TRIBUNE

ASSOCIATION INTERNATIONALE DES TRAVAUX EN SOUTERRAIN
AITES

ITA
INTERNATIONAL TUNNELLING ASSOCIATION

ITA newsletter - la lettre de l'AITES

N° 24 - DÉCEMBRE 2002 - ISSN 1267-8422

From a single source.

For the tunnelling of the 2km long highway tunnel in the district of Lefortovo in Russia's capital Moscow Herrenknecht not only provided the world's largest Mixshield (Ø 14.20m). In cooperation with affiliated companies Herrenknecht also provided the complete peripheral site equipment such as trucks, dumpers, separation plant, compressor station, grout mixing plant and cooling tower.

In August 2002 the tunnelling machine has already excavated 1,108m, more than half of the tunnel route. The project development, which has run smoothly so far, shows that Herrenknecht possesses the opportunities, the experience and the know-how to perform as a „Full Service Provider" in the field of mechanical tunnelling technology.

Herrenknecht. The Trailblazer.

Contractor:
AO Corporation Transstroy
Geology:
fine to coarse sand, clay, limestone
(medium strength, partially very fissured)

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HERRENKNECHT
Tunnelling Systems

***Refregirated rock caverns for propylene gas storage - the finished cavern** (photo courtesy of Skanska)*

***Le stockage en souterrain du propylène. La caverne achevée** (photo Skanska)*

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TRIBUNE

ITA newsletter
la lettre de l'AITES

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ITA IN BRIEF • L'AITES EN BREF

FOUNDED IN 1974

ITA has 52 Member Nations and 280 Affiliate Members.

The aims of ITA are to encourage planning of the subsurface and to promote advances in the preparatory investigations for tunnels and in the design, construction and maintenance of tunnels by bringing together information thereon and by studying questions related thereto.

The Association fulfils its mission :
- by facilitating the exchange of information among its members,
- by holding public or other meetings,
- by organising and coordinating studies and experiments,
- by publishing proceedings, reports and documents.

FONDÉE EN 1974

L'AITES compte 52 Nations Membres et 280 Membres Affiliés.

Les buts de l'AITES sont d'encourager l'étude de l'utilisation et de l'aménagement du sous-sol et de promouvoir les progrès dans les reconnaissances préalables, la conception, la construction et l'entretien des tunnels en rassemblant les informations ainsi qu'en étudiant les questions qui s'y rapportent.

L'Association remplit sa mission :
- en facilitant l'échange d'informations entre ses membres,
- en organisant des réunions publiques ou non,
- en organisant et en coordonnant des études et des expérimentations,
- en publiant des comptes rendus, rapports et documents.

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EDITORIAL

While our growing populations in the world continuouisly require further exploitation of land for transportation, storages and living purposes, they also demand better environments for all people. In combination, these needs mean that we must always look to a solution "down-under" (ITA Sydney 2002).

In this edition of TRIBUNE, you will find a selection of cases focusing on Sweden and which illustrate some recent technical developments and ongoing projects within the civil engineering and mining sectors. In particular, we would like to draw your attention to the road tunnel system Södra Länken, which is the largest and most comprehensive underground system ever built in Sweden. Contributing in this edition are also the Swedish manufacturers Atlas Copco and Sandvik, which together share a very large part of the world market for tunnelling tools and machinery.

Some other ongoing tunnelling projects in Sweden, not mentioned in this edition, are the rail road tunnel in Trollhättan of 3,5 km, the Åsatunnel road tunnel of 1,9 km and the Botniabanan railway link along the northern east coast comprising several tunnels totalling 17 km.. In the next-coming years we also expect to see the completion of the 4,2 km full faced-bored Citytunnel in Malmö and the completion of the Hallandsås tunnel with its two parallel 8.6 km long rock tunnels. A railway tunnel under the city of Stockholm is also being discussed.

The first large international events in Sweden to document know-how in underground construction were the Symposia "Rockstore 77 Storage in Excavated Rock Caverns in 1977 and "Rockstore 80 – Subsurface Space for Environmental Protection, Low Cost Storage and Energy Savings". These were followed by a United Nations Workshop in Stockholm in 1982 about the utilization of subsurface space with special regard to the developing countries. The latest congress, "Underground Construction in Modern Infrastructure", was arranged in Stockholm in 1998. All four were actively sponsored by the International Tunnelling Association and gave us the opportunity to welcome many participants from its member nations to our country.

With its many decades of experience from more and more advanced underground construction projects, Sweden is also well reputed, for having an open dialogue between the parties involved, clients, consultants, contractors and manufacturers. In recent years, however, with an increased pressure on time schedules and demands on environmental safety, risk sharing has become an issue of greatest importance in order to obtain a sound economy in each project. BK Swedish Rock Construction Committee (the national group of ITA) has for the last five years arranged a series of seminars with the objective to discuss these issues with the parties concerned.

We hope that the following information about underground construction and R&D activities in Sweden will be of value to the readers of TRIBUNE. And, in concluding, we wish to emphasize the importance of the International Tunnelling Association, the forum for professionals in all tunnelling categories in its 52 member nations continuously discussing an improved utilization of subsurface space.

Annica Nordmark
Office Manager
BK Swedish Rock
Construction Committee

EDITORIAL

Les populations en croissance continue exigent non seulement toujours plus de place pour leurs activités, les transports, les stockages mais également le respect de leur environnement. Pour combiner ces besoins nous devons trouver une solution « down-under » (AITES, Sydney 2002).

Dans ce numéro de Tribune, vous trouverez une sélection de cas suédois qui illustrent certains développements techniques récents et des projets en souterrain dans le domaine du génie civil ou des mines. En particulier, nous voulons attirer votre attention sur le projet routier « Södra Länken » qui est l'ensemble routier souterrain le plus grand et le plus complet du pays. Deux fabricants suédois, Atlas Copco et Sandvik, qui occupent une part importante du marché mondiale des outils et des machines utilisés en tunnel ont également contribué à ce numéro.

Il existe d'autres projets de tunnels en Suède, qui ne sont pas décrits dans ce numéro : • le tunnel ferroviaire de Trollhättan de 3,5 km de long, • le tunnel routier d'Åsa (1,9 km) et la ligne ferroviairede Botnie le long de la côte nord-est comprenant plusieurs tunnels d'une longueur totale de 17 km. Dans les prochaines années les ouvrages suivants devraient être terminés : • le tunnel foré de 4,2 km"Citytunnel" à Malmö et • le tunnel ferroviaire bi-tube d'Hallansås de 8,6 km. D'autre part un tunnel ferroviaire sous Stockholm est également envisagé.

Le premier évènement international à avoir eu lieu en Suède dans le domaine de la construction souterraine est le colloque « Rockstore 77 - Stockage dans des cavernes rocheuses » puis « Rockstore 80 – Espace souterrain pour la protection de l'environnement, stockage à bas prix et économies d'énergie ». Ces deux colloques ont été suivis par une conférence des Nations Unies en 1982 sur l'utilisation du sous-sol avec une attention particulière pour les pays en voie de développement. Le dernier congrès « Construction souterraine dans les infrastructures modernes » a eu lieu à Stockholm en 1998.

Ces quatre évènements ont été largement soutenus par l'Association Internationale des Travaux en Souterrain et nous ont permis d'accueillir de nombreux participants des différentes Nations Membres.

Avec son expérience vieille de plusieurs décennies et ses nombreux projets de construction en souterrain, la Suède est reconnue pour avoir depuis longtemps susciter le dialogue entre les différents intervenants : maîtres d'ouvrage, ingénieries, entrepreneurs, fabricants. Dans les récentes années cependant, à cause de la demande pressante en terme de délais et de sécurité environnementale, le partage des risques est devenu nécessaire pour le bon équilibre de chaque projet. BK Swedish Rock Construction Committee (le groupe national suédois de l'AITES) a organisé depuis 5 ans des séminaires en vue de discuter de ces sujets avec l'ensemble des intervenants.

Nous espérons que vous apprécierez les informations que vous trouverez sur la construction souterraine et les activités de Recherche & Développement en Suède. Et en conclusion, nous voulons insister sur l'importance d'une association comme l'AITES, qui constitue le forum de tous les professionnels, dans les 52 pays membres, qui leur permet d'échanger et d'améliorer l'utilisation de l'espace souterrain.

Annica Nordmark
Office Manager
BK Swedish Rock
Construction Committee

1 • CURRENT ROAD TUNNEL CONSTRUCTION IN SWEDEN

De nombreux projets autoroutiers sont en cours à Stockholm et à Göteborg. La "solution-tunnel" permet de résoudre les problèmes de croissance du trafic routier en prenant en compte la dimension environnementale. Grâce à une géologie favorable, la construction des tunnels peut être réalisée à des coûts raisonnables.

Swedish National Road Administration

A number of motorway tunnel projects are under way in Stockholm and Gothenburg, the two most densely populated regions in Sweden. The "tunnel solution" makes it possible to solve increasing traffic problems in an environmentally-sound way. The normally very competent crystalline bedrock in Sweden, making tunnelling reasonably cost effective is an important factor in this context. Four different projects are presented in the article.

SÖDRA LÄNKEN, SWEDEN'S LARGEST ROAD TUNNEL SYSTEM

Located in the suburbs immediately south of Stockholm's inner city, Södra Länken runs from Årstafältet in the west to Värmdöleden in the East. The tunnel was originally planned as part of a ring road around Stockholm. To date, Södra Länken, which is now under construction, is the project that has come along the furthest. Blasting works were begun at the end of 1998 and it is expected that the tunnel system will be opened to traffic in the latter half of 2004.

Södra Länken is 5.5 kilometres long, four kilometres of which run through underground tunnels. The project consists of a total of 15 kilometres of tunnel. In addition to the four-kilometre long parallel main tunnels (one in each direction of traffic) there are 7 kilometres of ramp tunnels and evacuation routes. The carriageway in each of the two parallel tubes has two lanes that are 3.5 metres wide to accommodate through traffic as well as one for access or exiting.

The tunnel design includes several features to enhance driver safety and comfort. The light-coloured ceiling provides excellent route guidance through showing the road alignment ahead. Light-coloured collision protection barriers running along the tunnel walls help spread light in the tunnels. A very spacious overall impression is also created by the light-coloured asphalt. The contrasting darker tunnel walls and dark shoulders facilitate route guidance. Emergency exits, located every 100 metres, are marked by amber-coloured doorframes easily visible at a distance if tunnel evacuation becomes necessary.

Major consideration has been paid to the overall safety system in Södra Länken, which in combination with the one-way traffic and proximity to emergency exits helps make driving in the tunnels very safe. The entire tunnel system will be kept under 24-hour surveillance from the Trafik Stockholm traffic management centre. The motorway control system with variable message signs that will be installed in the tunnels is another feature intended to promote driver safety and comfort.

In a project of this magnitude, a major challenge during the tunnelling period has been to keep people living in the almost 20 000 households in the area well informed of the progress of the works.

1 • CURRENT ROAD TUNNEL CONSTRUCTION IN SWEDEN

NORRA LÄNKEN

is the northern component in a planned motorway ring road around the Stockholm inner city. A smaller part of Norra Länken was built a little over ten years ago. Much of what now remains to be constructed will be housed in tunnels.

The remaining part of Norra Länken to be constructed runs between Norrtull and Värtan with a connection to Frescati. The dotted line indicates tunnel, and the solid line indicates road above ground. The thick dotted line is the national heritage city park boundary.

Norra Länken will substantially alleviate the heavy burden of through traffic on inner city streets. A narrow road through a valuable natural environment will be relieved of all motor vehicle traffic. New land use opportunities will be opened up in the vicinity of the harbour at Värtan (off the map to the east).

The main tunnel between Norrtull and Värtan is 2 800 m long and consists of two tunnel tubes, each housing two to four traffic lanes. The two tunnel tubes connecting to Frescati have two lanes and are approximately 900 metres long. The last 500 metres at the western end of the main tunnels will be constructed in concrete. The greater part of the remaining tunnel system will consist of rock tunnels.

The interior width of a four-lane tunnel will be approximately 18 metres. The average height inside the concrete tunnels is about 6 metres and some 8 metres in the rock tunnels. The tunnel construction will start in 2005/2006 at the earliest and is expected to take about six years.

The bottom of about half of the concrete tunnel will lie below the groundwater table. The soil materials on location and the considerable distance to solid rock below probably makes it impossible to draw down the groundwater level through pumping to be able to construct the concrete tunnel under dry conditions.

NORRORTSLEDEN

Norrortsleden will be an outer bypass system some 15 km north of the city of Stockholm. By connecting two major highways, it will be an important peripheral link that fulfils a major need for those living in Greater Stockholm. Norrortsleden covers a distance of some 16 km and includes two tunnels one of which is designed at motorway standard.

Construction of the first part of Norrortsleden was initiated in August 2002. It includes a 2065 metre long tunnel and some 8 km of highway. The tunnel, called the Tornskog tunnel, will be excavated using drilling and blasting technology. It actually consists of two individual tunnel tubes each housing two traffic lanes. These two tunnels are separated by a 10-metre thick rock wall, through which transversal tunnels will be located at 100 metre intervals to serve as evacuation routes in the case of emergency, such as fire.

Along one of the tunnels, three rock caverns have been designed to house the electrical and telecommunication installations that will serve both tunnels. An underground water treatment plant 56 m long, 18 m wide and 8.5 m high will be installed to clean wastewater in compliance with strict environmental standards before being flushed out.

The two tunnels are horseshoe shaped and are generally between 10.9 and 14 metres wide and 7.9 metres in height, with a cross-sectional area of between 92 and 100 square metres. The space required for the electrical cables in the larger tunnel accounts for the variance in dimension. This space is separated from traffic by a concrete wall running parallel to the tunnel wall, which allows for easy

maintenance of all installations while not disrupting the traffic in the tunnel.

Rock bolts and shotcrete are used to reinforce the rock in the tunnels and at other rock openings. In the roof section, the fibre-reinforced shotcrete will in general be between 25 and 50 mm thick. Pregrouting with cement to prevent water leakage will be carried out ahead of the tunnel face through drilling a number of probe holes.

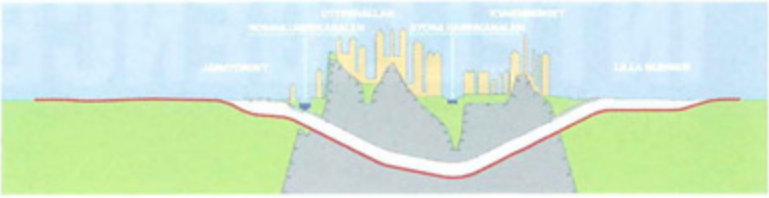
Norrortsleden will be officially opened to traffic in 2006.

GÖTALEDEN – TUNNEL CONSTRUCTION WORKS IN CENTRAL GOTHENBURG

Götaleden, which is part of Highway 45, is being upgraded along a three-kilometre stretch. Works have been in progress for the past year. In addition to the 1.5 kilometre long tunnel, new interchanges connecting to the present highway are being constructed at each end. The Göta tunnel will be a combination rock and concrete tunnel. The rock

tunnel will be about one kilometre long and connect to concrete tunnels at either end. It runs under Gothenburg where the buildings differ in age, condition, type of construction and foundation.

Moving through traffic down into an underground tunnel between Järntorget and Lilla Bommen will reduce accidents and improve the environment. The traffic rhythm will be less erratic, which reduces vehicle emissions and improves air quality. Improved access and mobility in the tunnel will also alleviate the traffic volume on local roads, thereby improving the environment in the inner city. When completed in 2006, the city can expand towards the waterside with housing, promenades, cultural and coastal centres, etc.



Tunnel design

The tunnel is designed as two separate tubes, one for each direction of travel, with three lanes in each. The tunnel tubes have a clear width of 14 metres and run parallel to each other at a distance of ten metres apart. The interior design of the tunnel, with its dark ceiling, light walls and good illumination creates a light and comfortable environment. The speed limit will be 70 km/h.

A safety system in the form of closed circuit television will be installed to be able to quickly detect such things as standstill vehicles.

The parallel tunnel tubes are connected by transversal tunnels, located at 100-metre intervals. In the case of traffic accidents or incidents, the tunnel will be closed. In this event, messages on information signboards will warn drivers as soon as possible to enable them to choose another route.

Construction works in rock and clay

Tunnel blasting operations are carried out in the traditional way where the tunnel runs through rock. This was preceded by the construction of two 300 and 350 m long work tunnels. The main tunnel is now being blasted towards both east and west.

In the transition between the rock and concrete tunnels, the excavations in the clay are very deep. At Lilla Bommen diaphragm walls are used for temporary support while robust sheetpiling is being used at Järntorget. At some places, temporary constructions will be used to shift the foundation of existing buildings.

During the construction period

During the construction works, the greatest possible consideration has been given to the local environment by setting stringent restrictions on noise and vibration levels. Traffic on Götaleden, amounts to 65 000 vehicles per day. Great effort has been made to minimise traffic disruption during construction, and to date, traffic has worked without any greater restriction.

2 • REFRIGERATED ROCK CAVERNS FOR PROPYLENE GAS STORAGE

Skanska Sweden et Skanska Technique ont construit, au sein de la plus importante raffinerie de Suède , un centre de stockage souterrain pour du propylène liquide de 20 000m³. Il s'agit d'un cylindre de 30 m de large et de 32 m de haut avec une couronne convexe.

Jan Hallgren, Editor Atlas Copco

Scanraff, Skandinaviska Raffinaderi AB, located on the West Coast of Sweden just north of Lysekil, is Sweden's largest oil refinery. They refine over 11 million m³ of crude oil and and semi-products per year. Over the past two years, they have invested 400 MSEK (€40 million) in a new production site for propylene. Propylene, a basic component for polypropylene, is used for everything from plastic film to large plastic components.

As part of the project Skanska Sweden AB and Skanska Technique constructed a refrigerated rock storage caverns for liquid propylene as a turn-key contractor. –It was a fixed-price contract where the contractor took all the geological risks. The owner, Scanraff, monitored a number of specific parameters during the construction phase of the project. These included the amount of water leakage, the shape of the rock storage cavern and the stability of the rock cavern. However, they strictly followed the terms of the agreement not to influence the production process or the choice of production methods allowing the contractors to take advantage of all geological possibilities.

The cavern serves as an interim storage when the propylene gas has been compressed and cooled to liquid, using piston compressors and air coolers. Design temperature is -48° C. The propylene remaining in gaseous stage is allowed to expand into the rock storage where additional cooling and conversion to the liquid phase occurs.

DESCRIPTION OF THE PROJECT

The scope of work includes design, construction and commissioning of a 20,000 cu. m rock cavern for storing liquid propylene at a temperature of -48° C. At this low temperature, the propylene gas condenses at atmospheric pressure allowing it to be stored in a liquid phase without specific pressure vessels. Designed as a 30 m wide by 32 m high cylinder with a convex crown, the rock cavern minimizes the heat loss and maximizes the stability.

Design and blasting of access tunnels, water curtain chambers, rock caverns and two vertical shafts to the surface were included in the entire project. Civil and mechanical work comprised, installation of concrete barriers in the tunnels; shafts for sealing of the rock cavern and the installation of pipes and pumps for the extraction and input of the propylene. The rock cavern's bottom is located at the level of -90 msl, the crown at -60 msl and the water curtain chambers at -30 msl to -40 msl. The ground surface is located at 18 m/above sea level. By using the existing tunnelling system in the area, the length of the access tunnel's was reduced.

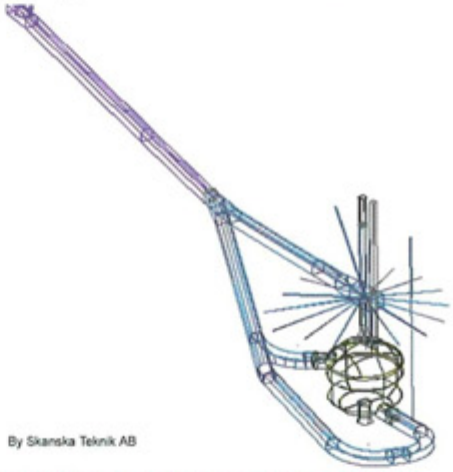
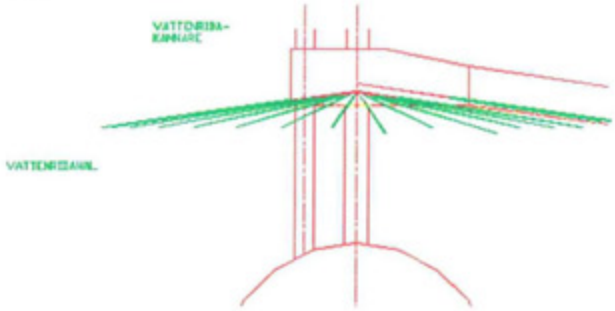


Fig 1 :Principle layout of the project.

The water curtain chamber, located 20 m directly above the rock cavern is necessary to prevent gas propylene from leaking out of the chamber. The water curtain was designed to prevent the frost from reaching too close to the surface. Ice may fracture and result in gas leakage, this scenario must be prevented by allowing sufficiently high groundwater pressure to act on the boundaries of the frozen rock. By circulating warmer water from the surface (approximately 14° C) down to the water curtain chamber, frost is prevented from reaching to high level.

Two shafts were built leading up to the surface. The first shaft, centrally located, includes permanent installations, such as pipes for pumping the propylene in and out, pressure gauges, level gauges, etc. These were encased in concrete before the entire

shaft was filled with concrete. The second shaft is used for mounting and dismounting the air cooling equipment.

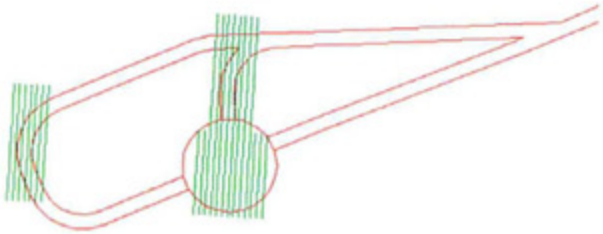


By Skanska Teknik AB

Figure 2: Design of the water curtain

BUILDING THE ACCESS TUNNELS

The construction of the access tunnels caused no problem down the level of the rock cavern (-70 m). Here, a change in tunnel direction caused mild rock bursts. –Increased use of steel fibre reinforcement shotcrete resolved the problem.



By Per Göting, examination worker at the project

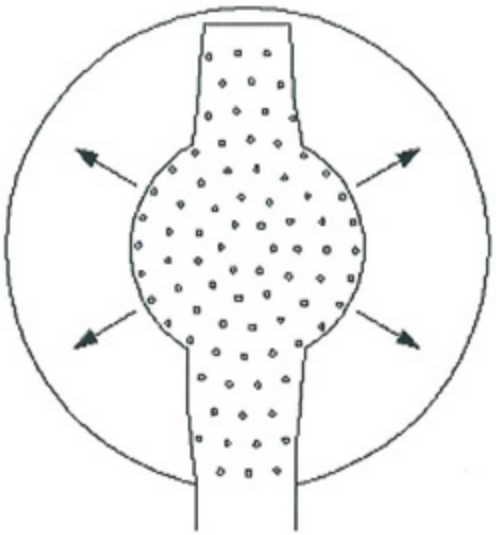
Figure 3: Areas of rock bursts

EXCAVATION OF THE ROCK CAVERN

The rock cavern was excavated in several stages as described in the following. During the first stage, the tunnel was made through the top of the rock cavern. The top of the tunnel followed the theoretical convex contour of the crown of the rock cavern. (see Figure 4) The lower section of the installation shaft was blasted from the rock cavern, allowing the remainder of the convex crown to be excavated radially from the center. As in the tunnel construction, rock-bursts were experienced during the excavation. Systematic bolting (bolt-length 6m) used with 80 mm fiber-reinforced shotcrete reinforces the convex crown.

By Per Göting, examination worker at the project

Figure 4: A tunnel was first made through the upper level.



By Camilla Allvin, Skanska Sverige AB

Figure 5: The convex crown was widened successively.

In a second stage, a horizontal bench was excavated from the level where the upper access tunnel enters the cavern. This was done to create roof space (6 m) at the cylinder wall for the bench drills. (See figures 6 and 7) The holes were drilled directly to the bottom of the cylinder.

Simultaneously with the excavation of the crown of the cavern, an access tunnel was excavated down and past the bottom of the cavern. At this point, the tunnel was widened to 12 m in diameter. Subsequentially, the rock cavern was blasted from the top level to the bottom.

Between each production step, exploratory drillings were made, along with water loss measurements. The rock mass was almost exclusively of good rock quality with a Q value of 10-20. Only small water losses were monitored and therefore

very little grouting was required.

Figure 6a: Bench drilling of the cylinder. (Photo courtesy of Skanska)

Figure 6b: Bench drilling of the cylinder (Photo courtesy of Skanska)

Figure 7: View from the rock cavern bottom when the cylinder part between ceiling and floor is removed. Total height of the bench is 20 m. (Photo courtesy of Skanska)

THE COOLING PROCESS

The rock cavern is cooled to -48° C in two stages. In the first stage, an air cooler is used and in the second stage, the cooling is carried out with the product itself. By first cooling the cavern with an air cooler, two advantages are achieved when compared with cooling the rock cavern directly with product.

1. As the surrounding rock mass reaches a temperature below 0° C, the water in the cracks freezes, resulting in a tight rock cavern. The water tightness of the rock cavern is monitored during the cooling-down phase.

2. The rock mass shrinks as it gets colder. This results in an off-loading of the load-bearing crown, which must be taken into consideration when the rock reinforcement is designed. The stability of the off-loaded rock mass was monitored and it was verified that a structural vault/arch was obtained in the crown.

TIMES

The excavation of the rock cavern was started in mid-February 2000 and was completed mid-June 2001.

The cooling of the air and rock mass at the Scanraff project began in mid-October 2001 and finished mid-January 2002.

Figure 8: Cooling unit in the rock cavern. (Photo courtesy of Skanska)

About Atlas Copco in Sweden

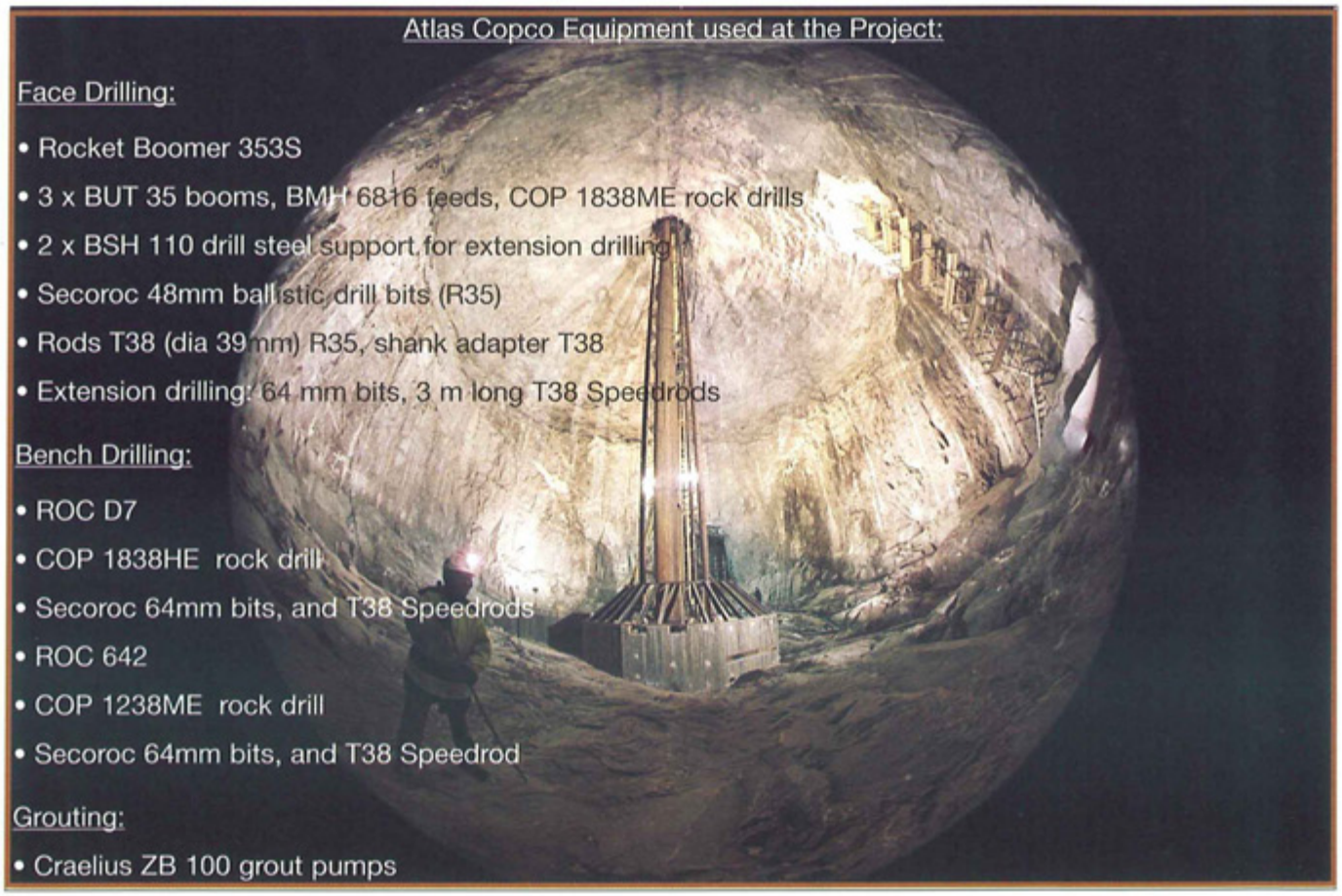
Atlas Copco is one of the world's leading producers of rock drilling and underground loading equipment. As a supplier to large infrastructure projects including power plant and transportation link construction projects, as well as global mining companies, Atlas Copco has a complete line of products including production drilling rigs, rock reinforcement equipment, rock drills, construction tools, crushers, pulverizers and much more.

The Atlas Copco Rock Drilling Equipment division is one of the largest producers of rock drill rigs in the world. The division manufactures drill rigs for tunnelling projects and mining operations, as well as surface drilling operations in construction work and quarrying.

The main products of the Atlas Copco Construction Tool division are hand-held pneumatic, electric and gasoline-powered drilling machines and breakers, as well as hydraulic breakers, crushers and pulverizers.

The Atlas Copco Craelius division is a full supplier of equipment for core drilling and ground engineering applications. The division manufactures computerized semi-automatic and manually operated core-drilling rigs, which are primarily used for exploration drilling to locate new ore bodies for the mining industry.

The Atlas Copco Secoroc division produces a large range of rock drilling tools, which are used principally by the mining and construction industry. The product range consists of top hammer equipment for drifting, tunnelling, bench and production drilling, the COPROD system, down-the-hole equipment and raiseboring equipment.



Atlas Copco Equipment used at the Project:

Face Drilling:

- Rocket Boomer 353S
- 3 x BUT 35 booms, BMH 6816 feeds, COP 1838ME rock drills
- 2 x BSH 110 drill steel support for extension drilling
- Secoroc 48mm ballistic drill bits (R35)
- Rods T38 (dia 39 mm) R35, shank adapter T38
- Extension drilling: 64 mm bits, 3 m long T38 Speedrods

Bench Drilling:

- ROC D7
- COP 1838HE rock drill
- Secoroc 64mm bits, and T38 Speedrods
- ROC 642
- COP 1238ME rock drill
- Secoroc 64mm bits, and T38 Speedrod

Grouting:

- Craelius ZB 100 grout pumps

3 • ROCK - THE FOUNDATION OF A SUSTAINABLE SOCIETY!

SveBeFo (membre affilié collectif de l'AITES) conduit des études scientifiques de recherche et de développement dans le domaîne des technologies liées à l'excavation des rochers et en particulier sur l'utilisation des explosifs, en associant l'industrie et les universités.

T. Franzén, Research Director of SveBeFo

In Sweden we have been privileged to have good geologic and climatic conditions. This have during centuries allowed us to excavate, process and refine our rock resources. The conditions also offer us great opportunities to utilise our subsurface space for a wide range of applications. However, rock is a material given by nature with varying properties, which must be treated with care and respect. Special competence and knowledge is therefore of utmost importance in order to utilise its inherent potential.

The Swedish Rock Engineering Research Foundation - SveBeFo (also a corporate affiliate member of ITA) carries out scientific R&D in the field of rock engineering, including blasting and explosives technology by combining resources from the industry and from technical universities. With present extensive plans for new investments as well as major tunnelling projects currently under construction in Sweden, research for improvement of the technology is more called for than ever with regard to both economical aspects and a sustainable environment.

Some major fields of research comprise:

- Geo-prognoses and rock mechanical design
- Fragmentation in quarries and open pits
- Smooth blasting, fracturing mechanisms, environmental effects
- Rock reinforcement – durability
- Grouting and lining of tunnels

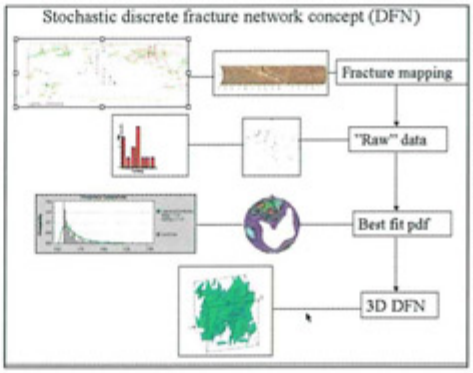
Illustrated below are a few examples of current research which also involve international co-operation.

PROGNOSES AND RISK EVALUATION

Statistical and geological analyses of data from investigation holes and mapped rock walls have been used for interpretation and input into a fracture model and used as a basis for prognosticating the rock mass structure. This concept "DFN Stochastic discrete fracture network" was developed by Peter Starzec, in his Dr Thesis, and has been applied by using data from the CLAB facility in Sweden (interim storage for spent nuclear fuel).

Stochastic discrete fracture network concept, DFN.

To estimate the methods and costs in major rock engineering projects requires that consideration is given to what happens should the predicted geology or other anticipated conditions change during construction. New ways to consider the stochastic character of geological conditions and their interaction with a chosen construction method have been developed to serve the needs of clients as well as contractors in the planning and procurement stages of major projects. The project is reported by Therese Isaksson in her Doctoral Thesis "Model for estimation of time and cost based on risk evaluation applied on tunnel projects".



Relation between geology, production technique and costs treated by using statistical methods.

BLASTING TECHNIQUES AND FRAGMENTATION

Within the EU programme "Competitive and sustainable growth", the project "Less fines production in aggregate and industrial minerals industry" aims at significantly decreasing the volumes of the fines fraction generated when blasting in quarries. Only in Europe about 270 million tonnes of fine material annually become waste. A decrease would mean lower production costs, an improved environment, less handling of waste and transportation activities. Participating countries are France, Spain, Austria and the Nordic countries. Field testing of fragmentation is done in quarries in Sweden, Austria and Spain, here the Nordkalk lime-stone quarry on Gotland, Sweden.

4 • SANDVIK DELIVERS BIG LEAP IN PENETRATION RATES IN WORLD'S BIGGEST RAISE-BORING PROJECT

NCC a utilisé le système de "raise-boring" développé par Sandvik pour réalisé les puits de ventilation des mines de fer de LKAB à Kiruna et Malmberget. Six machines ont été utilisées de manière simultanée.

Leigh Bartlett, Sandvik Tamrock Tools AB

Toward the end of 1997, Swedish civil-engineering contractor NCC switched to Sandvik raise-boring heads exclusively to help expedite the delivery of 35 000 metres of ventilation shafts and ore passes to LKAB's Kiruna and Malmberget iron-ore mines in the far north of the country. At the time, NCC cited higher penetration rates, robustness, stability and lower resistance to rotation among the decisive factors. Nearly five years down the line, and with the raises now complete, the contractor remains wholly satisfied with his choice of equipment and commends Sandvik additionally for first-class back-up service and technical support.

LKAB's massive investment in raises is part of two separate development projects to open up new mining zones to secure production in Kiruna and Malmberget until 2018 and 2010 respectively. The Kiruna project incorporates 19 000 metres of new ventilation shafts and 11 000 metres of new ore passes, all of them 3.1 metres in diameter. The Malmberget scheme includes around 3500 metres of ventilation shafts 3.5 and 4.5 metres in diameter and 1500 metres of Ø 3.1 metre ore passes. Started in 1994, the raise boring was originally outsourced to contractors Kraftbyggarna, who were subsequently acquired by SIAB, which was in turn acquired by NCC in 1997. After reviewing the raise boring activities and testing the performance of different makes of equipment in 1997, NCC appointed Sandvik as the sole supplier of pilot bits and reaming heads for the remainder of the project.

SIX RAISE-BORING MACHINES SIMULTANEOUSLY

Skanska Raise Boring, too, has been engaged continually since 1996 to bore raises in both mines, sub-contracting initially to SIAB/NCC and later to its parent company Skanska Civil Engineering (Sweden) AB, which is involved substantially in the overall development projects. Between them, NCC and Skanska have operated up to six raise-boring machines simultaneously, including two TRB Rhinos (the 2000 and 2008 models), Indau 500s and an AC Robbins 97R. To spearhead the boring work, both companies chose Sandvik SCMH pilot bits for the Ø 349-mm pilot holes for all raises. To ream out the Ø 3.1 metre shafts, both chose the new Sandvik CRH 10D integral reaming head. To ream out the Ø 3.5 metre shafts, Skanska used an older Sandvik CRH 10E multi-segment head and, for the Ø 4.5 metre shafts, chose the much simpler, more evolved and very service-friendly CRH 12E four-segment head.

AGGRESSIVE ROCK CONDITIONS AND HIGH PERIPHERAL LOADS

"Both the nature of the rock and the required slopes of the raises in Kiruna and Malmberget presented special demands," says Sandvik raise-boring product manager, Göran Strand. "With an average compressive strength of around 200 MPa – rising as high as 400 MPa in some zones – the rock is fine grained and abrasive. This, together with the average 60o slope of the raises from the horizontal, which creates a higher gravitational load on the periphery of the reaming head, can be a recipe for extreme wear to the gauge cutters and saddles. That is why we recommended our new CRH 10D integral reaming-head for the very numerous Ø 3.1 metre raises. Like the 12E segmented head used for the bigger raises, it is essentially flat in profile, but has more steeply angled gauge saddles that present the cutters in such a way that a much greater clearance is obtained between the raise wall and the periphery of the reaming head. The extra clearance, which makes the CRH 10D suitable of high gauge-load conditions and also reduces the amount of torque needed to turn the head, has a phenomenal effect on gauge-cutter and saddle life, giving increases of 3-400% in difficult conditions."

30% HIGHER PENETRATION WITH LESS TORQUE AND MORE THRUST

The average rate of penetration (ROP) achieved with the Ø 3.1-metre CRH 10D reaming heads in Kiruna and Malmberget mines is 0.76 metres per hour, a rise of around 30% compared with the make used earlier. According to NCC project manager Per-Erik Johansson,

the need for higher penetration rates was the primary motivation for changing to Sandvik equipment late in 1997. "In tests," he says, "we found that the Sandvik head had a lower torque requirement and rotated more smoothly against the rock, and this enabled us to raise the thrust and achieve higher penetration." Skanska project manager Johan Stagnebo cited similar reasons for choosing the Sandvik CRH 12E reaming head in 1999 for the Ø 4.5 metre ventilation shafts in Malmberget, where it has achieved an ROP of 0.3 metres per hour.

The higher ROP of Sandvik reaming heads can be attributed to several factors, including the flat profile of the head, its stability and the design, configuration and load-bearing capacity of the cutters. Göran Strand explains: "With the flat head, most of the cutters are presented to the rock horizontally, which means that each covers a greater area of rock. This means that fewer cutters are needed to give complete coverage of the rock face. Since resistance to rotation rises with the tilt and number of cutters on a raise-boring head, the combination of horizontal presentation and fewer cutters reduces the amount of torque needed to turn the head during boring and also contributes to smoother rotation. Lower torque requirement and smoother rotation, together with the higher load-bearing capacity of Sandvik cutters (up to 27 tonnes per cutter), allows the thrust to be raised substantially, resulting in a higher rate of penetration." According to Skanska's Johan Stagnebo, moreover, a higher loading actually increases the service life of Sandvik cutters. "There is a definite time-load factor affecting cutter life," he says. "The quicker you can bore the raise, the greater the number of advance-metres the cutters will last."

The higher ROP of Sandvik cutters is described in a thesis entitled 'Raise Boring Optimization' by PhD licentiate Jenny Svanberg, a graduate of Luleå University's Department of Mining and Civil Engineering, who closely monitored three raise-boring machines in Kiruna between 1995 and 1998. Among the many observations made by Svanberg was that a 13.5% increase in thrust permitted when the reaming heads were fitted with Sandvik cutters gave a 30% rise in penetration rate, indicating also that the raise-boring machine is utilized more efficiently when Sandvik cutters are used.

BENEFITS OF REDUCED LOAD AND STRESS

With the higher ROP of Sandvik reaming heads achieved with less torque and smoother rotation of the head against the rock, as described by the contractors in Kiruna and Malmberget, it is logical to assume a positive influence on the raise-boring system as a whole. With reduced load and stress, there will be fewer transmission failures, longer drill-pipe life and lower energy costs. With the more efficient utlization of the raise-boring machine described by Svanberg, moreover, any given machine should be capable of boring bigger raises when equipped with a Sandvik reaming head.

RAISE BORING OPTIMIZATION

During her studies and observations in Kiruna, Jenny Svanberg borrowed modern methodology, tools and techniques from the aerospace, automotive and nuclear industries to analyze the reliability, performance and 'degree of usage' of raise-boring hardware. Exploiting the scale and homogeneity of raise-boring activities in Kiruna, she investigated the parameters that affect penetration rate, identified failure modes, frequencies and consequences, defined the measuring parameters relevant to useful data collection and performed trend and serial correlation tests on the data collected. She investigated all non-boring time, whether machine and services related or not, and ranked the areas in which corrective action would lead to the greatest improvement in productivity and cost effectiveness. According to Svanberg, while the results of her analyses showed machine availability (92%) and degree of usage (55%) in Kiruna to be satisfactory considering the logistics, there is obviously room for improvement, particularly in degree of usage, which renders 45% of machine available time non-boring time. To help identify the specific causes of delay and prioritize remedial action, Svanberg recommends, in the first instance, more thorough, more relevant and more descriptive reporting, as well as computerization of the data-collecting function as far as possible. She also stresses the need for close, open co-operation between client, contractor and supplier. "This, together with good service, good technical support and on-site availability of tools and spares," she says, "is essential to the success of any raise-boring project."

5 • CLAB STAGE 2 -A CHALLENGE IN CONTROLLED ROCK CONSTRUCTION

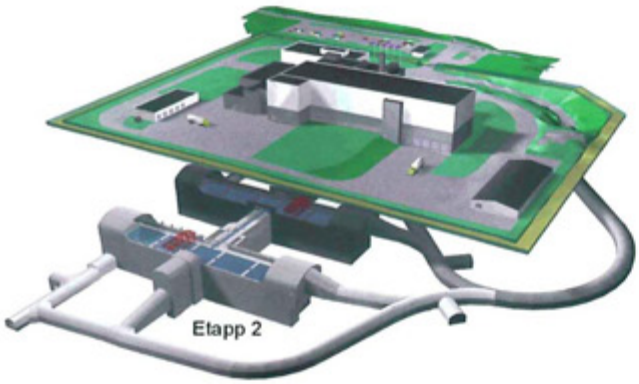
Le stockage de manière sûre des déchets nucléaires est une nécessité pour le futur de notre société. Les équipements de stockage intermédiaire sur la côte est de la Suède, connus sous le nom de CLAB ont été mis en service en 1985. Mais comme ceux-ci seront pleinement utilisés en 2004, il a été décidé de construire une autre caverne de stockage sur le même site. ***SKB***

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 3,700 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.

INTRODUCTION

PROJECT FACTS	
Cavern length :	120 m
Cavern width:	21 m
Cavern height	27 m
Access tunnel	400 m
Connection tunnel	40 m
Total volume	95,000m³

The existing facility for intermediate storage of spent nuclear fuel (CLAB) is a central storage serving all nuclear plants in Sweden. The fuel elements are stored in water filled concrete basins, located in a rock cavern with its roof positioned at about 30 m below the ground surface. A second cavern of the same size as the first one has now been constructed parallel to the existing cavern, at a distance of 40 m.



GEOLOGICAL INFORMATION

The bedrock consists of different types of crystalline rocks. Coarse-grained granitoids predominate .

From a strict rock-mechanical aspect, the granitoids can be considered as one unit, with a similar joint frequency. RQD-values are normally between 70% to 100%. About 60 to 70% of the rock mass The CLAB facility for spent nuclear fuel volume consist of these granitoids. Other rock types, of volcanic origin, are frequently found embedded in the granitoids. The composition is andesitic. These volcanic rocks have different rock mechanical properties showing a more brittle behaviour and a higher frequency of joints. RQD-values normally range from 40 to 70%. The block size in the granitoids normally exceeds _ m3. In the volcanic rocks it is normally less than _ m3, often around 1 dm3.

The estimated Q-values (with SRF=1) range from about 4 to 20, averaging around 10.

MEASURING SYSTEMS

An extensive monitoring program for deformations was developed, comprising the use of extensometers, sliding micrometers, and optical convergence measurements. Another system was introduced for supervision of the vibrations induced by the blasting.

Most of the measured data was electronically transferred to a computer in the site office for quick evaluation and planning purpose.

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.

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"

EXECUTION OF WORKS

The rock excavation was performed by drilling and blasting and completed in October 2000. Due to careful supervision and a well experienced contractor (Skanska AB) no incident

occurred in the existing facility with its stored spent nuclear fuel. The concrete works now under progress are performed by Peab AB.

Concrete works for the storage basins in progress

NORTH AMERICAN TUNNELING 2004 CONFERENCE Underground Construction – the Sensible Solution to Urban Problems
ATLANTA-GEORGIA-USA, APRIL 17-21, 2004

CALL FOR PAPERS

The American Underground Construction Association is sponsoring the 7th bi-annual North American Tunneling Conference and Exhibition to continue the examination and discussion of issues important to the development and use of underground facilities.

The conference will feature four tracks with four sessions in each track:

Track I – Management of Underground Projects

• Project Management: Of The Design And/Or Construction Process; Schedule / Budget; Quality Control; Use Of Consultant Boards; And Partnering, • Risk Allocation And / Or Sharing Techniques, Including Use Of Alternate Delivery Methods, • Predicting And Controlling Cost And Schedule, • Incorporating The Public Interest Into Design And Construction

Track II – Public Policy and Underground Facilities

• Going Underground – Protecting Critical Infrastructure, • Transit Oriented Development – Making the Case for Going Underground, • Going Public – Selling the Underground Solution, • Show Me the Money – Creative Financing for Underground Projects

Track III – Advances in Technology

• Mechanized Construction , • Non-Mechanized Construction , • Investigation, Inspection And Rehabilitation , • Analysis And Design

Track IV – Case Histories: The Trials, Tribulations and Triumphs of Underground Construction

• Specialized Urban Construction, • Ground Modification for Underground Construction, • Machine Mining – Soft Ground to Hard Rock to Everything in Between, • Conventional Underground Construction

Abstracts of 100 – 300 words should be sent no later than February 28, 2003 to the Conference Director, Susan Nelson, at nelsaua@pacbell.net; fax: 949-459-7813; or c/o AUA, 3001 Hennepin Avenue So., Suite D202, Minneapolis, MN 55408 USA.- www.auaonline.org

6 • NEW DEVELOPMENTS IN MINING AT BOLIDEN MINERAL AB

Dans les mines, chaque tir est différent du précédent. Le plan et le chargement ne sont pas toujours optimisés. Boliden Mineral a développé pour sa mine de Garpenberg Norra un nouveau système de navigation et d'optimisation du plan de chargement des explosifs.

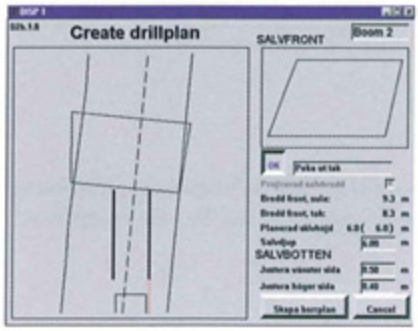
Authors: A.Renström, M.Andersson, Boliden Mineral, R.Elsrud, Atlas Copco Rock Drills

MINE MAP NAVIGATION AND DRILL PLAN GENERATION

In mining, the geometry of the stope is dictated by the geometry of the ore. Every single blast will be unique regarding size, heading and drill plan. This compared to tunnelling where the same profile and drill plan are used for several blasts. This irregularity together with insufficient knowledge of the ore leads to drill plans being individually created by each driller and hence to sub-optimal drill- and charge- patterns. This leads to waste rock dilution and/or ore loss as well as damages to the contour increasing the need for scaling and rock reinforcement.

This in turn may cause a longer blast cycle, increased costs per tonne metal due to lower grades and in some cases waste rock or low-grade ore may displace high-grade ore in the transport system or the dressing plant.

In the Garpenberg Norra mine, operated by Boliden Mineral – where mining at present is taking place at the minus 1000 m level–introduction of a new Mine Map Navigation and Drill Plan Generation-system has increased productivity and quality. The preferred mining method in Garpenberg Norra is Cut and Fill. The new system presents a map showing the planned ore boundaries to the driller when lining up for drilling. The system also generates a drill plan optimised for each individual blast.

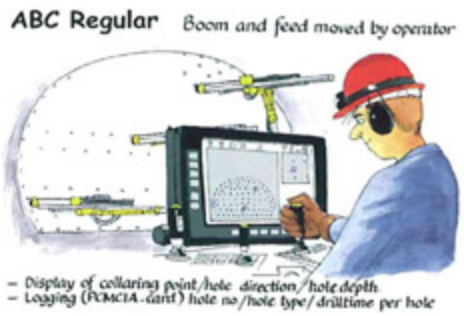


When positioning the drill-jumbo the driller sees a computerized map on the drill rig computer that shows him how the blast is positioned relative to the planned ore boundaries and it also places the roof of the drill plan at the correct z-coordinate.

The driller then points out the direction and geometry of the blast with the feeders and thereafter the Drill Plan Generator creates an optimised drill plan.

Positive side-effects of the new system includes better planning routines as well as more large scale mining methods due to the possibility to drill longer and higher blasts with the same or even better drill accuracy.

Development of this highly computerized system for the Garpenberg Norra mine has been possible due to Atlas Copco's new Rig Control System (RCS) together with Atlas Copco's ABC Regular drill guidance system.



After extended tests and improvements, Boliden Mineral goes forward with the introduction of the Mine map navigation and Mine Drill Plan Generator system in all underground mines operated by Boliden Mineral.

PRODUCTION CONTROL SYSTEM MINESTAR

In 2001 the production control system Minestar was introduced at Boliden's Aitik mine. The system makes it possible to GPS-navigate drill rigs with cm-precision; shovels are able to make the distinction between ore and waste rock with a resolution of about one meter and truck transport routes can be optimized. The annual production at Aitik involves 13,500 drill holes, 230,000 truckloads and approximately 830,000 buckets. When such volumes are involved, even small improvements of the cycle time have a great influence on the production results.

The main goals of 2003 consist in achieving a reduced number of drill meters per ton, the transportation of the right type of material to the correct destination, which means more ore is trucked to the plant and more waste rock is deposited at the waste rock dumps, even in the border zones. Moreover, the benches must be made more even with a precise drill depth and correct loading levels must be achieved. Truck operations must be optimized.

With successful results, as outlined above, it should be feasible to re-pay this investment of SEK 16 million within two years.

7 • MARKED SWING TOWARD PUMPABLE EMULSION EXPLOSIVES IN DRILL-AND-BLAST ACTIVITIES : EXEMPLE FROM ALPTRANSIT SCHEME

Dyno Nobel a développé de nouveaux systèmes d'émulsions explosives pompables qui sont notamment utilisés pour la construction des tunnels du Lötschberg et du Gothard en Suisse.

Mats Börjesseon, Dyno Nobel Sweden AB.

The principal components of Switzerland's ambitious New Transalpine Railway project are the north-south AlpTransit Gotthard and the northeast-southwest AlpTransit Lötsch-berg high-speed rail axes. Their main distinction is that they will run at the so-called 'base line', generally no more than 500 metres above sea level. Preliminary rock excavation work for the two longest tunnels in the scheme - the 57-km Gotthard Base Tunnel and the 34.6-km Lötschberg Base Tunnel - was started in 1996 and 1994 respectively. Together, and inclusive of ancillary works, construction of these two twin-tube tunnels alone will require over 200 kilometres of tunnelling to be done.

With the unprecedented amount of tunnelling to be done in often-unfavourable rock conditions, there has been predictable debate about the choice of excavation method, namely drill-and-blast or full-face boring with tunnel boring machines (TBMs). Following an introduction of the scheme and an outline of the Gotthard Base Tunnel, with brief details of progress to date, this report describes how the introduction of site-sensitized, pumpable emulsions, together with automated charging systems that enable computer-controlled charge-density regulation, are helping to re-establish drill-and-blast as the method of choice in a much broader range of conditions. Complemented by the substantial developments in rock drilling, rock reinforcement and mucking methods and technology in the last decade, as well as much more efficient interplay between the various systems used in the drill-and-blast cycle, increases of up to 30 per cent in productivity are being obtained. Another important development described in the report is how the introduction of pumpable emulsions, which do not become explosive until actually pumped into the blast hole, has liberated contractors from the effects of extremely restrictive legislation on the transportation and storage of explosives in Switzerland.

The European railway network

PROJECT BACKGROUND IN BRIEF

The much debated, long-awaited, full-scale New Transalpine Railway project (known locally under the Swiss-German acronym NEAT) was finally given the go ahead by the Swiss electorate in a referendum in November 1998. As a result, around SFr 35 billion (24 billion) is being invested in upgrading and developing the Swiss railway network to integrate it fully with the ever-expanding European high-speed railway network.

The primary aim of the NEAT project is to improve the environment by removing most of the heavy transit traffic from the Swiss motorway network. At the same time, the railways will take up the fight, by means of an efficient, competitive, high-speed train service, to win both passenger and freight traffic from the airlines, primarily on routes between Germany, Switzerland and the north of Italy. The journey time between Zurich and Milan, for instance, will be shortened from 3 hours and 40 minutes to just 2 hours and 10 minutes. One hour of the time saving will be due to faster tunnel routes, and a further 30 minutes due to a general upgrading of the Swiss railway network to accommodate high-speed traffic (part of the country's overall Rail 2000 project).

7 • MARKED SWING TOWARD PUMPABLE EMULSION EXPLOSIVES IN DRILL-AND-BLAST ACTIVITIES : EXEMPLE FROM ALPTRANSIT SCHEME

EXPERIENCE WITH PUMPABLE EMULSION EXPLOSIVES

Explosives systems.

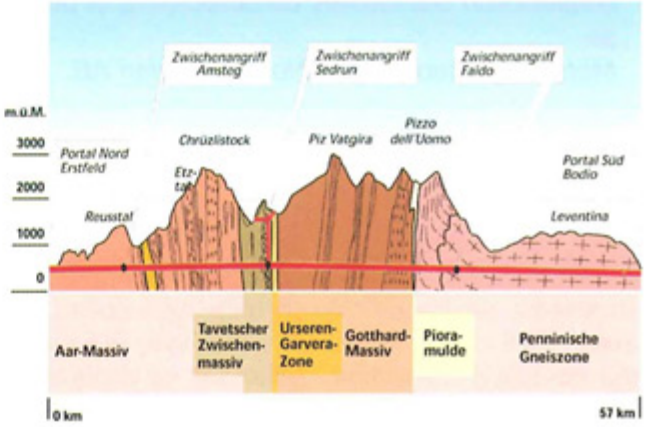
To regain ground lost to the TBM method, new systems for explosives and blast initiation have been developed and introduced. Non-electric initiation systems such as NONEL® and pumpable-emulsion explosives systems have come into being due in no small way to Dyno Nobel's investment in research and development. The non-explosive components of pumpable emulsions are mixed directly at the tunnel face and not converted into explosive until they actually enter the drill hole. During the past three years, this kind of explosive has become increasingly significant for all civil-engineering contractors involved in both the Gotthard and the Lötschberg base tunnels.

The Dyno Nobel Titan SSE, (Site Sensitized Emulsion) system and NONEL® initiation system have quickly become concepts for modern rock blasting in Switzerland. The Titan SSE system has been in commercial use in countries such as Sweden, Norway and Hong Kong for the past 8 years, and in Switzerland for the past 3 years. Other explosives manufacturers active in Switzerland include Société Suisse Explosifs SA, which has been working on a similar system called 'Emulga' for a number of years. In different subprojects in the AlpTransit Gotthard and AlpTransit Lötschberg schemes, both systems have been tested for functionality and performance.

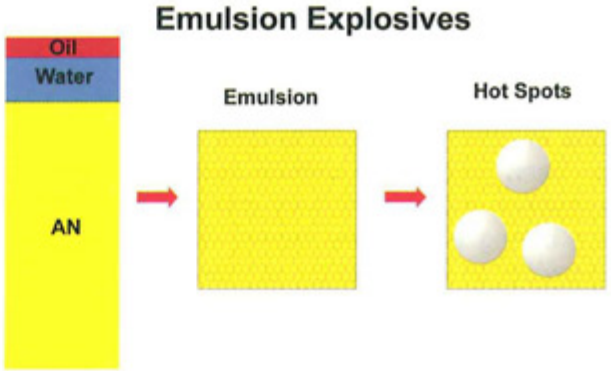
Dyno Nobel pumpable emulsions have been used (or are currently being used) in the following subprojects:

Emulsion explosives are distinguished by very high resistance to water. Compared with conventional explosives, moreover, they generate much lower amounts of toxic blast gases on detonation.

Gothard Base Tunnel	Lot	Consortium	Period
Amsteg acess tunnel	251	Ast-Holzmann geb Wüest (A/CH)	Mar00-Apr01
Bodio access tunnel	552	Batigroup/Frutiger/ Bilfinger-Berger (CH/D)	Aug00-Feb02
Sedrun base tunnel	360	Transco (CD/D/I)	Sept02
Lötschberg base Tunnel	**lot**	**Consortium**	**Period**
Ferden access tunnel	46.22.01	ATF (CH)	Aug99-jun01
Ferden access tunnel	46.23.01	Ferden (F/CH)	Jun01-
Base tunnel Sect North	45.3	SATCO (A/S/F/CH)	Oct00 -
Base tunnel sect South	46.61.01	MATRANS (UK/D/CH)	Mar 01-



The Gotthard Base Tunnel: Longitudinal geological profile, intermediate points of attack and excavation methods



The emulsifying process, step by step

CONTROLLED AND DOCUMENTED CHARGING

Underground construction in densely populated areas has increased considerably in recent years, and the transportation and storage of explosives has become increasingly complicated. At the same time, there has been a general increase in the automation and efficiency of machines and equipment for drilling, mucking, rock reinforcement, etc. Dyno Noble has developed systems such as Titan SSE, to keep pace with and strengthen this trend. The new alternatives for charging and blasting meet all modern criteria in respect of the efficiency, control and documentation of blasting work, as well as the increasing environmental stipulations. Controlled charging has been facilitated by com-

puterization of the system, whereby the setting of charge densities takes place on-screen via an LCD monitor.

LCD monitor

SUMMARY

Construction of all access tunnels for the Gotthard and Lötschberg base tunnels has been completed, and excavation of the main tunnels is now in progress. However, the problem regarding the location of the Gotthard tunnels' north portal at Erstfeld remains to be solved. The newly developed methods in drilling technology, with semi- and fully automatic drill rigs, have shown themselves to be competitive and profitable for tunnelling contractors. The introduction of high-performance Titan SSE, systems for pumpable emulsion explosives, as well as more efficient rock-reinforcement and mucking equipment, represents another major step forward for the drill-and-blast method. In addition to increased automation and higher efficiency, these systematic developments have made the drill-and-blast method more environmentally friendly, making it an increasingly attractive alternative to the TBM method.

8 • DEVELOPMENT OF HIGH VOLTAGE CABLES IN TUNNELS IN THE STOCKHOLM AREA

La mise en souterrain des cables à haute tension est devenue nécessaire dans la région de Stockholm. Le premier projet de 1,7 km est achevé et actuellement un deuxième tunnel de 2,5 km est en construction. Les permis ont été demandés pour 20 km de tunnels supplémentaires.

Curt Wichmann, Nitro Consult AB, Sweden

The Stockholm region is supplied with electric energy by 400 kV overhead power lines. The power lines are connected to a 220 kV feeding ring from which the local distribution takes place via distribution stations. This feeding ring is partly from the early 20th century and with the expansion of the city these power lines have ended up in the urban area.

Already in the 1980's the earlier half circle was closed to a ring via an existing tunnel system for district heating. In pace with the growth of the city and consciousness of the risks involved with the high voltage cables as well as the need of more land for exploiting the city environment, voices were raised to replace the overhead power lines.

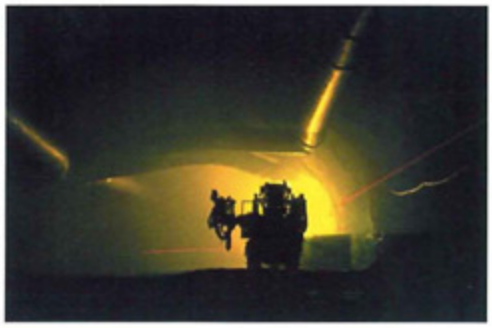
Previously, when building close to existing high voltage power cables the pools were moved and the power line was locally re-routed. This is not longer possible. Therefore, the nearest solution would therefore be to place the cables in tunnels.

The decision on the first project to place the cables in a tunnel (1.7 km) was based on comparative studies made on the replacement of existing overhead power lines with cables in the area of Stockholm. Today, the first project is completed and a second cable tunnel of 2.5 km is under construction. For further 20 km planning permission has been granted.

ROCK MECHANICS

The bedrock in Stockholm consists of granite with good rock mechanic properties. The depressions in the bedrock surface are normally filled with unconsolidated clays, which do sustain dewatering. If dewatered by drainage, the clay consolidate and consequently compress, risking settlement of buildings, roads and cables.

Up to now the tunnels were driven by conventional drilling and blasting. For longer tunnels most probably the TBM-technique will be used. The driving capacity at each tunnel face will therefore be higher. It is estimated that the advance per round in Stockholm by drilling and blasting is some 20 m per face and week while the TBM allows an advance per round of some 100 m per week. In most cases in the granite rock of Stockholm, it is only necessary to reinforce the tunnels with bolts and shotcrete. However, to avoid ground water depression in the clay pockets, large water loss in the stand-by water reservoirs along the tunnel and to reduce the qua tity of water to be pumped out from the tunnel system, an extensive pre-grouting of the bedrock will be necessary. Pre-grouting is done with cement slurry that is pumped into 20 m long probe holes drilled in front of the tunnel face. The tunnel has a cross section area of 18 m^2 .



The water allowed to leach into the tunnel is about 25,000 m^3 per year and km and can be pumped out to the sewage water recipient, which in Stockholm is the Baltic Sea.

CABLES

The technical concept is based on replacing the existing 220 kV overhead power lines with cables in rock tunnels. The cables will be bunched together three by three. By arranging the cables like this the electromagnetic field around the cables will be reduced.

The cables consist of XLPE-cables with 1200 mm^2 Al-core, which emit about 20 W/m per cable at normal load. This heat flow is mainly eliminated by ventilation. Though cooling is achieved by contact with the rock walls, further ventilation is needed. The air is taken in and evacuated at different locations along the tunnel.

The connection to the distribution terminals is

made on the ground level. The cables are drawn via shafts to terminals connected to the existing overhead power lines within the terminal area. There are plans today to put even these terminals underground at such a depth that the magnetic field cannot cause damages to human beings.

SAFETY

The tunnels are the nerve fibre of the electricity supply for the Stockholm area. Extensive safety analyses have been carried out to study the risk of disturbing or interrupting the supply.

This can be caused by faults in the cable or the junctions, external damage caused by activities in the tunnel, other installed functions or sabotage. The risk analysis pointed out the primary risks:

1. Maintenance and inspections in the tunnel

2. Combined functions such as heating and cooling installations water supply or similar. If people should be in the tunnel during operation an extensive safety system is necessary to provide for their safety. It will be necessary to install lighting, alarm, supervision and internal communication systems.

The systems themselves require even more inspection and the risks of disturbing these systems are considerably higher.

The safety concept for the tunnel was therefore established as follows:

1. The tunnel should only contain high voltage cables and optocables for supervision.

2. The tunnel should be closed for unplanned inspections or visits.

3. The inspections of the tunnel and cables should follow an established supervision programme and be carried out at times when the cables are not in operation.

4. Sensitive installations such as pumps and cable joints should be installed outside the tunnel area in special niches enabling access for maintenance and inspections at any time.

With regards to the above the isolated parts of the tunnel are approx. 1200 m long, only interrupted by pumping stations.

DEVELOPMENT

So far each step to replace overhead lines with cables in tunnels has been justified and financed by the need for exploitation of land. Each project, located at different places along the Stockholm ring so far, have different technical solutions and individual legal agreements as to environmental impact or concession for electrical transmission.

To get a better overview of the power supply to a major city like Stockholm the system should have a technical solution based on one legal agreement and should be supervised by the net owner. The motivation for converting the system should be governed by technical reasons such as a safer system or the possibility to upgrade the system and not by the need for exploitation of land. Necessary capital for upgrading the system can be raised either from the profit of exploitation or from the mains users.

International Conference on Tunnelling and Underground Use
Istanbul, Turkey Oct 16-18, 2002

International Conference on Tunneling and Underground Use organized by General Directorate of Highways(KGM), Turkish Road Association (TRA) and International Tunneling Association was held in Istanbul-Turkey between 16-18 October 2002.

Before the conference on 15 October, a workshop on Displacement Measurement Data Evaluation and Interpretation for Tunnels was carried out with app. 60 attendees, designers, site engineers, engineering geologist and academic person.

Lecturers were Prof. Wulf Schubert from University of Technology Graz-Austria, Prof. Reinhard Rokahr from Hannover University- Germany and Dr. Albert Steindorfer from 3G Gruppe Geotechnik Graz –Austria. After giving an introduction and state of the art in displacement measurements and data evaluation, working groups were formed and problems on evaluation of real monitoring data from tunnels were solved in groups and solutions were discussed.

Conference started on 16 October with opening lecture of Prof. Dr. Andre Assis , President of ITA, on "Critical Overview on Tunneling Methods" and two technical session on "Planning, Research and Design Aspects on Underground Structures" and "Geotechnical Problems in Tunnels". On 17 October Prof. Dr. W. Krajewski gave a key lecture on "Risk and Damage Prevention in Shallow Tunneling, Case Histories" and four technical sessions took place on "Construction Problems" . At the last day of the conference Mr. Willy De Lathauwer gave a lecture on "Safety of Road Tunnels" and three technical session were carried out on " Contract Management, Financing and Risk Analysis", " Maintenance, Rehabilitation and Operation Works" , "Seismic Design of Tunnels"

French Tunnelling Association (AFTES) International Conference- Underground Works : Living structures
Toulouse, France, Oct 21-23, 2002

The general topic of this Conference, sponsored by the International Tunnelling Association, was : « Underground Works : Living Structures ».

For the first time, AFTES have had two partners for this Conference : the Spanish Association (AETOS) and the International Society of Soil Mechanics and Geotechnics (Technical Committee 28).

About 400 delegates participated in the Conference, of which about 120 came from 16 foreign countries (64 from Spain). Simultaneously of the Conference itself, an important exhibition took place with about 100 exhibitors.

The two first days were dedicated to the French Spanish joint Conference. In his opening address on behalf of the ITA, the Past President Alfred Haack congratulated the two ITA Member Nations for this common action, underlined the important role played by France since the creation of the ITA, notably in hosting the Secretariat of the Association for more than 25 years, but also urged France and French Companies to continue to play an active role in the life of the ITA.

Three main tracks were treated : • Feedback on respecting of the function of a structure, construction materials and their response to extreme conditions, maintenance issues, commencing and financing new projects, and construction techniques and contracts. • The adaptation of existing underground structures and space for new purposes or constraints, such as an increase in traffic, changes of transport means or tighter demands in regulations. • The setting of programmes (financial, contractual and technical) which must be respected in the construction of underground structures and in the conditions leading to their application.

The third day was dedicated to the 3rd International Conference of TC 28 on geotechnical aspects of underground construction in soft soils. Three sessions treated respectively the following topics : design methods of tunnels, bored tunnels construction, and ground movements caused by tunnelling. In a special lecture, Yann Leblais presented the results of the French National Research project « Eupalinos ».

The closing address of the AFTES – AETOS Conference was delivered by André Assis, President of the ITA.

ROUND-TABLE ON PYRENEANS CROSSINGS

At this occasion, a round-table organized by the French & the Spanish Tunnelling Associations (AFTES & AETOS) and sponsored by the ITA, took place on the subjects of Pyreneans Crossings.

Technical and Socio-economicals topics have been discussed by French and Spanish specialists.

Two preliminary presentations described the present situation: • the heavy good traffic between Spain and France is mainly road traffic with an average daily traffic of 15, 000 lorries • the growth of this traffic is 9%per year and will lead in 2020 to a yearly traffic of 140 million tons (33,000

PARTICIPANTS

- **M. Bernard BELLOC**, *President Université des Sciences Sociales, Toulouse, Vice-president d'Eurosud Transport*
- **M. Olivier VION**, *Acrotère Marketing - Communication*
- **M. José-Luis GARCIA DE VIEDMA**, *GIF*
- **M. Dominique BECKER**, *Conseil Général des Ponts & Chaussées*
- **M. Michel GASPARD**, *Réseau Ferré de France*
- **M. Bernard MARQUIE**, *Vice President of the Conseil Régional Midi-Pyrénées*
- **M. Jesus SÁNCHEZ FARRACES**, *Transport and Communications, General Director, Diputacion General de Aragon*
- **M.J. TAVERNIER**, *Autoroutes du Sud de la France*
- **M.VILANOVA**, *Ministerio de Fomento*

- Closing -

- **M. Martin MALVY**, *President of the Conseil Régional Midi-Pyrénées*

lorries per day) which will be incompatible with the existing infrastructures, • this situation may perhaps not be fully taken into account by the two governments and French & Spanish population is certainly not aware of it, as it is for the crossing of the Alps, • few tunnels have been built through the Pyrenees, but several are planned for the short term, and various scenarios are imagined, including the construction of a Central Pyrenees Crossing (TCP) with a base tunnel (32 to 50 kms long depending on the alignment).

Then, representatives of French and Spanish governments as well as French (Midi-Pyrenées) and Spanish (Aragon) regions and representatives of RFF & GIF (rail infrastructures operators and ASF (motorway operator) debated on the subject.

All the participants at the round table did agree on the rapid and strong growth of exchanges between the Iberic peninsula and the rest of Europe, going through the Pyrenees. The heavy trafic grows by 7-9% per year and the trafic is already bigger than the one crossing the French Alps. The rail traffic is very low (around 4%of the total), while the maritim traffic is 44% and road trafic over 50%.

Every one agreed on the fact that a new equilibrium has to be reached between road and rail, as the forecast growth will not be supported by the road infrastructures.

In fact only two routes exist one on the Atlantic coast and one on the Mediterranean coast, with 40% each of the road trafic.

The routes of the rail infrastructure are the same, but their capacity is very low, due to a different gauge between Spain and the rest of Europe.

At short term, the new High speed rail line between Perpignan (France) and Figueras (Spain) with a tunnel (8,2 km long) will increase the capacities and offer the possibility to observe in which respect a part of the road trafic can go on trains.

Among others, the intervention of M. Tavernier General Director of Autoroutes du Sud de la France, the company in charge of financing, constructing, expoiting and maintaining the French motorway network in the region of the Pyrenees, was very instructing as he declares that there is too many lorries on the motorway network and that the lorries are costing them money.

In his closing, M. Martin Malvy insisted on the fact that decision of building new infrastructures, and especially a new rail route crossing the Central Pyrennes, mainly dedicated to freight transport, has to be made by decision makers, who must not be stopped, at the early stage, by technical or financial topics. It is of their duty to take the decision to launch the project and then to study how to find the financing. In order to have the TCP built in 2020-2025, the decision has to be taken now, eventhough the financing will only take place in 10 years.

Tunnelling in Russia and in CIS Countries at the Beginning of the Century: Experience and Prospects
Moscow, Russia, Oct 29-31 2002

The Conference was organised and held by Russian Tunnelling Association under the aegis of the International Tunnelling Association.

Russian and foreign specialists were invited to take part in the Conference. Representatives of scientific/research, design and construction organisations dealing with underground construction were among the Conference participants. In accordance with the registration results 294 specialists took part in the Conference including 221 specialists from 21 regions of Russia, 73 ones from 20 countries (Austria, Brazil, Canada, China, Czechia, France, Germany, Great Britain, Greece, Italy, Japan, Turkey, Sweden, Switzerland, United States of America and 5 countries of the former USSR – Azerbaijan, Byelorussia, Kazakhstan, Uzbekistan, the Ukraine).

The Executive Council of the International Tunnelling Association headed by Mr. A. Assis took part in the Conference work. Leaders of Gosstroy of Russia (State Organisation for Construction) and Moscow Government took part in the Conference Opening Ceremony.

The Conference work was organised in four Sessions: • Plenary Reports – 7 ones and C. Berenguier's presentation on the activities of the International Tunnelling Association. • Underground Construction Projects, Implemented and Ongoing – 13 reports. • New Technologies and Work Mechanization – 20 reports. • Applied Science and Scientific Supervision of Underground Construction Works – 13 reports. So 53 reports were presented at the Sessions including 37 ones by Russian specialists. 109 reports were published in the Conference Proceedings.

During the Conference there was a Technical Information Exhibition of 38 posters on various aspects of design and construction of underground structures.

Three technical excursions were organised for the Conference participants in Moscow: • Lefortovo road tunnel construction • Construction of "Boulevard Dmitriya Donskogo" metro station and Boutovo line running tunnels • Construction of the "Moscow-City" objects.

The tasks of exchange of the experience in design and construction of underground structures stated by the Conference Organising Committee were rather successfully solved during the Conference according to the opinion of participants.

The decision has been accepted: to make available the technical information materials presented in reports at the Conference for wide circles of Russian specialists.

Russian Tunnelling Association sincerely thanks Russian and foreign participants of the Conference and the ITA Executive Council for their support of the Conference organisation and their active participation in its work.

ACUUS 2002 International Conference - Urban Underground Space : a Resource for Cities

Torino, Italy, Nov 14-16, 2002

The International Conference "Urban Underground Space: a Resource for Cities" organized jointly by GEAM (Associazione Georisorse e Ambiente), ACCUS (Associated Research Centres for Urban Underground Space) and by the Politecnico di Torino, with the patronage of UNESCO, ITA/AITES and SIG but also Institutional Organisations: Regione Piemonte, Provincia di Torino and Turin Municipality took place at the Politecnico di Torino on the 14 and 15 November.

This convention is the eighth of a series of international appointments on the use of underground space in urban areas, promoted by ACUUS, at three yearly intervals of which the most recent have been "Indoor Cities of Tomorrow" in 1997 in Montreal and the conference "Agenda and Prospect for the Turn of the Century" in 1999 in Xi'an (China).

The objective of the conference in Turin was to facilitate the exchange of information and knowledge between the technicians, designers, discussion makers and the academic component in the sector of underground works in urban areas, but also allowing the possibility of directly viewing the large works that are at present being constructed for the Turin Underground system and the Railway Junction.

More than 250 members from over 13 different countries (including Japan, France, Germany, China, Canada, the USA, Holland, Russia, the UK, Spain, Austria, Egypt, and the Check Republic participated in the conference in Turin. It was thus possible, thanks to the high technological level of the papers that were presented, to compare examples, practical cases and theoretical studies on the rational use of the underground throughout the entire world offering numerous hints on why it is necessary and useful to " go underground", as explained in the introductory presentation to the convention made by Dr. J.P. Godard, Past Vice President of the International Tunnelling Association.

The Convention was organised in three sessions that allowed each guest to present and discuss their works: • "City Planning and Underground Infrastructures in Urban Areas" • " Safety and Advanced Technical Solutions for Underground Construction", • "Advanced Imaging Techniques for Underground Space> Educating People and Training Professionals. Cultural Heritage in Underground Space". Each session was proceeded and introduced by a Keynote Lecture in which Professor A. Colombo, Engineer I. Signoretti and Dr. T. Kurokava presented the architectural development of underground stations throughout the world, the safety and construction aspects of underground stations with specific reference to stations at present under construction in Turin and the applicative case of underground stations in Tokyo, respectively.

As part of the initiatives connected to the Convention, the technical seminary on recent innovations in the field of concrete for special applications should be recalled. This seminary, organised by MAPEI S.p.A. allowed the very interested public made

up of professors and designers to become updated on some interesting technical innovations in the concrete sector, and to see the drawings made by children from primary schools in Turin as part of a competition.

This competition, specifically announced in the month of May 2002 with the patronage of the Municipality of Turin and the Provincial Education Office with the collaboration of SATTI and MAPEI entitled ' THE WORK OF MAN UNDERGROUND" and "TURIN AND THE UNDERGROUND" resulted in an incredible participation with over 28 schools in the Turin area taking part and over 400 works, all of which were awarded prizes. The pupils were exceptionally good at representing the image that they have of the inhabitable underground of the city and of the constructive procedures of works underground, with designs that were sometimes skilful and full of life though obviously simple yet with great imagination.

The works came to an end, offering the participants, thanks to the contribution of Satti, the opportunity of visiting the construction works of the Turin Underground and the historical military tunnels of the XVI-XVII centuries of the Turin citadel.

NEWS FROM ITALY

Modern TBMs are finally excavating modern tunnels in the Turin subsoil

Three centuries have passed since several kilometres of military tunnels were excavated by hand around the Turin fortress and these can in part still be visited today. Today we are finally starting out again with a new programme of deep underground excavations, a considerable part of which is made up of the first Underground Line.

As is known, the VAL light automatic underground system will be used in Turin. This line passes from the West (Collegno) towards the East (Porta Nuova) and the Southeast (Lingotto) for over a length of more than 13.5 km, includes 21 stations (all constructed on the surface) and should be completed and working for the Winter Olympics of 2006. The East and Southeast sections are under the water table. The first western section of about 9616 metres, with 15 stations is at present under construction and all of these stations are being constructed contemporaneously. The use of 3 EPBs (mechanised shields with soil counterpressure at the face) with an excavation diameter of 7.9 metres and 8 metres is foreseen. The Turin sub soil is made up of sedimentary soil fans, represented by muddy sand of various degrees and gravel. This soil however presents two problems: on one hand there is the presence of irregular and random lenses of carbonic cement conglomerates with very variable extensions, thicknesses and degrees of cementation from place to place; on the other there is the occasional and infrequent presence of large boulders of resistant rock with dimensions even up to 60 cm. The EPBs will therefore have a rather difficult task ahead of them. The first machine (LOVAT) was inaugurated on 3 September 2002 and inserted in the Fermi station tunnel. The second machine (LOVAT), which is now being assembled in the Principi d'Acaia station, should also start working in February 2003 and immediately after the third machine (recycled) should be available.

These machines will doubtlessly have a certain period of adjustment: let's hope that they can quickly reach their production capacity in order to quickly give the city of Turin its Underground.

Prestigious career award confered to Riccardo Lovat by the Politecnico di Torino

The Laurea Honoris Causa in Engineering for the Environment and Territory was conferred by the Rector of the Politecnico to Riccardo (Richard) Lovat on Thursday 14 November in the Aula Magna of the Politecnico.

This career award was conferred to Riccardo Lovat because "he has known how to join the themes of mechanical engineering with those of underground construction engineering and of geotechnology acquiring deserved fame for his rare skill in the construction of tunnel boring machines (TBMs)".

The ceremony was attended by numerous academic and scientific authorities in the tunnel sector and culminated, after the Laudazio by Professor S. Pelizza, Professor in Tunnel Construction at the Politecnico di Torino and President of ITA/AITES (International Tunnelling Association) between 1995 and 1998, with the Lectio Magistalis by Riccardo Lovat entitled "Recent developments in the TBM sector".

In this lesson, thanks to his great experience, the author outlined thirty years in the development of full section tunnel boring machines: starting from the dawning, where he played a pioneering role, up going up to the present day where these machines have reached a very high technological level.

The new engineer Riccardo Lovat also solicited the academic authorities who were present, in particular the Rector of the Politecnico di Torino, Professor Engineer Giovanni Del Tin and the Dean of the First Faculty of Engineering, Professor Engineer Romulado Conti to continue with the formation of specialised engineers in the tunnelling sector as even the best excavation machines cannot function efficiently if not properly guided and if the tunnel design has not been adequately developed, in relationship to the use of integral excavation machines.

Among the many who participated at the ceremony mention should be made of the interventions by the President of SIG (Società Italiana Galleria), Professor A. Colombo, who offered the greetings and congratulations of both the Italian tunnel technology community and of the Board of Directors of SIG of which Riccardo Lovat is a member, and those of J. P. Godard, Past Vice President of ITA/AITES.

INAUGURATION OF THE ITA SECRETARIAT IN LAUSANNE DECEMBER 3-4, 2002

L'association avait choisi de célébrer l'inauguration de ses nouveaux locaux à Lausanne à l'occasion de la Sainte-Barbe

Le mardi 3 décembre dernier, la plupart des membres du bureau, les représentants et sponsors suisses, ainsi que des représentants de plusieurs nations membres limitrophes (et notamment des représentations française et italienne importantes et de très haut niveau), voire de pays beaucoup plus lointains (et notamment une représentation japonaise de très haut niveau), se sont retrouvés à Lausanne pour célébrer cette inauguration avec les nouveaux amis de l'EPFL, Ecole Polytechnique Fédérale de Lausanne

Une conférence de Presse a permis à Laurent Vulliet, Doyen de la faculté ENAC (Environnement Naturel, Architectural et Construit) de confirmer tout son intérêt pour le domaine de l'utilisation du sous-sol et pour l'AITES, aux membres francophones du bureau de présenter l'Association ainsi que la brochure «Pourquoi utiliser le sous-sol ? ».Le premier vice-Président de l'AITES Harvey Parker et le Président du groupe suisse de l'AITES ont retracé le contexte du transfert du siège de l'association de la France vers la Suisse et chacun a rejoint Laurent Vulliet pour formuler des vœux pour que ce transfert permette à l'EPFL et à l'AITES de développer des collaborations fructueuses.

Un cocktail, puis un dîner convivial autour d'un menu typiquement suisse ont clos cette journée.

Le mercredi 4 décembre, à l'invitation du groupe suisse, les représentants de l'Association ont eu l'honneur et le plaisir de participer à la célébration de la Sainte Barbe avec les constructeurs du tunnel de Lötschberg, au cours d'une messe de communion au cœur du tunnel puis dans la vallée autour d'une bonne table.

Des photos de tous ces évènements seront bientôt disponibles sur le site Web de l'Association.

A bientôt à Amsterdam et longue et fructueuse vie à l'AITES dans ses nouveaux locaux.

The association had chosen to celebrate the inauguration of its new office in Lausanne on the occasion of the Santa-Barbara. On Tuesday , December 3, most of the members of the ExCO, the representatives and the Swiss sponsors, as well as the representatives of several Member Nations close to Switzerland (and notably important French and Italian representations and of very high level), even of much more distant countries (and notably a Japanese representation of very high level), met themselves in Lausanne to celebrate this inauguration with new friends of the EPFL, Ecole Polytechnique Féderale of Lausanne. A press conference allowed Laurent Vulliet, Dean of the faculty ENAC (Natural, Architectural and Constructed Environment) to confirm all its interest for the domain of the use of the underground space and for the ITA, and French-speaking members of the ExCo to present the Association as well as the booklet "Why go underground?" .The first vice-president of the ITA, Harvey Parker, and the President of the

Swiss group of the ITA redrew the context of the transfer of the office of the Association from France to Switzerland and each joined Laurent Vulliet to formulate wishs so that this transfer allows the EPFL and the ITA to develop fruitful collaborations.

A cocktail, then a friendly dinner around a typically Swiss menu closed this day.

On Wednesday , December 4, at invitation of the Swiss group, the representatives of the Association had honor and pleasure to participate in the celebration of the Santa Barbara with the builders of Lötschberg's tunnel, during a mass celebrated in the heart of the tunnel and then in the valley around a good table.

Photos of all these events will be soon available on the Web site of the Association.

See you in Amsterdam and long and fruitful life to ITA in its new office.

Le Secrétaire Général
Claude Bérenguier

Introducing Sandvik CAPP bits for drifting and tunnelling

Sandvik CAPP bits for drifting and tunnelling have been developed in our unique product processing system – CAPP, *Computer Aided Product Processing*.

Everything from order processing, stock control, production loading and production planning to manufacturing, pricing and delivery is included. And, most important, product design and engineering. All our joint drilling experience, yours and ours, forms the parameters for the various bit designs.

Together we have set the standards and together we can now achieve a mutual economic return on our efforts.

Outstanding price/performance – we are convinced that a Sandvik CAPP bit will outperform any other conventional bit. The streamlined processing of the bits (we have even built a new factory) means that we can offer our best bits ever at a price you can't refuse.

The right bit – on time – our local sales and service staff will accurately guide you to the right bit. Sandvik's world-wide distribution network guarantees fastest and most reliable delivery.

Highest possible product quality – achieved by employing state-of-the-art manufacturing processes and our own quality materials.

Sandvik CAPP bits for drifting and tunnelling. A new world standard.

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