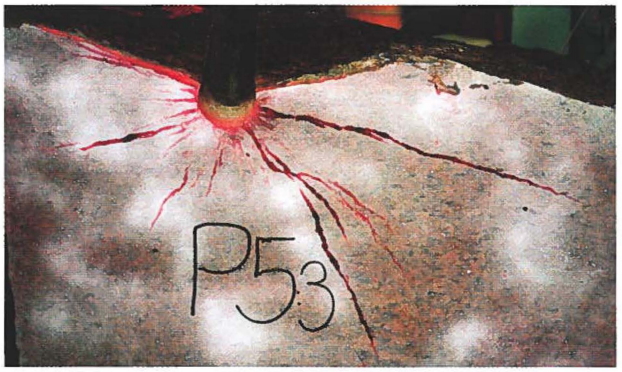
Such a model describes in detail: i) the drawn out burning reaction through which the chemical energy of the given explosive is transformed into high pressure and high temperature gases; and ii) how these gases transfer their energy to the surrounding rock.

With these models we can predict the initial stages of the blasting process, e.g. how the explosive energy is partitioned between shock wave and heave of the fragmented rock.

To confirm these predictions SveBeFo has also developed a unique pressure gauge, which survives inside a fully charged blasthole and delivers the pressure time history for about 1 ms.

Numerical models for the initial stages of the blasting process are developed with the help of high-speed photography in SveBeFo's blasting tank.





Examination of blast generated cracks, aiming at improved recommendations for smooth blasting.

SveBeFo

SWEDISH ROCK ENGINEERING RESEARCH

S v e B e F o is promoting and performing research and development in the field of rock engineering, including rock blasting and explosives technology, with application to construction in rock, above and under ground. The research is conducted according to a research programme outlined by SveBeFo's principals and performed by external research resources at universities as well as in-house staff, specialized in the field of detonics and blasting technology.

Research results are transferred to the industry through direct project involvement, by reports, seminars and conferences, like the annual "Rock Mechanics Day". Thus, providing research results in the international forefront as well as high standing competence as a resource for the rock engineering industry are the main objectives of SveBeFo.

SveBeFo's research programme is financed by industry (60%) and the government (40%) and comprises about 25 projects costing SEK 30 million over a three year period.

BK

Swedish Rock Construction Committee

BK BergsprängningsKommittén, the Swedish Rock Construction Committee, is a non-profit association of enterprises working with design, construction and operation of mines and other installations in rock or with production of machines and other equipment for the rock engineering industry.

The main objective of BK is to contribute to the exchange of experiences between principals, thereby promoting research and development in our area. BK also advocates the interests of the principals in information activities directed towards authorities, organizations, the public and media.

BK s activities are reported to the members at an annual meeting normally attended by over 500 persons. A number of technical papers are also presented, covering interesting works, technical novelties, market development etc. Examples of external information activities are seminars focusing on the use of under-ground space in modern infrastructure.

Together, the more than 70 members of BK and SveBeFo comprise public and private construction managers, contractors, equipment suppliers, mining companies, consulting firms and institutions, organizations and research foundations representing a major part of Swedish industry and trade.

MEMBERS of BK

If you consult BK's web-site - www.bergsprangningskommitten.a.se - you will find there is a link directly to most of our members. Below you will find the mailing addresses to all of them.

Public and Private Construction Managers

Banverket (Swedish National Rail Administration)	SE-781 85 BORLÄNGE
Botniabanan AB	Strandgatan 7, SE-891 33 ÖRNSKÖLDSVIK
Göteborgs Energi AB	Box 53, SE-401 20 GÖTEBORG
Swedish Nuclear Fuel and	
Waste Management Co	Box 5864, SE-102 40 STOCKHOLM
Swedish National Road Administration:	
Vägverket Produktion	SE-781 87 BORLÄNGE
Vägverket Region Stockholm	Box 4202, SE-171 04 SOLNA

Consulting Companies

Ansvarsbesiktning AB	Skönviksvägen 284, SE-122 66 ENSKEDE
BERGAB	Stampgatan 15, SE-416 64 GÖTEBORG
Bergutbildarna AB	SE-184 85 ÅKERSBERGA
Bergsäker Konsult AB	Celsiusgatan 8, SE-422 56 HISINGS BACKA
Birka Teknik & Miljö AB	Box 27804, SE-115 93 STOCKHOLM
Geosigma AB	Box 894, SE-751 08 UPPSALA
Golder Grundteknik AB	Box 4244, SE-102 65 STOCKHOLM
Göteborgs Byggmästartjänst AB	Herkulesgatan 3 A, SE-417 01 GÖTEBORG
H-Vall Consult AB	Box 73, SE-131 07 NACKA
ITASCA Geomekanik AB	Stenbocksgatan 1, SE-114 30 STOCKHOLM
AB Jacobson & Widmark	SE-181 83 LIDINGÖ
Mineconsult AB	Banérgatan 37, SE-115 22 STOCKHOLM
Nitro Consult AB	Box 32058, SE-126 11 STOCKHOLM
Petro Bloc AB	St. Badhusgatan 6, SE-411 21 GÖTEBORG
Rock Team AB	Norrskogsv. 26, SE-112 64 STOCKHOLM
SCC Bygg och Mark AB, Bygg Öst	Box 4205, SE-102 65 STOCKHOLM
Sycon Energikonsult AB	SE-205 09 MALMÖ
Sycon Teknikkonsult AB	Pipers väg 165, SE-170 73 SOLNA
Tyréns Infrakonsult AB	SE-118 86 STOCKHOLM
SwedPower AB	Box 800, SE-771 28 LUDVIKA
VBB Anläggning AB	Box 34044, SE-100 26 STOCKHOLM

Contractors

BESAB	Tagenevägen 7, SE-422 59 HISINGS BACKA
Drillcon AB	Box 89, SE-713 22 NORA
Lemminkäinen Construction Ltd	Torsgatan 12, SE-111 23 STOCKHOLM
PEAB Berg AB	SE-401 80 GÖTEBORG
Midroc Construction AB	Hjalmar Petris väg 32, SE-352 46 VÄXJÖ
NCC AB, NCC Anläggning	SE-112 89 STOCKHOLM
Selmer Anläggning AB	Box 811, SE-191 28 SOLLENTUNA
Skanska Teknik AB	SE-118 99 STOCKHOLM
Stabilator AB	SE-182 25 DANDERYD

MEMBERS of BK

Mining Companies

Boliden Mineral AB	SE-936 81 BOLIDEN
Björka Mineral AB	Björkaverken, SE-705 97 GLANSHAMMAR
Cementa AB	Box 102, SE-620 30 SLITE
LKAB	SE-981 86 KIRUNA
LKAB	SE-983 81 MALMBERGET
Partek Nordkalk Storugns AB	SE-620 34 LÄRBRO
Zinkgruvan Mining AB	SE-696 81 ZINKGRUVAN

Manufacturers

Alimak AB	Box 720, SE-931 27 SKELLEFTEÅ
Allmex AB	Pl 8902, SE-653 46 KARLSTAD
Atlas Copco Rock Drills AB	SE-701 91 ÖREBRO
Boart Longyear AB	Exportgatan 33, SE-422 46 HISINGS BACKA
Cavotec AB	Box 2024, SE-128 21 SKARPNÄCK
De Neef Scandinavia AB	Långvallsgatan 15, SE-424 57 ANGERED
Dyno Nobel Sweden AB	Gyttorp, SE-713 82 NORA
Essverk AB	Svetsarevägen 2, SE-771 42 LUDVIKA
G-Drill AB	Hornsgatan 79, SE-113 47 STOCKHOLM
GIA Industri AB	Box 59, SE-772 22 GRÄNGESBERG
Hydro Chemicals	Box 516, SE-261 24 LANDSKRONA
KGS	Box 817, SE-981 28 KIRUNA
Kimit AB	SE-981 86 KIRUNA
Leica Geosystems AB	Box 781, SE-191 27 STOCKHOLM
Sandvik Tamrock AB	SE-811 81 SANDVIKEN
Secoroc AB	Box 521, SE-737 25 FAGERSTA
Slanggrossisten Ekonil AB	Depågatan 11, SE-254 64 HELSINGBORG
SMAB Svets & Maskin Reparationer AB	Box 2007, SE-981 02 KIRUNA
Trelleborg Industri AB, Industrigummi Sverige	SE-231 81 TRELLEBORG

Institutions, Organizations and Research Foundations

Bergskolan i Filipstad	Box 173, SE-682 24 FILIPSTAD
Swedish Fortifications Administration	SE-631 89 ESKILSTUNA
Geotec	Box 174, SE-243 23 HÖÖR
Swedish Sand, Gravel and Crushed Stone Association (GMF)	Box 14104, SE-161 14 BROMMA
Swedish Rock Engineering Research-SveBeFo	Box 49153, SE-100 29 STOCKHOLM
Swedish Mining Association	Box 5501, SE-114 85 STOCKHOLM
Swedish Geolocical Survey SGU	Box 670, SE-751 28 UPPSALA

PRINCIPALS of SveBeFo

If you consult SveBeFo's web-site - www.svebefo.se - you will find there is a link directly to most of our members. Below you will find the mailing addresses to all of them.

The Swedish Construction Federation's Rock Research Group

Skanska	SE-118 99 STOCKHOLM
NCC	SE-171 80 SOLNA
PEAB	SE-401 80 GÖTEBORG
Midroc Construction	Box 2004, SE-174 02 SUNDBYBERG
BESAB	Tagnev. 7, SE-422 59 HISINGS BACKA
Stabilator	SE-118 99 STOCKHOLM
Byggs Sprutbetong	Box 187, SE-782 24 MALUNG

Consulting Companies

Golder Grundteknik	Box 4244, SE-102 65 STOCKHOLM
Geosigma	Box 894, SE-751 08 UPPSALA
Jacobson & Widmark	SE-181 83 LIDINGÖ
Rock Team	Norrskogsv. 26, SE-112 64 STOCKHOLM
Petro Bloc	St. Badhusg. 6, SE-411 21 GÖTEBORG
Scandiaconsult	Box 4205, SE-102 65 STOCKHOLM
Sweco	Box 34044, SE-100 26 STOCKHOLM
SwedPower	Box 533, SE-162 16 STOCKHOLM

Manufacturerers

Atlas Copco Rock Drills	SE-701 14 ÖREBRO
Dyno Nobel	Gyttorp, SE-713 82 NORA
LKAB	SE-981 86 KIRUNA
KIMIT	SE-981 86 KIRUNA

Public and Private Construction Managers and Orgainizations

Banverket (Swedish National Rail Administration)	SE-781 85 BORLÄNGE
Vägverket (Swedish National Road Administration)	SE-781 85 BORLÄNGE
Sydkraft	SE-205 09 MALMÖ
Swedish Nuclear Fuel and Waste Management Co	Box 5864, SE-102 40 STOCKHOLM
Swedish Sand, Gravel and Crushed Stone Association	Box 14104, SE-161 14 BROMMA

ITA International Tunnelling Association

Since 1996, the Swedish Rock Construction Committee (BK BergsprängningsKommittén) has represented Sweden as a member of the International Tunnelling Association. The ITA was founded in 1974, has 45 member nations, and more than 200 affiliate members.

The overall objective of the Association is to encourage the rational utilisation of space underground for the benefit of society. This is carried out mainly through the activities of a number of working groups within the Association which undertake studies and investigations, and compile guidelines and recommendations. For example, they examine alternatives to surface construction; formulate positive public strategies to take advantage of sub-surface potential; and seek out better and cheaper methods of planning, geo-investigation, design, construction, operation and maintenance of underground structures.

In 1999, ITA covered the following subjects: Research, WG 2; Contractual Practices in Underground Works, WG 3; Subsurface Planning, WG 4; Health and Safety in Underground Works, WG 5; Maintenance and Repair in Underground Works, WG 6; Immersed and Floating Tunnels, WG 11; Shotcrete in Tunnelling, WG 12; Direct and Indirect Advantages of Underground Structures, WG 13; Mechanised Tunnelling, WG 14; Tunnels and Environment, WG 15; Quality, WG 16; and Long Tunnels at Great Depth, WG17.

A number of guidelines, recommendations and Working Group reports have also been published over the years.

Information on further activities, such as annual meetings and conferences, may be found on ITAs Internet Homepage: www.ita-aites.org, e-mail: aites@imaginet.fr

EFEE European Federation of Explosives Engineers

The Swedish Rock Construction Committee (BK) represents Sweden also in the European Federation of Explosives Engineers (EFEE), presently through BKs chairman, Mr R. Holmberg. EFEE was founded in 1989, and has 14 member nations. Its purpose is to provide a European forum for professionals working in the field of explosives techniques in rock.

In 1998, EFEE started issuing European Shotfire Licences based on existing national licences in the member nations. The aim was to enable this category of professional engineers to apply for jobs outside their own countries without time-consuming delays in obtaining appropriate permits. EFEE is also strongly involved in current discussions concerning EU working standards in this field.

In September 2000, the Federation will organise its first World Congress on Explosives and Blasting Techniques.

Further information about the EFEE may be obtained from the EFEE Secretariat in the UK, on fax number +44 1924 25 35 35, e-mail: alison@spand.demon.co.uk

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