TRIBUNE

ASSOCIATION INTERNATIONALE DES TRAVAUX EN SOUTERRAIN
AITES

ITA
INTERNATIONAL TUNNELLING ASSOCIATION

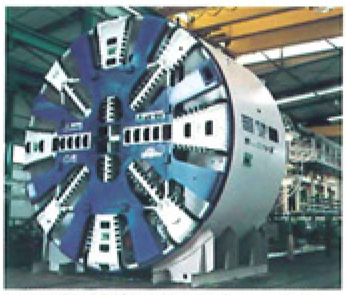
ITA newsletter - la lettre de l'AITES

N° 22 - JUIN 2002 - ISSN 1267-8422

Go for the Olympic Games 2004

Assembly of the EPB-TBM in the startup shaft

Athens is getting organised for the Olympic Games in 2004. In order to cope with the rush of Olympic fans, the city is connecting the new airport Eleftherios Venizelos to the city. As it was the case in the Olympic city Sydney 2000, a Herrenknecht TBM is excavating the metro tunnel. In January 2002, the EPB machine (Ø 9.46m) started the 3.5km long tunnel of Line No. 3. The machine will cross silt, clay and Athens schist, a calcareous meta sand and silt stone. In addition to the tunnel boring machine, Herrenknecht also provided the engineering and equipment for the peripheral muck transport.

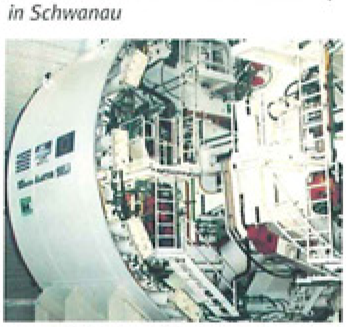


EPB-Shield Ø 9.46m in the workshop in Schwanau

Tunnel construction is opening up the future

Machine Data:
EPB-Shield, Ø 9.46m
Cutterhead Power 2,400kW
Tunnel Length: 3.500m
Geology: Silt, clay and Athens schist

Contractor:
AEGEK General Construction Company,
AKTOR S.A., S.E.L.I. Società Esecuzione
Lavori Idraulici S.p.A.



View of the rear side of the shield with thrust cylinders

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Tunnelling Systems

The future Antwerp Central Station. Courtesy of S.N.C.B. / S.A. TUC RAIL & EUROSTATION N.V

La future gare centrale d'Anvers. Remerciements. S.N.C.B. / S.A. TUC RAIL & EUROSTATION N.V

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www.ita-aites.org

Find all ITA on the web:
You can find a list of all articles published by T.U.S.T. since the beginning with special mention of ITA papers.

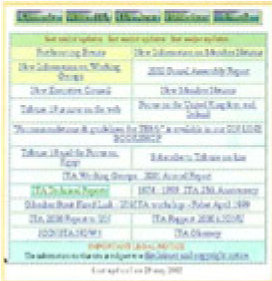
NEWS FROM THE ITA WEB SITE

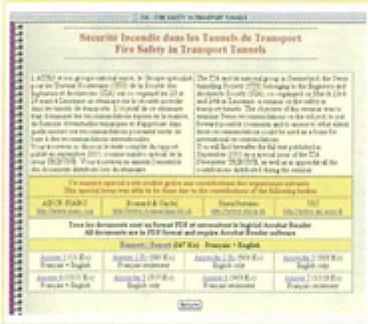
The ITA web site (www.ita-aites.org) is regularly updated. It provides the ITA family and the tunnelling community, world-wide, with useful information.

On the web site you can find general information on the ITA's life and especially the activities of the Member Nations and the Working Groups.

You can also download or order ITA publications, such as the report of the workshops on fire safety in transport tunnels or Gibraltar Strait fixed link - costing of TBM built tunnels or the recommendations and guidelines for TBMs produced by the ITA WG on mechanized tunnelling as well as the articles written by the ITA Presidents at the occasion of the 25th anniversary.

The web site is well visited with more than 500 pages visited per day throughout the year, by more than 5000 different people per month coming from 90 countries.





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EDITORIAL

For centuries, Belgium has been located in the heart of the most industrialised region in Europe with a very high population density.

Major projects are now a matter of urgency if we are to stave off the economic suffocation of this region due to the saturation of its transportation network. To make these projects environmentally acceptable, most of the work must be carried out underground.

Belgium has a very rich tradition and long-standing experience of underground work: coal mines, railway tunnels (more than 100 including the north-south link in Brussels), 70 km of subway in Brussels, Antwerp and Charleroi, and more than 30 road tunnels, including 4 submerged tunnels. In addition, these projects were very often implemented in soft water-bearing soil or heterogeneous rocks.

With regard to the techniques used in underground work, Belgium has always been open to the application of all kinds of new techniques as soon as they appear. In fact, Belgium has quickly acquired considerable experience whenever such new techniques come on stream: compressed air shields (1936), jacked pipes (1960), diaphragm walls (1962), submerged tunnels (1969), large-diameter bentonite diaphragms (1977), jet grouting (1979) and compensation grouting (1999).

A number of techniques have even been developed in Belgium, such as "timbered trenches" and underground roofs made with jacked pipes.

The ABTUS / BVTOS is proud of the key role it has played throughout the 25 years of her existence as the intermediary bringing together all the players involved in underground work. The ABTUS / BVTOS has also sought to play an important part in international exchanges within the ITA.

La Belgique se trouve depuis des siècles au cœur de la région la plus industrialisée de l'Europe avec une densité de population très élevée.

Des grands projets deviennent urgents si l'on veut éviter que l'économie de cette région ne s'étouffe sous la saturation de ses moyens de communication. Pour rendre ces projets acceptables au point de vue environnemental, la plus large part de ces travaux devra se faire en souterrain.

La Belgique est riche d'une très grande tradition et d'une grande expérience en travaux souterrains (mines de charbon, plus de 100 tunnels ferroviaires, en ce compris la jonction Nord-Sud à Bruxelles, 70 km de métro à Bruxelles et Anvers et Charleroi, plus de 30 tunnels routiers y compris 4 tunnels immergés) et cela dans des terrains meubles aquifères ou dans des sols rocheux très hétérogènes.

Au point de vue des techniques employées en travaux souterrains, la Belgique s'est toujours montrée très ouverte en mettant en œuvre les toutes nouvelles techniques dès leur apparition. De ce fait elle a chaque fois acquis rapidement une grande expérience dans ces techniques : bouclier à air comprimé (1936), fonçage horizontal de tuyaux (1960), tunnels immergés (1969), parois moulées (1962), bouclier à bentonite de grand diamètre (1977), jet grouting (1979), compensation grouting (1999).

Certaines techniques comme les fouilles blindées et toitures souterraines avec tuyaux foncés horizontalement ont été mises au point en Belgique.

L'ABTUS / BVTOS est fière du rôle qu'elle a pu jouer tout au long des 25 ans de son existence pour mettre en contact, les uns avec les autres, tous les acteurs des travaux souterrains. L'ABTUS / BVTOS a aussi voulu jouer un rôle important dans les échanges internationaux au sein de l'AITES.

Vincent Dierckx
Chairman of the
ABTUS / BVTOS

The International Tunnelling Association held its twenty-eighth meeting in Sydney from 2 to 6 March, in conjunction with the World Tunnel Congress 2002 organised by the Australian Tunnelling Society (AUCTA). The meetings were attended by representatives, delegates, observers and working group members from 34 of the 52 Member Nations of the Association.

L'Association Internationale des Travaux en Souterrain a organisé sa vingt-huitième réunion annuelle à Sydney du 2 au 6 mars 2002, en liaison avec le World Tunnel Congress 2002, organisé par le groupe national australien de l'AITES (AUCTA). Elle a réuni des représentants, délégués, observateurs et membres des Groupes de Travail de 34 des 52 Nations Membres de l'Association.

MEMBERSHIP

The Association has registered the membership of two new Member Nations (Chile and Croatia) and of 11 new Affiliate Members (1 Corporate Member and 10 Individual Members); the total results to 52 Member Nations and 273 Affiliate Members (92 Corporate Members and 181 Individual Members) taking into account radiations and resignations.

NOUVEAUX MEMBRES

L'Association a enregistré l'adhésion de deux nouvelles Nations Membres (Chili et Croatie) et de 11 nouveaux Membres Affiliés (1 Membre Collectif et 10 Membres Individuels); ce qui porte le nombre total à 52 Nations Membres et 273 Membres Affiliés (92 Membres Collectifs et 181 Membres Individuels) compte tenu des radiations et des démissions.

NEW EXECUTIVE COUNCIL - NOUVEAU BUREAU EXECUTIF

A.	Assis	Brazil	President
A.M.	Muir Wood	United Kingdom	Honorary President
A.	Haack	Germany	Past President
H.	Parker	USA	Vice-President
K.	Sørbraten	Norway	Vice-President
J.P.	Godard	France	Past Vice-President
J.	Hess	Czech Republic	Past Vice-President
C.	Berenguier		Secretary General
A.	Nordmark	Sweden	
J.	McKelvey	South Africa	
K.	Ono	Japan	
H.	Wagner	Austria	
H.	Oud	Netherlands	
J.	Zhao	Singapore	
Y.	Erdem	Turkey	

COMMUNICATION

Tribune: Last year, four issues of Tribune (152 pages) were published and about 3 000 copies per issue were edited. In addition, a special issue entitled "Why go Underground?" will be widely distributed to Governments, international associations, etc. in order to present ITA, and also to serve as a good means to convince authorities or managers of the necessity to go underground in some cases.

Tunnelling and Underground Space Technology: in 2001, four issues of TUST were published, consisting of thirty-three papers written by authors coming from twenty-one different countries. In addition, a special issue has been edited on "Tunnelling in Taiwan". Next year, TUST aims to increase its issues from 4 to 5 per year, consisting of a total of 40 to 45 papers written by authors coming from 20 to 25 countries. The ITA Working Group No 2 "Research" will bring two reports into TUST. Moreover, there are plans to publish a special issue focused on "Tunnelling in Japan".

COMMUNICATION

Tribune: l'année dernière quatre numéros de Tribune (152 pages) ont été publiés, dont environ 3 000 exemplaires par numéro. De plus, un numéro spécial intitulé "Why go Underground?" a été édité et sera largement distribué aux gouvernements, associations internationales, etc. afin de présenter les activités de l'AITES. Dans certains cas, il pourra servir de support pour convaincre les autorités ou décideurs de la nécessité de choisir une solution en souterrain.

Tunnelling and Underground Space Technology: en 2001, quatre numéros ont été publiés, constitués de trente-trois articles écrits par des auteurs provenant de vingt-et-un pays différents. De plus, un numéro spécial a été consacré à "Tunnelling in Taiwan" (Travaux souterrains à Taiwan). L'année prochaine TUST espère augmenter le nombre de ses parutions en passant de quatre à cinq numéros, comprenant en tout quarante à quarante-cinq articles d'auteurs provenant de vingt à vingt-cinq pays différents. Le Groupe de Travail No 2 "Recherche" rédigera également deux rapports pour TUST. Finalement, un numéro spécial paraîtra sur "Tunnelling in Japan" (Travaux souterrains au Japon).

Web Site: it should gradually become the main means of communication between members of ITA; in 2002 links will be activated with TUST and Member Nations and a private forum for Corporate Members will be set up.

The web site now contains about 1 000 pages and is visited by 5 000 different visitors per month coming from more than 95 countries.

Site Internet: il devrait progressivement devenir le moyen de communication principal entre les membres de l'AITES; en 2002 des liens seront activés avec TUST et avec les Nations Membres, et un forum privatif pour les Membres Collectifs sera mis en place.

Le site Internet contient actuellement 1 000 pages : il est visité en moyenne par 5 000 personnes par mois, provenant de plus de 95 pays.

NEXT ANNUAL MEETINGS

- Amsterdam (Netherlands) from 14 to 17 April 2003, during the ITA-AITES 2003 "(Re)claiming the Underground Space".
- Singapore from 22 to 27 May 2004, during the ITA-AITES 2004 "Underground Space for Sustainable Urban Development".
- Turkey in 2005 on invitation of the Turkish National Group

PROCHAINES REUNIONS

- Amsterdam (Pays-Bas) du 14 au 17 avril 2003, dans le cadre du congrès ITA-AITES 2003 "(Re)claiming the Underground Space" (Re-conquérir l'espace souterrain).
- Singapour du 22 au 27 mai 2004, pendant le congrès ITA-AITES 2004 "L'espace souterrain pour un développement urbain durable".
- Turquie en 2005 sur l'invitation du groupement national turc.

OPEN SESSION - FIRE & LIFE SAFETY

ITA Open Session 2002 was devoted to a very topical subject: "Fire and Life Safety". Considering the recent severe and catastrophic fire accidents in road tunnels as in the Mont-Blanc Tunnel, the Tauern tunnel and the St-Gotthard-Tunnel, this item calls for an intensified discussion on an international basis. The ITA Open Session gave an excellent stimulus in this direction following the ITA organised workshops in Lausanne, Switzerland, in March 2000 and amending the efforts of ITA Working Group 6, dealing with structural fire safety in Tunnels, in correspondence with the sister organizations.

La séance publique de l'AITES au congrès 2002 a été dédiée à un sujet d'actualité: "La sécurité incendie". Comte tenu des incendies graves et catastrophiques survenus récemment dans les tunnels routiers tels que ceux du Mont Blanc, du Tauern ou du St Gothard, ce sujet requiert un débat de fond au niveau international. A cet effet, la séance publique de l'AITES a été un excellent stimulant. Faisant suite aux ateliers organisés par l'AITES à Lausanne, Suisse, en mars 2000, elle a également permis d'apporter des améliorations aux efforts fournis par le Groupe de Travail No 6. Ce dernier traitant de la sécurité au feu des structures en tunnel en collaboration avec des organisations sœurs

David Stuart Watt of the Roads and Transit Authority Australia was the opening speaker. As a result of the European Tunnel fires of the past few years, Watt noted, that the issue of fire and life safety has become a pre-eminent concern throughout the world. However, he pointed out that the question of how to respond to needs is highly debatable and variable among countries. Some of their differing responses have to do with the age of tunnels; others are a function of differing local and national standards.

Dr Alfred Haack presented an overview of current fire protection methods in Europe, where approximately 15 000 km of metro, rail and road tunnels are currently in operation. Worldwide, increasing traffic density, higher speed (e.g.; railway), a growing number and length of tunnels, and an increase in vandalism and arson has increased the risks of fire in tunnels.

He discussed general problems associated with fire in tunnels and reviewed catastrophic tunnel fires in the Mont Blanc tunnel, the Tauern tunnel and the Gotthard tunnel. Dr Haack briefly presented recommendations for guidelines for fires in road tunnels, general needs for design, and general safety concepts. He concluded by describing two European research initiatives studying fires in tunnels and mentioning ITA's effort in the field of fire and life safety.

Colin Kirkland discussed the fire in the Channel Tunnel which occurred in November 1996. Mr Kirkland discussed the fire management system, the fire itself, and lessons learned. He noted that the fire "proved that the systems designed into the Eurotunnel actually worked". The real tragedy, he commented, was that the fire was deliberate. Mr Kirkland reviewed the safety features of the Channel tunnel and the refurbishment of the tunnel, which lasted from Christmas 1996 to 15 May 1997. He also discussed modifications in the tunnel safety features of the Channel Tunnel that resulted from the accident.

Ken Bryant, chief superintendent and assistant director of risk management for the NSW fire brigades, discussed the process of fire services in tunnel construction. He acknowledged that "tunnels provide a unique challenge to designers and users and emergency service personnel". While emergency service personnel are not designers, he said, they can provide advice about problems they face when there is a fire. Fire fighters also provide a different perspective on a tunnel project, he said. "Tunnel designers can walk away to the next job". The fire brigade's job doesn't end until the end of the life of the tunnel".

Regarding design of escape and evacuation procedures, Bryant stressed that "tunnels are a very foreign environment for the average person". Therefore, designers of fire escape systems must give people "every chance they can survive that situation". Bryant also discussed fire safety measures affecting fire brigades.

The presentation by Daniel Gabay of the RATP (Paris Transit Authority) concentrated on the evolution of natural and mechanical ventilation systems in the Paris subway network over the past 30 years. At present, Paris is served by 14 metro lines (380 stations, 350 of which are underground) and 2 RER railway lines (66 stations, 12 underground). Each day about 6 million journeys are made on this system. RATP has conducted simulation tests to define and improve fire ventilation procedures. The tests highlighted the weakness of some components of the ventilation system. As a result, the ventilation smoke removal system has been refined. Mr Gabay also described continuing RATP research operations. He concluded by noting that while "prevention is crucial and different equipment and procedures are necessary, some disasters are unavoidable so, stay humble".

H. Mashimo, with Japan's Public Works Research Institute, noted the increase in the total number and length of road tunnels in Japan over the past half-century, mainly as a result of expansion of Japan's road network through mountainous areas and continual improvements of tunnel technology. As of April 2000, there were 8,189 road tunnels in Japan. Though fewer accidents occur in tunnels than on open roads, Mishimo noted, the consequences of tunnel accidents were much more serious because of the enclosed space, the rapid expansion of heat and smoke, and the more complicated evaluation procedures.

Therefore, the two main goals of the tunnel safety program in Japan are to: 1. Reduce the probability of accidents occurring (e.g. through tunnel design and material), and 2. Reduce the consequences of accidents and fires (e.g. by installing emergency facilities and construction fire-resistant tunnel structures). Mr Mashimo concluded by summarizing lessons learned from past accidents in Japanese road tunnels: • the highest priority must be given to securing escape routes, • building escape passages much be given special consideration, • safety also depends on the user behaviour, • there is no such thing as " absolute safety" in road tunnels.

Dr François Vuilleumier reported on safety aspects of railway and road tunnels. He used the Lötschberg Rail Tunnel and Mont Blanc Road tunnel to illustrate how safety in tunnels affects the following 4 safety concepts of tunnels use: 1. Operation (e.g. ventilation, smoke extraction); 2. Infrastructure (e.g. direction of traffic, communication between tubes, length of tunnels); 3. Vehicles and 4. Tunnel users themselves (escape route, communication equipment). He concluded his presentation by showing a video of the Mont Blanc Tunnel fire testing completed in early 2002.

A.G. Bendelius, who is chairman of PIARC's Working Group 6 -Fire and Smoke Control, discussed the global activities of the World Road Association (PIARC) in the area of fire and life safety in road tunnels. Mr Bendelius reported that PIARC WG 6 is now working on 8 main topics: 1. Lessons learned from past disasters, 2. Safety concept for road tunnels, 3. Structural resistance to fire (jointly with ITA), 4. Transverse ventilation, 5. Emergency exits (spacing, door design, handicapped access, response planning), 6. Fire specific safety equipment, 7. Fire response management, 8. Emergency ventilation system operations. Results of these studies will be published in the next several years. "How safe should we make the tunnel? is a good question to ask", he concluded. "Using the worst case can be an extremely costly proposition". This concern was mentioned by several participants during the discussion period following the presentation.

Following a lively question-and-answer period, the session was closed by ITA President, Prof André Assis, who stressed the need for countries and organizations to share information on this topic.

The ITA open session 2002 can be judged as very successful. It drew high attention in the audience and proved once more, the importance of the subject "Fire & Life Safety" and ITA's deep as well as successful involvement in this field of highest public interest.


AITES
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HARVEY PARKER
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ANNICA NORDMARK
JIM McKELVEY
AITES-ITA

WG 2 "Research"

Animateur: Y. LEBLAIS, Vice Animateur: Y. TAKANO, Tutor: H. WAGNER

Ten members from six countries (Australia, Denmark, France, Japan, The Netherlands, United Kingdom) attended the meeting of Working Group Research. We have one complete study, two studies in progress and one new study, as follows. 1. State-of-the-arts report on seismic design of tunnel (Coordinator; Youssef Hashash) We had finalized this study in the last meeting in Milan. After the approval of the Executive Council, "Seismic Design and Analysis of Underground Structures – A State-of –the-Arts Report" was published in Volume 16, No.4 of TUST. 2. Settlement induced by urban tunnelling (Coordinator; Eric LECA and Barry NEW) We have studied this theme for more than ten years and we should finalize it in the last year. The target of this study is to make the recommendation. The proposed recommendation is based on the recommendation of AFTES in 1996. In consideration of the development of the tunnelling technology and the technology of analysis of ground movement in these 10 years, we have restarted this study. We will modify the proposed recommendation based on the one made by AFTES with the new standard of each country such as BTS Standard and make the final draft of it in this year. This study will be finalized in the next meeting in Amsterdam and published in TUST in the next year. 3. Risk analysis (Coordinator; Soren ESKESEN) Coordinator presented the final draft of the Guidelines for Tunnelling Risk Assessment". We agreed it on the main point. Other comments will be accepted by the end of April. Then, with the approval of the Executive Council, the Guidelines will be published in TUST in this year. 4. Site investigation (Coordinator; Yoshihiro TAKANO) This is a new study, which was proposed by Prof. Andre ASSIS firstly, and TAKANO leads this study with the assistance of JTA. The target of this study is to make the Guidelines for Site Investigation of Tunnelling Project". At the first stage, we will collect each guideline or recommendation of each country and make the draft. We will discuss this draft in the next meeting in Amsterdam. It will take about 2 years to finalize this study. We decided to use the website of Working Group to make our activities more efficient.

WG 3 "Contractual Practices in Underground Construction"

Animateur: W. MAARTENS, Vice Animateur: A. DIX, Tutor: J. MCKELVEY

The Contractual Practices in Underground Construction Working Group met on Sunday, 3 March and was attended by thirteen representatives from eleven Member Nations: Australia, Egypt, France, Greece, Korea, Lesotho, Norway, Singapore, South Africa, Switzerland and Turkey. A presentation was made to the WG on the Lesotho Highlands water project experiences with DRB's. This presentation sparked a lively discussion within the WG. A summary of the main issues discussed are as follows: • The purpose of an Alternative Dispute Resolution (ADR) is to resolve disputes fast, fair and in a cost effective manner. • The Dispute Review Board must base its decision on the provisions of the contract and on established legal principles. This decision must be in writing with a detailed and reasoned justification. The Board must not act as a mediator, trying to find the "middle ground" or a compromise between the parties. • An ADR fundamentally favours the contractor. This is clearly evident in the time allowed for preparation of the Statements of Case and that allowed for the Response thereto. This is inherent in the "mediator" or "find a solution role" mindset of many DRB members. Splitting the difference or making a deal for "pragmatic" or "commercial reasons" must favour the contractor if only because the more he claims the more he gets. • Tender specifications and conditions were also discussed. The clear allocation of risk, the mechanisms for compensation for changing conditions, how these mechanisms synchronise with standard conditions or what should, or should not, form part of the tender document, the tender data or the contract documents, are all issues that must be carefully considered. • An atmosphere conducive to amicable settlement must be created. We must remember that the DRB process is a consensual process and if either party is not happy with the proceeding they can stop it and go home. With all respect to the legal profession – keep the lawyers out of the DRB hearings.

The WG approves the document "Evaluation of Tenders for Consulting Engineers and Contractors". This document aims to sensitise potential parties to a contract on possible constraints and the steps required to ensure that a contract is ultimately to the benefit of all. This document will be loaded on the ITA Website and presented to the Executive Council for possible publication in the Tribune.

The draft document "Comments on the FIDIC's three new Standard Forms of Contract" was discussed. It was decided that the two lawyers in our WG must review this document carefully before it can be approved. The approval of this document by the WG will be during our next meeting in Amsterdam in 2003.

Two first draft documents were distributed and discussed by the WG, namely: • The need for better management of underground projects, and • The use of DRB's as an alternative dispute resolution mechanism.

Members of the WG will provide comments on the proposed frameworks and possible additional information that needs to be included in these reports. A second draft of these reports will be circulated to the WG members by September 2002.

The World Commission on Dams (WCD) report has been widely distributed and discussed. It provides important guidance for governments, financial institutions and impacted communities, to consider before projects are implemented. There is very little in the report about any positive impacts of development on humans. Development cannot be stopped, because it is the most important basic requirement for human development in developing countries. Is a better life for all people not the driving force behind all our activities?

A joint paper by our WG and the South African Institute of Civil Engineering WG on Contractual Practices has started. This paper aims specifically on the contractual implications if the recommendations by WCD are implemented. This document will be finalised during the coming year for approval by the WG in Amsterdam.

WG 5 "Health and Safety"

Animateur: D. LAMONT, Vice Animateur: W. CHROMY, Tutor.:A. NORDMARK

Working Group 5, Health and Safety in Works, met once during the ITA General Assembly in Sydney in 2002. Donald Lamont from UK was Animateur with Walter Chromy from Germany as Vice Animateur. Garry Ash from Australia was the ITA Tutor. Representatives from seven countries attended along with the Tutor. The Working Group reviewed the progress which had been achieved since the Milan meeting on the three projects currently being undertaken.

ITA publication – Safety in Tunnelling : This document, which is important for worker safety, has been almost completely revised and it is planned that it should be presented to the ED in October 2002. The majority of the illustrations in it have been updated and some minor suggestions for change to these illustrations were made this week. The final document will be presented in the form of a CD-Rom master, from which copies can be made and from which the text can be translated into any language. Funding of the publication was discussed. Production of the illustrations and CD-Rom will cost 25000 euros. This is being jointly funded by the TBG and ITA. It is proposed to seek advertising sponsorship to offset these costs. It is intended that a copy of the CD-Rom will be given to each Member Nation. Member Nations will be responsible for arranging translation and printing. It was agreed that the Working Group would confirm the outstanding illustrations by e-mail.

Database of Health and Safety Legislation : It was agreed in Milan that the WG would undertake this project to assist designers and contractors working outside their home countries. A questionnaire seeking the relevant information was circulated to all Member Nation Representatives earlier this year. To date only three replies have been received apart from those from Working Group Members. It is intended to recirculate this questionnaire through the secretariat later this year.

ITA Tunnelling Safety Guidelines: The first revision of this document has been carried out. Members of the Working Group have commented on it before coming to Sydney and discussed its content this week. Further comment is expected and progress on finalising the text will continue by e-mail during the forthcoming year. It is hoped to finalise discussions on the text in Amsterdam next year and to present the final text to the EC in Singapore. As health and safety is fundamental to good tunnelling, the Working Group wishes the document to be freely available and intends to prepare the text as a .pdf file for posting on the ITA website. All costs of preparing the document in this format will be met by the UK.

WG 4 "Subsurface Planning"

Animateur: A. NORDMARK, Vice Animateur: E. GROV, Tutor: J-P. GODARD

Working Group No.4 met on Monday, March 3 to finalize its business in anticipation of a positive vote of the General Assembly for the merge with Working Group No.13. Ten members attended the meeting from Russia, Czech Republic, Netherlands, Norway, Australia, USA, Morocco, Japan, Singapore and Sweden. Our delegate from UK excused himself for other pressing business.

The report about Water Installations Underground which was approved by the Executive Council will be published in an up-coming edition of TUST.

As regards the report "Underground works for landslide stabilization", the group regrets that due to a combination of the start of WG 18 Training which is chaired by the coordinator of this report, Daniele Peila, and the closing down of Working Group No. 4 in Sydney, it will not be possible to finalize this work.

A second draft of the report "Access Ways to Underground Facilities" was presented by Mr Ota of the Japan Tunnelling Association. In spite of the fact that only nine member nations have contributed, the opinion of the group was that this report well meets the initial objectives which are to emphasize the importance of mobility and easy access for all categories of people to and inside an underground facility and to keep costs down by taking into account the required design measurements at an early stage of a project. To further improve the report, however, it was decided to make some complements. A Final Report will be submitted to the Executive Council before the next General Assembly in Amsterdam.

Concluding remarks: I think we are all aware that the By-Laws of ITA recommend a life-time of about 5 years for a working group. As regards WG 4 with a life-time as long as ITA itself - maybe it should be called disobediance! In defence of this, however: The group has produced several reports and a large number of valuable technical papers about subsurface utilization throughout these years.

As the Animateur during the last 9 years, I wish to thank all members - also those not present here in Sydney - for your long and devoted work during the 27 years of the group's activity.

WG 20 "Urban Problems - Underground Solutions"

Animateur: J. REILLY, Vice Animateurs: E.GROV & J. BESNER, Tutor: JP GODARD

Based on a request of the Executive Council in Milan, initial preparations for the creation of this new Working Group, Number 20, with the topic "Urban Problems - Underground Solutions" were made during 2001 by the Animateurs of the former WG 4 (Subsurface Planning) and WG 13 (Direct and Indirect Advantages of Underground Structures).

The basis for the formation of this topic comes from the progressive increase of urban populations around the world as our civilisation demonstrates a steady movement towards urban life as the basis of social organisation, resulting in a continuous growth and increasing density of population in cities. This trend raises a number of serious problems which grow proportionally with the size of the city. An important part of the solutions to these problems is the use of underground space – which increasingly has an important role to play in solving such urban problems.

The creation of the new Working Group has now been confirmed by the General Assembly today (March 6th). The representatives for the new WG are the members of WG 4 and 13 and persons nominated by the Member Nations through the ITA Secretary General.

John Reilly has been selected as Animateur by the Executive Council and the Working Group has selected Eivind Grov as the ITA Vice Animateur. Additionally, discussions between ITA and ACUUS (Associated Research Centers for the Urban Underground Space) have resulted in a "Sister Organization" relationship between ITA and ACUUS with high-level representation in the new Working Group by the ACUUS Secretary-General, Jacques Besner, as one of the two Vice Animateurs of the Working Group. Other ACUUS members will also participate in the Working Group.

After finalization of the affairs of Working Groups 4 and 13 on Sunday March 3rd, the members of these two working groups combined on Monday March 4th to initiate discussions on the topic of the proposed new WG 20 (Urban Problems, Underground Solutions). Susan Nelson represented ACUUS in this meeting. It was decided to proceed with a concise request to Member Nations Representatives, and others as appropriate, for information on this topic, including an indication of those "urban problems" that are of concern to the respondents, with associated data on projects that illustrate the problem or the solution.

WG 6 "Maintenance & Repair of Underground Structures"

Animateur: H. RUSSEL, Vice Animateur.: R. MACHON, Tutor.: A. HAACK

The Working Group met on Sunday 3 March, and Monday 4 March 2002. The meetings were attended by 13 representatives from 10 member nations comprising: Australia, Egypt, Germany, Japan, Netherlands, South Korea, Sweden, Switzerland, United Kingdom and the United States of America. In addition to the member nations, a representative of The World Road Association, (PIARC) attended the meeting. Mr. Arthur Bendelious, Animateur of PIARC Working Group 6 (PIARC C5) "Fire and Smoke Control Working Group" represented the World Road Federation.

Mr. Jim Richards of South Africa has resigned as Animateur of the Group. The Group gratefully acknowledges Jim's contributions to the Group over the years in particular over the last six years where he served as Animateur. Jim's resignation was regretfully accepted. Mr. Henry Russell from the United States of America was elected Animateur and Mr. Richard Machon of Germany will continue to serve as Vice-Animateur.

The Working Group continued the work on the development of guidelines for the Resistance of Tunnel Structures to Fire. The document is approximately 50 % complete with some chapters to be written and edited. Mr Bendelious, provided the Group with the latest information from PIARC in regard to the development of new time temperature curves. A new schedule for the development of the remaining portions of the document was prepared and assignments made for the completion of the remaining chapters. The Group has scheduled a draft of the report to be available for the meeting in Amsterdam.

A brief review of the Report on the Repair of Damage To Tunnel Linings was performed. It was agreed to have the draft scanned and a CD be made and available to the Group, and a copy provided to Dr. Haak. Dr. Haak advised the Group that the Executive Council has approved the publication of the report.

Two presentations were made to the Group, from the members, they were: • Mr. Ian Barry, of the United Kingdom presented update on the types of materials available for the cladding and coating of tunnels for fire protection of structures. •Mr. Andreas Henke, of Switzerland presented a case study of the Gotthard tunnel fire and subsequent repairs.

The Working Group in association with our Tutor Dr. Haack of Germany has selected the topic of our next document which will be The Inspection and Maintenance of Tunnels and Underground Structures. The Group wishes to invite any members of the Association who would like to participate in the development of this report to contact the Working Group members or myself.

WG11 "Immersed and Floating Tunnels"

Animateur: J. SAVEUR, Vice Animateur: C. MARSHALL, Tutor: H.J.C. OUD

Working Group 11 held two meetings during the Congress in Sydney, involving 12 participants from 8 countries, namely Australia(partly), Korea, Japan, New Zealand, the Netherlands, Norway, Sweden and USA. The first meeting was used to exchange information on new projects and new developmetns in the countries represented and also to discuss the set up of the ITA Open Session to be held during the next World Tunnel Congress in Amsterdam in April 2003 under the title: Immersed Tunnels the next generation. The second meeting was used to coordinate the contributions for the next State of the Art Report.

Prof Kiyomiya gave a very intresting presentation on the fabrication of Immersed Tunnel elements using the steel-concrete sandwich concept, as used for the Naha tunnel at Okinawa. The Working group as a whole is supporting the ITA Open Session on Immersed Tunnels in 2003. In addition to the special presentations that we will prepare, 11 abstracts have meanwhile been registered for the 2003-Congress.

The State of the Art Report will be made especially for publication on the Web. It will be incorporated in ITA's website. It will be divided into chapters and subchapters with easy access to the various parts. The target is to have a substantial part operational by April 1, 2003, to enable demonstration during the Congress. The intention is to extend or update contents at regular intervals. The aspects covered are: Introduction, Basic engineering concepts, Dredging, Foundation, Joints, Design for earthquake, Structural design, Environmental aspects, Maintenance and repair, Durability, Documentation and instrumentation and the updated Catalogue of immersed tunnels. New technology developments will be covered.

The Internet report will not only require major commitments from the members of the Working Group, but also external professional support for good graphics and for the website preaparation. The out of pocket cost for the professional help is estimated up to Euro 20,000. The working Group will call on ITA for partial financial support.

Working group 11 is actually the only true international expertise platform on Immersed and Floating Tunnels. The objective is still to encourage Immersed tunnels as viable solutions for traffic links by providing knowledge about the trade around the world. This comprises the basic principles and aspects for engineers and owners who are new in the field and new developments for practicing engineers. The working group also welcomes participation by engineers who want to learn.

WG 12 "Shotcrete Use in Tunnelling"

Animateur: K. GARSHOL, Vice Animateur: K. ONO, Tutor: J. HESS

The WG 12 meeting on Sunday 3 March from 1400 to 1630, had 24 participants representing 15 countries: Australia, Brazil, Belgium, Czech Republic, Colombia, Finland, France, Germany, UK, Japan, Norway, South Korea, Sweden, Switzerland and USA.

Task 1 (State of the Art of Sprayed Concrete) has received contributions from 16 countries so far. For the quality and recognition of the final report, it is important to receive contributions from more countries. This is the first priority of the next few months. Compilation of the summary report will be done between the end of this year and a Final Report will be ready before the Amsterdam meeting.

The task coordinator Rene Michel Faure reported task 2 (Fire protective sprayable cementitious materials). A status report covering the 14 products listed so far, with the available technical data, will now be distributed to the WG members for review. A draft report including received comments will be ready within six months. Final Report should be ready before the Amsterdam meeting.

Professor Koichi Ono presented the Task 3 status (Shotcrete rock support mechanism). Even though the input from WG members so far has been very limited, a problem description will be made defining specific open questions to allow for targeted input from the WG12 members. This document will be posted on the Private Forum. The meeting decided to keep the option open to terminate this task if the response level turns out to be unsatisfactory. A final decision will be made in Amsterdam.

T. Celestino and T. Franzen have written a paper for the Sydney conference about the Task 4 (watertight tunnel linings). The meeting agreed that this paper shall represent the first reporting of this task. When all WG12 members have had time to review the paper, comments will be given to the authors and the paper will be integrated into the Task 1 final Report. Task 4 is thereby concluded.

The reference list on projects with permanent lining shotcrete has attracted much interest. The Japanese delegates kindly agreed to continue the compilation of this list and a general request was made to provide further references.

It was decided to invite suggestions for new WG12 tasks to be listed and distributed before the Amsterdam meeting. Decision about further tasks to be taken in the 2003 meeting.

WG12 members will be given the opportunity to make short presentations at the next meeting. However, this will take place after the formal agenda points are covered and to the extent that time and room availability allow. Subjects must be announced to the Animateur in advance and should not take more than 5 to maximum 10 minutes each.

WG12 had a very constructive meeting. It was emphasized at the opening that participation is open and that wide reaching active contributions to the agreed tasks is crucial for the ongoing work. The different tasks of WG12 are outlined in the Private Forum along with other general information and the meeting participants were requested to use the Private Forum and to spread information about WG12 to as many as possible of potentially interested contributors. The Animateur will reply Private Forum password requests.

WG 13 "Direct & Indirect Advantages of Underground Structures"

Animateur: J. REILLY, Vice Animateur: P. KOCSONYA, Tutor: J.P. GODARD

WG 13 members met on Sunday March 3rd in Sydney and finalized their report "Underground or Above-ground? - Making the Choice for Urban Mass Transit Systems".

The report is based on an extensive set of data from a very comprehensive questionnaire - 30 Transit Systems in 30 Cities in 19 countries and 4 continents responded.

The report presents findings and general conclusions on this topic. The conclusions are general because the data shows great variations of characteristics from country to country and region to region - meaning that the choice of above-ground or underground alignment for Urban Mass Transit Systems is very dependent on the specific policies and urban design characteristics of the region or city.

The report has now been submitted for Executive Council review and subsequent publication in ITA's Technical Journal, Tunnelling and Underground Space Technology.

With the finalization of this report, the WG will conclude its activities. Most members of the WG intend to transition to the new WG 20 "Urban Problems, Underground Solutions".

WG 14 "Mechanized Tunnelling"

Animateur: M. KANAI, Vice Animateur: F. AMBERG, Tutor: K. ONO

1. WG activity to year 2002

At Milan, to make our database on the mechanized tunneling informative for prospective users interested in tunnel and tunneling, we decided to tackle with the old but fundamental subject of "Classifications and Definition of TBMs" to reflect the current trend of rapid and continuous technology development. And a sub-WG consisting of eight WG members was formed led by Mr. Pierre Longchamp from France. The issue was discussed at Milan and on our e-mail communication network in succession. A consensus was reached and the subject was concluded in January 2002.

2. WG activity at Sydney 2002

We had eleven participants from ten(10) member nations, namely Australia, Germany, Japan, Korea, Lesotho, Netherlands, New Zealand, Norway, United Kingdom and United States of America.

Our activity started with the WG member recognition and identification with self-introduction from newly attended members from Australia and New Zealand before going into the main subject.

2.1 Discussion on the Main Subject

As the unified classifications and definition of TBMs is finalized, it was decided to make the achievement open to outside of our group by placing it on the ITA web-site shortly.

Our next discussion was database structuring and its operation. To make the database most valuable and usable, it was our mutual understandings that we should clarify "What is the purpose of the database?" and "Who would be our prospective users of the database?" at this time, and that we should ask the question to ourselves time and time again.

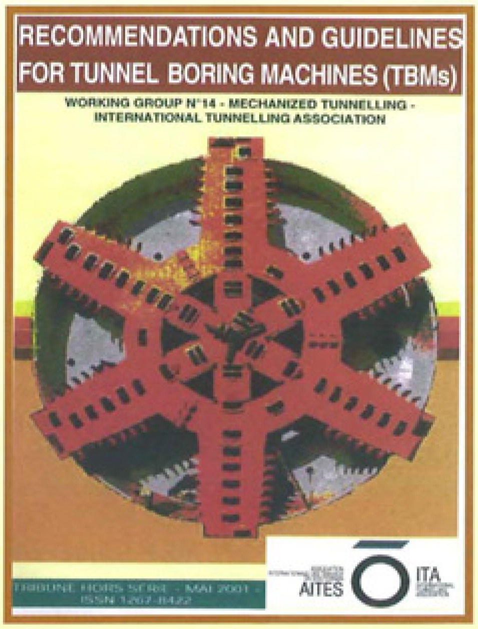
The purpose is to learn from the past experience to avoid similar mistakes or unnecessary increase of tunneling cost, to discover new things by studying the past through scrutiny of the old, and to enhance inter-relations among tunnel engineers worldwide and any body interested in tunnel and tunneling including college students. Therefore, we believe the database should be completely open to public.

Next discussion was "How could prospective users reach their demanded data?" We assumed the process as followingly:

Firstly, they hit `tunnel`, `tunnels`, or `tunnelling` on general web-site to reach the ITA web-site. Then, ITA-owned search engine will lead them to a title, authors and abstract of their desired papers, by which they will know what papers to look at. The WG members' opinion is that up to this point we should not charge them. However, when they place an order to get those papers in a digital form through internet to ITA, then we think they will be charged. It was a group members' consensus that we should ask legal and managerial advice on copyright and etc. At this point, the Animateur had a meeting with our Tutor and the Secretary General on this matter. We are happy to hear that the WG and the General Secretary hold the same opinion, and that the issue will be handled appropriately.

Going back to a scientific part of database structuring and its operation, we discussed how we can help users search for their requested information most effectively. And we decided to select our recommended keywords a maximum of five words which should be placed in the matrix of the items of interest selected in WTC2000 at Durban and the classifications and definition of TBMs finalized in WTC2002 at Sydney. After our recommended keywords being finalized and made public by the end of April 2002, prospective authors of scientific paper to ITA such as WTC proceedings, TUST or TRIBUNE should follow our requirement in writing their abstract and selecting its keywords. At the moment our attention will be looking forward, which is, as a first step, authors of scientific paper at and after WTC2003 have to meet our requirement. We sincerely would like to express our appreciation to the scientific committee of WTC2003 Amsterdam who has agreed to our request.

To complete our recommended keywords by the end of April 2002 so that prospective authors of WTC2003 could follow the requirement, a sub-WG consisting of nine(9) WG members was formed. Mr. Tony Peach from Australia is leading the sub-WG. The group will discus the matter on our e-mail communication network or on the private forum.



WG 15 "Environment"

Animateur: R. CRAIG, Vice-Animateur: J. RHODE, Tutor: H. PARKER

The Underground Works and the Environment Working Group met on two occasions and was attended by ten representatives from seven Member Nations: Australia, France, Japan, Norway, South Africa, United Kingdom and the United States of America.

The operational summary of the first report by the Working Group was not discussed at the meetings and the responsibility of the finalisation of the report is with the Animateur, the Vice Animateur and the Tutor. The redraft will be completed before leaving Sydney.

The Working Group has concentrated during the year on projects which have been placed underground for environmental and sustainable development reasons. This information has been collected from Member Nations who have filled in a short single page Questionnaire. However, beyond the Member Nations represented on the Working Group, only one Member Nation has responded.

Some 80 projects, covering seventeen different countries, have been identified to date. Some of the projects fall directly under this category while other projects may have other additional reasons for going underground.

The questionnaire will be resent to Member Nations in the near future with the view of having some 200 or more projects, from as many Member Nations as possible, by the end of June 2002. The questionnaire will also be placed on the ITA website for the Working Group with an e-mail address for completed questionnaires.

The information will be collated and a draft report circulated in advance of the Amsterdam meeting. It is envisaged that the report will compliment the ITA recent publication ' Why go underground' and that it should be published in Tribune.

During the first meeting of the Working Group there were presentations from four of the members on projects which had been placed underground for environmental and sustainable development reasons - Australia, The United States of America, Norway and the United Kingdom. The Australian presentation was particularly interesting as the projects were reviewed from the point of a contractor's environmental manager rather than from a tunneller's points of view.

Summaries, by country, of the majority of projects were reviewed. There was a lively discussion on the meaning of 'environment', 'sustainable development' and 'lifecycle costs' and on how the collected information should be collated into the report. When the different categories of projects have been identified more information will be collected on selected projects together with illustration material.

The Working Group had a short meeting with the New Working Group 20 – Urban Problems – Underground Solutions' and plans to cooperate and share relevant data.

At the second meeting of the Working Group the three other topics being studied were considered. It was agreed that further information should be collected on:

• Projects whose construction or operation have affected the environment • Projects where major environmental constraints where imposed during the construction, and • Projects whose design and construction have had to take into account major environmental constraints

As an individual project may fall into several of these categories only one questionnaire would be circulated.

The Working Group reviewed the topic ' TBM tunnelling and the Environment'. It was decided to await the information from the Member Nations on the first of the topic - projects whose construction affected the environment - before deciding to develop this topic further. However, selected members of the Working Group would collect information from their own countries on guidelines on this topic.

The Working Group understands that following the European Union's risk assessment on the environmental and health & safety aspects of using acrylamide grouts that they will be banned in the EU.

The Working Group discussed communication between its members. This is mainly by e-mail. A monthly or bi-monthly progress report is issued by the Animateur and it was agreed that this should continue to encourage regular participation.

About 80% of the members on the e-mail circulation list, of 28 members, had registered with the Working Group Forum, but participation was low. It was agreed that to get more participation a topic should be chosen for discussion in the Forum.

Lastly, Mr President, you will recall that I set the Executive Committee two targets in Milan to be achieved before our meetings in Sydney. These targets were related to ways of increasing the participation of Member Nations on the Working Groups. This is a concern of all Animateurs.

• The first topic was to ask that each member of the Executive Council should ensure that their Member Nation should have a representative on each of the Working Groups. I can report that, whilst this target was not achieved for my Working Group, it is encouraging and there are only two Member Nations not represented, in fact after the elections today it is now only one. You have nearly achieved the target!

• The second target was for the Executive Council to make a concerted effort to get each Member Nation to have a representative on some, and in some cases all, Working Groups. For my Working Group there have been only one or two new members, despite circulating Member Nations by e-mail or fax. So I think that the annual report would be ' disappointing and could do better'.

Which brings me to my final, and other regular topic, please could all Member Nations let the Secretary General know their e-mail address.

WG 16 "Quality"

Animateur: C. OGGERI, Vice-Animateur: G. OVA Tutor: K. SØRBRATEN

W.G. 16 on Quality in tunnelling has prepared a report concerning the technical aspects and links to contractual practice and involved bodies as far as quality matters are concerned.

On the basis of the previous draft edition (March 2001) the members of the WG have received a series of comments – both positive and negative – from different experts and consultants that have gone through the text. Comments, corrections and suggestions came from six countries.

This final edition has now taken into account the comments and the WG has revised the structure and the expressed idea.

It should be mentioned that Quality and contractual practice are continuously developing items (for example in the last two years new standards came from ISO and new types of contracts from FIDIC have been issued) and the work of the group can not be considered as the final stage in Quality procedures and evaluation of results of a well done project (for example consider the new trends in Process orientation, Customer orientation and so on).

The WG 16 will be still active in order to complete the final stages of the report.

It should be finally emphasized that more being standard procedures, the report has been aimed to give operative suggestions for understanding the links between project of phases, key players and their relative role.

WG 18 "Training"

Animateur: D. PEILA, Vice Animateur: N. CHITTENDEN , Tutor: J. ZHAO

The meeting was attended by 7 members coming form Australia, France, Japan, Italy, Russia, Singapore, UK.

After the discussion of the Agenda the Animator presented the results of the actions developed during the year 2001, after the first meeting which took place in Milano.

The improvement of the collection of data of tunnelling professors names and addresses was discussed and the strategy for improving it in the next year was developed.

The working group members thougth that these data are very important to create, under the umbrella of ITA, a network of teachers and professors involved in tunnelling education at various levels. After this item there was the presentation of some examples of Power Point slides for teaching purposes, prepared by Italy and UK, and the Japanese delegate gave to the group Members two videos which could be used for didactic purposes.

These videos will be distributed by the animateur through the group members during 2002.

From France there was a presentation of a code under development for a systematic collection of data on tunnel projects.

After and open discussion on the future activities of the working group the following actions were agreed:

1) Action directed towards Member Nations: Ask for help for the collection of the data of tunnels already designed and constructed with photes, pictures, schemes and a wide description of the geological and technical aspects which were encountered. This data could be used as significant examples for lessons and teaching purposes.

The information should be given in a Power Point structure under a general framework. The Animateur will send through the Secretariat the standard format to be used. The help of everybody is sought to prepare such material. In our next meeting in Amsterdam we hope to have a lot of material to work on. We suggest that each member nations should describe 1 or 2 examples for the next meeting sending to the animateur for homogenizing them and distributing throught the members of the group.

2) Action directed towards ITA Working Groups The working group members propose to organize a collection of teaching material which is directly linked with the activity of the working groups. The working group members suggest that when a WG report is finished a Power Point presentation should be prepared and made available to facilitate the teaching activity in the specific subject.

This material can be collected and made available through the web site The working group members are available for helping in setting a general scheme to be used for this purpose. Some contacts with other Animators has already been taken. When such presentation will be prepared they can be distributed for teaching purposes.

Finally the present vice-animateur Zhao has asked to desist from his function, because we feel that it is better to have a Vice animateur who is able to cover the training side of professional education After a discussion the WG members has decided to appoint as vice- animateur the representative of Switzerland Mr. Nick CHITTENDEN, who is directly involved in the industrial professional training.

The working group members thanks Jian very much for the very good work done in the past.

In completion all the members of the Working Group ask strongly the Member Nations to nominate a representant in Training Working group to facilitate our work.

The animateur asks also for your Association and your personal help in providing the requested information to improve the activity of Working Group.

WG 17 "Long Tunnels at Great Depth"

Animateur: F. DESCOEUDRES, Vice Animateur: P. GRASSO, Tutor: F. VUILLEUMIER

The meeting was attended by 11 members from 10 different countries: Australia, Austria, France, Iran, Italy, Japan, Korea, Norway, Switzerland and USA.

The group had received only a few replies to the questionnaire decided upon during the previous meeting in Milan. Some interesting contributions and examples of long tunnels in Japan and Europe. were presented.

It was decided to focus only on long traffic tunnels (railways and road) with particular attention to the situations which involve the extreme conditions for risk assessment and risk management throughout the lifetime of the project (from the feasibility to the operation).

The structure of the WG report was defined and the main chapters assigned to the various members.

Proposed WG report/guidelines: 1 Definition of long and deep tunnel; 2 Project specifications (project stages and corresponding requirements); 3 Ground conditions (Austria); 4 Safety and Environment (req. for construction and operations, rescue exits, fire and ventilation, dewatering (France and Switzerland), Use and management of excavated material (Sweden); 5 Design requirements (Italy); 6 Construction (USA); 7 Special conditions for railway tunnel (France and Switzerland); 8 Special conditions for road tunnel (Italy, Norway and Switzerland); 9 Risk Assessment, time-cost-durability-safety aspects, investigations to reduce the risks, multi-criteria analysis, probabilistic approach (Austria and Italy)

Email communications and sharing of contributions are planned in the next months in order to finalize the first draft to be discussed in a special working group meeting that will be organized in Switzerland end of next May with a technical site visit at the Loetschberg tunnel, under construction.

WG 19 "Conventionnal Tunnelling"

Animateur: K. KUHNHENN, Vice Animateur: H. LAUFER, Tutor: A. ASSIS

During the last ITA Congress in Milan, the General Assembly decided to install this Working Group.

ITA's reason for this was to clarify a great deal of misunderstandings caused by specifics of local practice and, in many cases, by application of the methods beyond their limits and, therefore, full of risks.

The goals of this working group will include the following: 1. Definition of conventional tunnelling; 2. Catalogue of all methods; 3. Basic characteristics of all methods; 4. Summarising world experience; 5. Defining the limits of applicability; 6. Publishing fundamental rules for national application of conventional tunnelling by issuing recommendations and design guidelines.

Following the invitation letter from the ITA Secretary-General, 13 participants from 9 countries were present at the first meeting during this Congress. Austria, the Czech Republic, Germany, Greece, Japan, Korea, Norway, Singapore and Turkey were represented, but countries like the USA, Great Britain, Russia, France and the P.R. of China, whose input would be desired, were not present.

To really implement the relevant variances of conventional tunnelling, the practice and experience of these countries should be made available.

During the meeting the members reported about their state of the art concerning: • guidelines, recommendations and regulations; • design specifications and design stages;• contract models and documents;• experience on project execution.

After discussion of the possibilities on how to work out the report, the members agreed on the following topics: 1. Purpose, scope of work; 2. Principles of conventional tunnelling method; 3. Strategy of project development; 4. Design principles and stages; 5. Ground investigation; 6. Geological and geotechnical evaluation; 7. Detail design (incl. monitoring); 8. Building contract model and document; 9. Organisation of project execution; 10. Management (supervision, risk, safety, claims, etc.)

Within the next four months (end of June 2002), the members will work out their national state of the art as draft reports via the ITA Website on the private forum of WG19. This forum is available to all interested members of ITA and is also an opportunity for corresponding members to participate in the elaboration of the report. Also a collection of regulations and design guidelines should be produced by using the Website.

On the basis of these results, the WG19 will prepare a meeting during the international conference on tunnelling in Istanbul from 16 to 18 October 2002 to discuss the further steps of elaboration of the report.

1 • TUNNEL TGV DE SOUMAGNE

The Soumagne tunnel is situated on the high speed train line between Brussels and the German border. It is a single tube, 5,840m long tunnel excavated with conventionnal means. The works began in May 2001 and the tunnel will be operationnal in 2006.

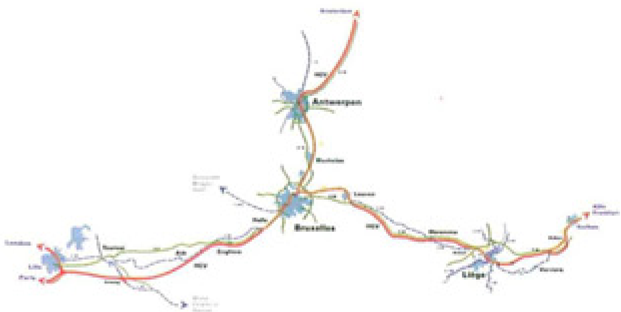
Author : Jean Herbauts, Manager general honoraire SNCB

Fin des années 80, la Belgique a décidé de participer activement à la création du réseau européen de trains à grande vitesse TGV PBKAL (Paris – Bruxelles – Köln / Amsterdam / London). Ce réseau a été mis en exploitation en décembre 1997 après inauguration, par le Roi, du tronçon Ouest (Bruxelles – frontière française) de la LGV (Ligne à Grande Vitesse = 300 km/h) sur le territoire belge.

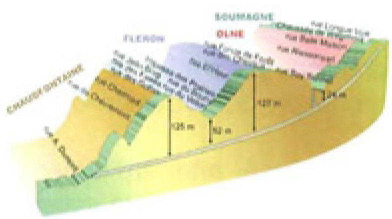
La relation PBKA (Paris – Bruxelles – Köln / Amsterdam) est desservie par des rames TGV Thalys, aptes à circuler sur les réseaux français, belge, allemand et néerlandais.

La relation Paris / Bruxelles – London est assurée par des rames Eurostar, aptes à circuler sur les réseaux français, belge et britannique.

Les deux branches Nord (Bruxelles – Antwerpen - Pays-Bas) et Est (Bruxelles – Liège – Allemagne) de la LGV en Belgique sont en cours de construction . Elles permettront aux rames TGV Thalys de circuler sur des tronçons de lignes nouvelles, en remplacement des lignes classiques empruntées aujourd'hui, avec de nouveaux gains de temps.



La branche Nord comporte un très important chantier souterrain à Anvers, qui fait l'objet d'un autre article. Dans le cadre de la construction de la branche Est, avec le concours de TUC RAIL, la Société Nationale des Chemins de Fer Belges (SNCB) construit près de Liège un tunnel à double voie (dit « de Soumagne ») de 5.940 m. de longueur prolongé par des tranchées couvertes respectivement de 177 et 388 m. de longueur. Cet ouvrage permettra aux TGV de rejoindre la frontière allemande en site propre, après arrêt dans la gare en rénovation de Liège Guillemins.



Ce tunnel est en pente régulière de 1,7 %, portée à 2 % près de la sortie Est. La tête Ouest du tunnel est située à Vaux-sous-Chèvremont (commune de Chaudfontaine) dans la vallée de la Vesdre, à une altitude de ± 90 m. La tête Est sera située à Soumagne, 120 m plus haut. La couverture maximale sur le tunnel atteint environ 130 m.

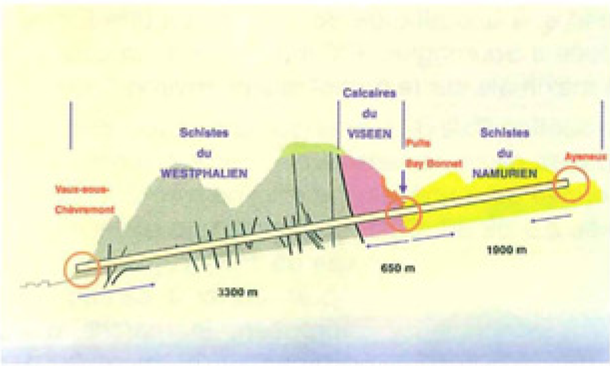
La section libre du tunnel (surface située au-dessus du plan de roulement – voir coupe 4) a été dimensionnée pour une vitesse nominale de 200 km/h et fixée à ± 69 m². Cela représente une surface excavée de 110 m².

Après appel à candidatures européen, le marché a été attribué le 29 mars 2001 à une association momentanée (Bouygues TP – SA CFE – SA Duchêne – Dumez-GTM – Fougerolle Borie – SA Galère – Wayss & Freytag AG) qui a entamé les travaux le 14 mai 2001 en vue d'une mise à disposition en août 2005 afin que ce tronçon de ligne nouvelle puisse être mis en service fin 2006.

En section courante, la section finale du tunnel sera constituée des éléments suivants :
• une coque extérieure en béton projeté fibré, épinglée au terrain au moyen de boulons à ancrages répartis et renforcée par des cintres réticulés ou exceptionnellement par des cintres lourds
• un radier en béton armé
• un complexe de drainage et d'étanchéité
• une coque intérieure en béton coffré.

En raison des délais à respecter et en fonction des sites de versage des terres, quatre attaques ont été retenues :
• une attaque montante au départ de Vaux-sous-Chèvremont
• des attaques montante et descendante au départ d'un accès intermédiaire situé dans la vallée du Bay-Bonnet où la couverture est faible
• une attaque descendante au départ d'Ayeneux.

A chacune de ces attaques, la section totale à creuser, soit ± 110 m², sera réalisée par passes successives :
• d'abord la calotte, réalisée par cycles de 80 à 150 cm de longueur en fonction de la qualité des terrains
• ensuite le stross, creusé alternativement à gauche puis à droite afin de maintenir un accès au front
• enfin, le radier, réalisé par plots de 22 m de longueur.



A chaque front, un dispositif de ventilation est installé, comportant une ventilation soufflante (amenant l'air jusqu'au front) et une ventilation aspirante (évacuant les fumées et les poussières).

Dans les terrains à faible cohésion, la calotte sera réalisée en deux phases : d'abord une galerie de dimensions réduites permettant d'accéder aux terrains à traiter ; ensuite l'élargissement de la galerie au gabarit de la calotte. Différents traitements (injections, jet grouting, boulonnage du front, drainage par forages, enfilage de barres en calotte, colonnes injectées) sont prévus.

Des contraintes acoustiques et vibratoires ont été imposées en fonction des plages horaires, des appareils de mesure étant placés à l'extérieur de la zone du chantier, le plus près possible des voisins concernés par ces nuisances. Réalisées en continu, les mesures sont transmises en temps réel au laboratoire via Internet.

Les deux tunnels concernés (Anvers et Soumagne) constitueront le centre d'intérêt des Journées d'études de l'ABTUS (25ème anniversaire) organisées en novembre 2002 avec la collaboration de TUC RAIL et de la SNCB.

25° Anniversaire
25th Anniversary

ABTUS - BVOTS

1977 - 2002

• 19.11.2002 : Bruxelles / Brussel

• 20.11.2002 : Anvers / Antwerp : HST
Liège (Soumagne): TGV

2 • NEW NORTH-SOUTH RAILWAY LINK IN ANTWERP

La liaison ferroviaire Nord-Sud à Anvers fait partie de la ligne à grande vitesse entre Bruxelles et les Pays-Bas. Une adaptation des lignes existantes est nécessaire avec notamment la construction de deux tunnels forés sous la Dam Plaas.

Author : Ir Dirk van Ooteghem - Project manager TUC Rail

HISTORY

Previous turn of the century

At the turn of the 19th century, Antwerp celebrated: from that time on, the railway lines coming from Brussels and Gent entered the "Metropolis" on elevated rails. In 1905, a new and monumental station building, "the Antwerp Cathedral", became a reality. The urban traffic was no longer disrupted by the trains, all level crossings were eliminated from the city, the structures were monumental: the station, copy of main station of Lucerne (at the request of King Leopold II), iron bridges (Belgiëlei – in "art deco" style) and masonry (Plantin and Moretuslei, calcareous stone from Vinalmont). Nevertheless, even there, saving costs was required, e.g. imitation of natural stones by concrete, retaining walls of the Oostenstraat made of contiguous masonry arches called "Centers"

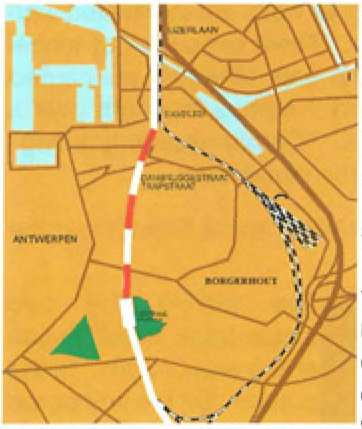
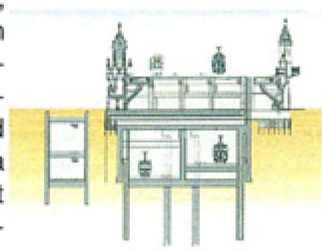


Fig. 1. Plan view with the Ring line and the North-South connection

Every 100 years a "railway revival" surprises the Metropolis.

For around 30 years, railway engineers planned a link between the terminal station of Antwerp Central and the north with a tunnel under the city, avoiding change of direction for through trains via the eastern ring rail line. But budgets could not be found for such enormous works during the "poor railway years 1970-1990". However, thanks to the European extension high-speed railway network through Belgium, however, this old dream finally became a reality, and the green light was given for the North-South link for the through trains to the Netherlands. An important argument was a significant improvement of suburban traffic with the completion of a new station "Groenendaallaan" in the north of Antwerp, similar to the Berchem station in the south. This new North-South link is indicated in figure 1, the location of the new twin-tube rail tunnel approximately 1200 meter long beiing indicated in "red-white".



IMPLEMENTATION

From the early 1990s, two subsidiaries of the National Railway company, the SNCB / NMBS, were set up in order to implement this project (among others): EUROSTATION for the station of Antwerp. TUC RAIL, in charge of the new HST lines or the adaptation of the existing lines, for all of the works from Berchem to Antwerp Dam, except for the station itself (between the Lange Kievitstraat and the Astridplein). Execution works began in 1998, and are foreseen for a period of 8 years.

The construction of the North-South link can be divided up into four large distinct zones:

- The construction of the access incline between Berchem station and the Antwerp Central station, with preservation of all listed structures (retaining walls-arches and bridges)
- The renovation works in and under the Central Station
- The construction of two bored tunnels from the northern part of the station to the Dam place
- The works beyond the Dam place, to the north connecting to the existing line 12, and the HSL, both in the direction of the Netherlands.

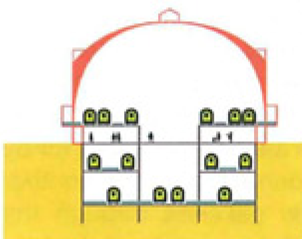


Fig. 2 Cross section of the tunnel structure in its final state at the level of the Belgiëlei, where underground double railway lines diverges, two of them going to the track levels –1 (on the left, west side) and two to the level –2 (on the right, east side).

Works between Berchem and the Central Station

Works must be carried out taking account of some specific conditions:

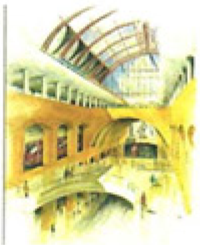
• The Central Station has to remain in service during the works, 70% of the train traffic being able to reach permanently the station, which has to dispose of at least three platforms;

• The existing monuments (bridges and retaining walls, listed imonuments to be protected), under which the tunnel works must be carried out, have to be preserved

• Surface traffic on major roads around the works, (Belgiëlei, Plantinlei and Moretuslei), can not be interrupted, but traffic can eventually be reduced to only a single lane.

In order to be able to achieve this, various kinds of civil engineering techniques were carried out namely:

- Grout columns, executed under various angles, for underpinning brickwork or unreinforced concrete foundations (sometimes of poor quality),
- Timbered trenches, up to 25-30 meters deep,
- Nailed walls as temporary earth-retaining structure,
- Excavations, after strengthening with steel profiles and shotcrete, under the revetments of the famous masonry arches,
- Execution of bored piles which had to support temporarily half of the structure in the first phase (construction of the eastern tunnel roof structures, while on the west side two tracks are in service),
- Excavation of the stross under the half-built roof structures.



In this zone the new tunnel also underpins three existing bridges: therefore foundations must be completely compensated for by "new bridge structures" under the bridges. The foundations of the tunnels under the existing structure in the Belgiëlei along each side are compensated for by two concrete box girders, connected to one another by concrete beams, built in galleries through the brickwork foundations. For the execution of the tunnel wall structure, where the track bedding widens in the direction of the Central Station, there was enough space to build reinforced-concrete mud walls executed under bentonite. These walls are going deep into the Boom clay.

Works under the central station of Antwerp

The transformation works of Central Station are divided into two sections :

- <u>Section between the Lange Kievitstraat and the Central Station building</u>

4 levels are realized, giving finally 14 platforms:

• On level +1 (the initial level with former 10 end platforms) - approx. 5 metres above street level – there will be 6 end platforms,

• On level 0 - the street level - a shopping-pedestrian zone,

• On level –1, 4 end platforms,

• On level –2, 4 platforms, tracks being connected to the two tracks running north wards under Antwerp. The cross sections of the future station are illustrated in the figures.

- <u>Section under the existing station building to be protected</u>

The tunnel has to be built under a temporary roof structure made of 8 jacked pipes. Starting from the two outermost pipes tunnel walls are excavated with timbered trench method. Then, execution of tunnel structure starts. Roof and floor structure are carried out in sections of around 7 metres in length over a total length of 80 metres. "Compensation grouting" is used to compensate the settlements

Works between the Antwerp Central Station and the Damplein

The boring the two single-track tubes began at the end of 2001. In the autumn '02 the first bored tunnel will be completed from the Damplein in the southern direction. Then the shield will be taken down and brought back to its starting point in order to bore the second tube. This phasing is worked out to optimise the earth transport, avoiding trucks traffic through the city.

Beyond the Damplein, to the north

Northwards from the Damplein tracks rise back to level +1. The new line then goes over the Albert Canal on a new arch bridge. Somewhat further, at the level of the Groenendaallaan, the construction of the new station of "Groenendallaan" is already far advanced. Northern, the new line meets the high-speed line to the Netherlands, established west of the motorway E19 Antwerp-Netherlands and there will also be a link to the existing line 12, for the local suburban traffic.The first trains are planned to run on the North-South link in 2006.

3 • CONSTRUCTION OF CONNECTING GALLERY IN THE BOOM CLAY AT MOL

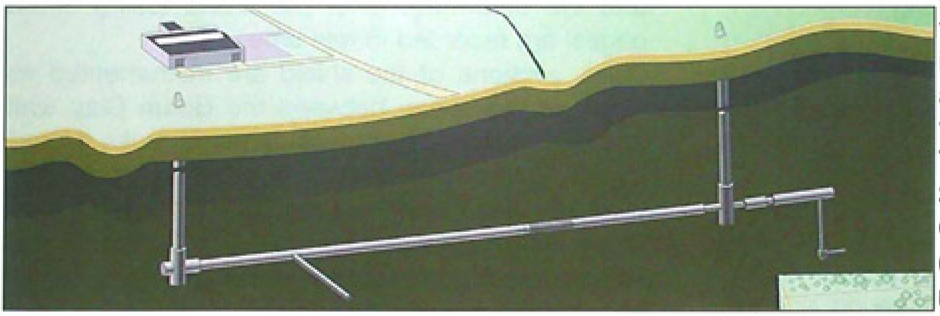
Des galeries de connection ainsi qu'un puits de 230 m ont été construites dans le laboratoire de Mol. Elles serviront d'accès supplémentaires et de galeries de test pour un possible entreposage de déchets nucléaires.

Authors : ir. Bart De Poorter (Smet-Tunnelling), ir. Alain Van Cotthem and ir. Koen Nulens (Tractebel Development Engineering), ir. Frédéric Bernier (EIG Euridice).

INTRODUCTION

As of March 8 2002, tunnelling works have been successfully achieved at the SCK site (Studiecentrum voor kernenergie) to realise the link between the existing Hades gallery and the second shaft at a depth of 230 metres. This connecting gallery will serve as extra access as well as an underground laboratory for further testing of the possible nuclear waste disposal in the Boom Clay.

Works are carried out by the Joint Venture SCM (Smet-Tunnelling • Wayss & Freytag AG • Deilmann-Haniel GmbH) on behalf of the Client EIG Euridice, and supervised by SECO. Tractebel Development Engineering is in charge of the overall concept, lining design and tender documents.



The internal diameter of the gallery is 4,00 metres; total length between the starting chamber and the HADES laboratory is app. 80 metres.

CONSTRUCTION PHASES AND PARTICULAR WORKING CONDITIONS

Although this work is based on a well-known tunnelling technique in the London clay, particular conditions require a very detailed working program and quality plan :

Works are carried out at a 230-metre depth, the only access being the existing 2nd shaft (i.d. 3.0m). The lifting capacity of the hoisting equipment is limited to 3,7 tons and has a free clearance of 1.2 x 2 x 2.9 metre, hence restraining all dimensions of the TBM components, muck lorries and concrete lining segments.

The gallery is serving as 'real time' measurement at real scale of the behavior of the Boom clay. To guarantee a minimum convergence of the clay, special holdpoints were set by the Client and the Designer:

- Minimal length of the installation and optimization of the equipment;
- Minimum progress of 2 metre on 24 hours. Penalties are applied if this progress is not guaranteed;
- Continuous progress, i.e. 7 days per week at 24 hours per day;
- Imposed lining technique ('Wedge block' system);

Assembling chamber

Starting from the existing Northern onset, the excavation front is reinforced with glass fibre anchors of 3 and 8 metres prior to the start of the excavation works. Then a cavern of app. Ø6.40 m x 3,15 m is dug, using an Atlas Copco Brokk-180 equipment (hydraulic hammer) and a temporary lining of sliding ribs (TH44) and shotcrete is installed.

This chamber enabled to assemble the tunnelling machine and minimal backup equipment.

Gallery : Wedge block lining

The lining used is of an expanded type. The expanded lining or wedge block technique has been developed for impermeable cohesive soils with a stand-up time of several hours (as the over-consolidated London clay). The shields used are provided with a sharp cutting edge which serves also as an over-cut. The edge of the shield cuts smoothly the excavation profile to a perfect circle while the inside is excavated with a roadheader. At the rear of the shield this leads to a smooth cylindrical un-supported zone which facilitates the building of a ring of concrete segments. A ring consists of a number of 10 unreinforced concrete segments and two wedge shaped key segments. The introduction of the two wedges expands the ring against excava-

ted profile inducing a prestress in the lining. The absence of bolts and grouting behind the ring considerably reduces the cycle time for excavation and erection of a ring.
The cohesive Boom clay, which can be classified as a 'soft rock' is perfectly suited to apply this technique. The main difference with the tunnels in the London clay is the depth and the resulting higher pressure relief, convergences, and convergence rate. The behavior of the Boom Clay has been monitored and modeled during several years. This has allowed to predict the convergence and therefore to optimize the geometry of the shield. To meet the high convergences, occurring in front of the excavation, from the front to the rear of the shield and further in the unsupported zone, the shield is provided with a variable over-cut (0-30mm), a conicity of 10mm on diameter and finally the rear diameter of the shield (4820mm) is 20mm greater than the average lining diameter (4800) due to further convergence at the back of the shield.

Tunnelling machine:

The entire equipment consists of a circular cutting shoe with an external diameter of 4820mm at the rear and a maximal cutting diameter at the front of 4890 including the variable oversize (0-30mm) and the conicity (10mm). Twenty hydraulic jacks at 200 tons each enable the shield to penetrate the stiff clay and execute the necessary steering corrections. The jacks have a stroke of 1200 mm, compatible with the length of the segments (1000 mm). Two extra hydraulic jacks of 80 tons are foreseen for the introduction of the two wedges or key segments to com-plete and prestress the ring.
The steel cutting shoe has a wall thickness of 50 mm, and is reinforced with extra stiffeners, hence withstanding to the earth pressures up to 2.4 MPa and 4000 tons of thrust capacity.
A Bird Wing erector is hung up to the steel structure of the cutting shoe to pick up and install segments (weight 1.25 tons), within a range of diameters up to 4890mm (in the case no convergence should occur).
Excavation of the clay at the inside of the cutting shoe is done with a Fuchs roadheader, equipped with special teeth. The Fuchs has been modified to the required excavation diameter, and the capacity of the machine is calculated with respect to the maximum capacity of the hoisting equipment. A total of 6 muck lorries of 1.5 m^3 are supplied for horizontal and vertical transport of the muck.
Four (backup trains) behind the shield complete the TBM up to a total length of 10,5 metres.
The design and construction of the TBM was done by the workshop department and engineering staff of Smet-Boring NV, and was based on the ex-perience of previous tunnels in the Boom Clay by Smet-Tunnelling NV.

MONITORING OF TBM, CLAY AND SEGMENTAL LINING :

The excavation of the connecting gallery is accompanied with an extensive instrumentation program. Special attention is given to characterize the instantaneous response of Boom Clay during excavation.

Instrumentation of the shield and the lining

Pressure and displacement of the hydraulic jacks and the deformations of the shield (using strain gages) are recorded in real time.
Three sections of the shield are instrumented to measure the space between the Boom Clay wall and the shield. These measurements make it possible to determine the convergence occurring between the excavated front and the rear of the shield.
Diameter measurements are performed in the unsupported zone between the rear of the shield and the last installed lining ring.
Three sections of the lining are instrumented with strain-gages to deduce the stress field in each lining element. Convergence measurements of the lining are performed in ten sections (with invar-wire).

Instrumentation of the rock

As the connecting gallery is excavated from the second shaft to the existing URF HADES (Test Drift), a unique and original opportunity was given to monitor hydro-mechanical parameters ahead of the front during advancing the excavation of the gallery. This is the purpose of the EC CLIPEX instrumentation program. For the first time in the Boom Clay formation, the hydro-mechanical response of the rock ahead of the face of the advancing tunnel has been measured. The instrumentation is located in two zones around the connecting gallery: from the Test Drift and from the bottom part of the second shaft.

3 • CONSTRUCTION OF CONNECTING GALLERY IN THE BOOM CLAY AT MOL

CONCLUSIONS

The realization of the connecting gallery at 223 metres depth using wedge block system was really a challenge. Modeling has made it possible to predict correctly the convergences between the excavated front and the lining and to choose the optimal geometry of the shield. This has allowed to reach a progress rate of about 3m/day. Measurements performed during excavation will lead to an accurate characterization of the hydro-mechanical instantaneous response of Boom Clay.

PARTNERS OF THE PROJECT

- Client : EIG EURIDICE (European Underground Research Infrastructure for Disposal of nuclear waste In Clay Environment)
- Design : Tractebel Development Engineering (Belgatom)
- Supervising : SECO
- Contractor : JV SCM (Smet-Tunnelling • Wayss & Freytag AG • Deilmann-Haniel GmbH)

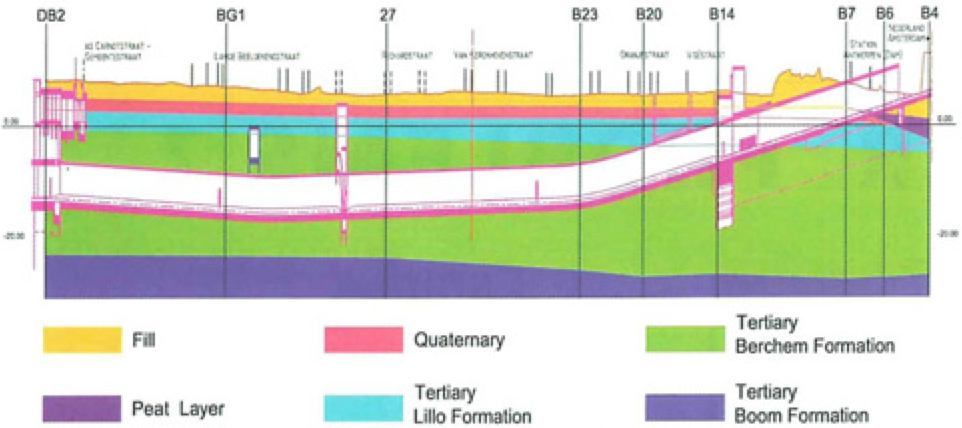
4 • THE HIGH SPEED RAILWAY TUNNELS IN ANTWERP - 2001 – 2004. THE UNDERGROUND NORTH-SOUTH LINK

Cet article décrit les travaux prévus pour la liaison souterraine Nord-Sud à la gare centrale d'Anvers dans le cadre de la ligne à grande vitesse.

Authors : Etienne Hemerikckx, Head of division at Centrale Studiedienst de Lijn & Ph van Bogaert, TUC RAIL

The underground north-south link being realised north of the Antwerp Central railway station can be split up in the following sections:
- The tunnel section located between the Viséstreet and the Central railway station bored with the shield method,
- The departure shaft for the shield in the Viséstreet executed with slurry walls; safety measures are taken for the houses in the neighbourhood using the pipe-jacking method;
- The section executed with the cut-and-cover method beyond the Viséstreet to the viaduct to be renewed across the IJzerlaan.

The Central Study Office of De Lijn contracted by TUC RAIL LTD carried out the feasibility study. Under-



ground construction methods are the applicable solution because of: • The restricted expropriations in a very built-up area, • Important building located in the neighbourhood of the Queen Astrid place, right in front of the central railway station; • The passage under existing metro stations and metro tunnels; • The possibility to deviate from the small street pattern; • The maintenance of a smooth traffic flow; • The implantation of restricted work sites in the city; • The maintenance of cables, conducts, sewers and other public utility installations by application of restrained safety measures.

In the shield tunnelling area, the substrata present the following geological characteristics: • a 2 to 2.5 m top layer of fill and/or disturbed soil, • Quaternary: a quaternary layer with a thickness of 2 to 2.5 m consisting of argillaceous to loamy sand containing shells, • Scaldian Pliocene tertiary: is found under the quaternary grounds and fills. This layer consists of fine to moderately coarse-grained glauconitic sand containing shells. The thickness of this layer varies from 5 m to 3 m in the neighbourhood of the central railway station. • Antwerp Miocene tertiary: is found up to a depth of ca. 30 m and consists of loamy compact sand with shell fragments and hard shells, • Rupellian Oligocene tertiary: this heavy clay contains septaria and organic material from marly horizons and is found up to a depth of about 30 m under the street level.

Alignment

The alignment is situated underneath a closely built up and occupied old part of the city. Most of the buildings are 40 years or older. The highest concentration of important buildings is located in the neighbourhood of the Queen Astrid place. The alignment passes under the central railway station, underground to the metro station Astrid, under the Astrid Park Plaza Hotel, a business centre and a shopping centre. Also the Astrid - Elisabeth metro tunnel and a number of streets are under crossed.

Concept

The distance between the tracks, axis to axis varies from 9 m to max. 17 m. An inner diameter of the shield tunnels of 7.30 m results in an intermediary distance of 5 to 9 m between the shield tunnels. Shield tun-

Location	Concept	Length
Queen Astrid place	Arrival of shields	
Section Astrid place-Viséstreet	Shield tunnel single track	± 1200mx2
Viséstreet	Departure shafts for the shields	inner length ca 30m
Section between the departure shaft and the north side of the Dam place	Covered area double track	ca 314m

4 • THE HIGH SPEED RAILWAY TUNNELS IN ANTWERP - 2001 – 2004. THE UNDERGROUND NORTH-SOUTH LINK

nelling occurs from north to south, as the departure of a shield requires enough space, which is available in the Visèstreet. Moreover all the necessary devices, segments can be delivered by rail. Trains via the rail infrastructure in the neighbourhood can transport the excavated soil.

Safety measures

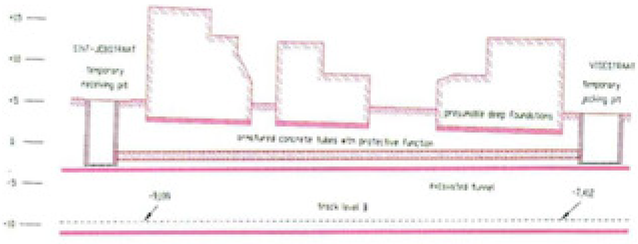
The alignment has to be provided with emergency exits to the open air. Next to these emergency exits, the adjacent tunnels have to be linked by a transverse connection, accessible for the fire brigade.

Location	Type		Particularities
Shield arrival location	Emergency exit via Astrid metro station to the open air	±110mfrom the central railway station	
Corner Nachtegaal street Dambrugge street	Emergency exit to the open air	±650mfrom the Queen Astrid place	±680mfrom departure shaft
Departure shaft Visestreet	Emergency exit to the open air	±340mfrom the open ramp	the distance between the 2 emergency exits is <762m
Between the Van Schoohovenstreet and Lange Beeldekensstreet	Transverse connection between both tunnels	±320mfrom the central railway station	situated half-way the implantation of the emegency exits
Between the Geraniumstreet and the Everaertstreet	Transverse connection between both tunnels	±1020mfrom the central railway station	
Queen Astrid place garden	Ventilation shaft		With ventilators to suck in smoke
Visèstreet	Ventilation building		With ventilators to suck in smoke

The old buildings in the neighbourhood Visèstreet - Sint-Jobstreet have direct foundation. Foundation depth is about 2.5 m.

The upholding of the foundations would cause damage in the houses. The minimal ground cover of the shield tunnels in the Visèstreet area requires safety measures between the shield tunnels and the houses. The realisation of a roof slab with the pipe-jacking method stands for the most adequate solution for a safe passage. The jacked pipes in the Visèstreet and Oranjestreet have a total pipe-length of 76.2 m and 60.5 m in de Visestreet - Sint-Jobstreet.

The departure shaft is executed by means of slurry walls till 7.5 m under the bottom plate. This method allows an internal ground water lowering.



longitudinal section

A concrete-bentonite stopper at the outside of the shaft allows the demolition of the slurry wall panels within the tunnelling alignment area before the start of the shield tunnelling.

When both tunnels are realized and the installations are removed, a watertight layer can be placed. In second phase the bottom plate and the inner walls can be executed.

The next main structure comprises the intermediary walls, stairs, topping of the bottom plate, intermediary slabs and roof slab and also the construction of an extraction and evacuation building at street level.

Section between the departure shaft Visèstreet and the north side of the Dam place

The whole area between the departure shaft and the Dam place will be executed with slurry walls.

That part of the tunnel that is situated in the departure shaft neighbourhood will be executed with a dewatering within the slurry wall area and a return dewatering at the outside of it.

The installation of temporary struts allows the excavation under the level of the bottom plate.

The area of the Dam place is situated close to peat layers and will be executed with slurry walls and tremie concrete.

Planning

- Start of the north-south link in Antwerpen: May 1998.

Section between Berchem station and the central railway station.

- Start of the section Luchtbal and connection with high-speed line in the direction of the Netherlands: 1999.
- Start of the section central railway station - Dam place: May 2001. End: 2004.
- Start of the shield tunnelling: October 2002.
- High-speed rail to the Netherlands: 2006.

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5 • PUITS POLYGONAUX

Nearly all underground works begin by the excavation of a shaft. The polygonal shaft is an innovative construction method, in one phase with precast elements.

Author : P Afshrift, Denys sa

INTRODUCTION

Presque tous les travaux souterrains commencent par l'exécution d'un puits. Parfois certains ouvrages souterrains existants ne sont composés que d'un puits. Il existe beaucoup de méthodes permettant de réaliser un puits. Les méthodes d'exécution ont été développées en fonction du but du puits, de l'environnement où le puits doit être réalisé et des circonstances géologiques.

Les développements les plus récents en construction de puits sont basés sur l'utilisation de parois moulées dans le sol et de pieux forés (sécants et en jet grouting.) Ces méthodes présentent l'avantage de créer peu de vibrations. Il est possible de travailler sous la nappe phréatique, donc sans rabattement, ce qui minimise le risque de tassements. Les inconvénients sont : l'exécution en phases successives, ce qui requiert un délai relativement long, et les parois du puits sont insuffisamment finies et non étanches de telle façon qu'il faut réaliser un revêtement intérieur complémentaire.

Système innovant, le puits polygonal supprime les inconvénients (pas de rabattement, pas de vibrations et donc diminution du risque de tassements) et les travaux sont réalisés en une phase, ce qui entraîne un gain de temps. La finition des éléments préfabriqués et leur étanchéité élimine la nécessité du revêtement interne.

DESCRIPTION DE LA MÉTHODE

Les éléments préfabriqués de l'anneau forment ensemble un polygone. Donc, avec un seul coffrage, on peut réaliser différents diamètres, ce qui n'est pas possible pour un puits circulaire pour lesquels la réalisation en segments circulaires devient non concurrentielle étant donné les différents diamètres que l'on peut rencontrer.

Le puits polygonal comporte 12 angles avec des segments de longueurs variables. En faisant varier cette longueur, on peut réaliser tous les diamètres (en pratique de 6 mètres à 12 mètres). La hauteur de 2.4 mètres permet de réduire le temps de construction par rapport aux méthodes classiques.

Les joints se composent d'un double profil en caoutchouc placé dans une rainure. Ce joint en caoutchouc est comprimé avec des boulons pour lui donner une résistance de 6 bars. Le caoutchouc choisi a fait ses preuves dans les segments des tunnels. Comme les liaisons par boulons se trouvent à la face externe, le travail de havage peut s'exécuter sans risque. A l'endroit du puits où un forage horizontal ultérieur doit être réalisé, la paroi en béton préfabriqué est remplacée par des éléments métalliques.

HAVAGE DU CAISSON POLYGONAL

Ancrages dans le sol

Pour enfoncer le puits préfabriqué dans le sol des ancrages sont forés sur le chantier tout autour du puits. Lors de l'étude des ancrages, il faut tenir compte du procédé de havage. Pour ne pas perturber ce procédé, il faut :
- ne pas perturber l'espace annulaire autour du puits par une compression,
- ne disposer aucun matériel d'injection dans le gabarit du puits,
- ne pas réduire la capacité des ancrages par le procédé de fonçage.

Après le havage du puits, les ancrages peuvent assurer la stabilité au soulèvement (uplift) du puits.

Poutre de ceinture

Les tirants d'ancrage sont fixés au niveau du sol dans une poutre de ceinture, qui servira de point d'ancrage pour le havage. Après le fonçage, la poutre de ceinture est liaisonnée à l'anneau supérieur du puits afin d'assurer sa stabilité au soulèvement.

Trousse coupante

La partie inférieure du puits est munie d'une trousse coupante métallique qui en découpant le sol avec précision facilite l'opération de fonçage. Cette trousse coupante déborde un peu à l'extérieur du puits pour créer un vide périphérique où la bentonite sera injectée. Après le fonçage, la trousse coupante est considérée comme coffrage perdu pour la dalle coulée sous eau qui sert de radier provisoire du puits.

Montage

La trousse coupante est montée à l'intérieur de la poutre ceinture. Un anneau d'éléments préfabriqués est fixé à la trousse coupante, sur lequel on place le dispositif de fonçage.

Installation de fonçage

L'installation de fonçage se compose de 6 cylindres hydrauliques, qui, avec un palan, pendent au-dessus du mur du puits et s'appuient sur une couronne de compression. Cette couronne de compression est à son tour liée aux ancrages dans la poutre ceinture au moyen de chaînes.

Injection de bentonite

Pendant le fonçage du puits, on injecte systématiquement le vide annulaire avec de la bentonite. Cette bentonite doit réduire le frottement durant le fonçage et maintenir l'effet voûte du sol autour du puits.

Le fonçage

Avant tout terrassement une pression verticale axiale est appliquée sur la paroi du puits afin qu'un bouchon de sol se forme dans la trousse coupante pour éviter toute rupture du sol et un enfoncement incontrôlé. Le puits est rempli d'eau jusqu'à un niveau supérieur à la nappe existante. Ensuite le terrassement et le fonçage sont réalisés systématiquement sous eau.

Après le fonçage sur une hauteur de 2.4 mètres, l'installation de vérinage est enlevée et un nouvel anneau est installé sur le premier. Un système particulier de mesure contrôle la verticalité et un système automatique de conduite corrige et garantit la verticalité.

Ce cycle est répété jusqu'au moment ou le puits atteint sa profondeur. Une fois arrivée à profondeur, la trousse coupante est nettoyée avec des lances à eau. La qualité de ce travail est contrôlée sous eau avec une caméra et le puits est bloqué dans le sol par bétonnage ou injection du vide annulaire créé par la trousse coupante.

Le bétonnage ou l'injection est réalisée de bas en haut en une phase pour éliminer systématiquement la bentonite.

Ensuite, dans la plupart des cas, une cage d'armatures descendue dans le puits pour réaliser un radier en béton colloïdal

<u>Stabilité</u>

Pour le calcul de la stabilité du puits, on considère la pression neutre du sol, parce que lors de l'élimination de la bentonite, le béton est pompé sous pression.

A la fin de cette opération on obtient une colonne en béton qui s'appuie isostatiquement contre le sol. On peut considérer qu'à ce moment l'effet voûte autour du puits disparaît et l'état naturel du sol se rétablit, soit la pression neutre.

<u>Parachèvement</u>

Après remplissage du vide annulaire, le puits est ancré contre le soulèvement par la poutre annulaire à liaisonner et étendre autour du puits de façon à faire travailler les ancrages dans le sol. Quand le radier coulé sous eau a atteint sa résistance, on peut vider le puits de l'eau contenue et réaliser le radier définitif.

CONCLUSIONS

- Le puits polygonal est une alternative valable pour les puits profonds dans des domaines sensibles aux tassements.
- Le délai d'exécution relativement court, notamment pour l'assemblage du puits à partir d'éléments préfabriqués réduit fortement les phases de bétonnage et de durcissement des constructions traditionnelles.
- Quand le puits est prévu pour le départ d'un tunnel, on peut remplacer certains éléments du puits par des éléments métalliques auxquels il sera facile de fixer la structure de départ du tunnelier.
- La grande précision du fini des éléments préfabriqués du puits assure un bon fini intérieur qui, de plus, est étanche.
- Le creusement d'un puits polygonal ne demande qu'une relativement petite emprise, et donc est applicable dans beaucoup de cas.

6 • METRO ET PRE-METRO DE BRUXELLES

The Brussels metro and pre-metro network is 45.2 km long, 39.4 km of which are underground. From the beginning accessibility for disabled persons has been taken into account and many specific infrastructures have been built.

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MÉTRO ET PRÉ-MÉTRO DE BRUXELLES : ÉVOLUTION DU RÉSEAU

Le premier tronçon du futur métro de Bruxelles (schéma 1) fut mis en service en décembre 1969 entre les stations SCHUMAN et DE BROUCKERE (2,8 km – 6 stations) situées sur ce qui allait devenir « l'axe Est-Ouest ». Dès l'origine, ce tronçon était utilisé par les tramways (on parlait alors de pré-métro).

En 1976, les tramways cédèrent la place au métro sur l'axe Est-Ouest entre les stations DE BROUCKERE (au centre ville) et les stations TOMBERG (à l'Est) et BEAULIEU (au Sud-Est). Lors de sa mise en service en mode « métro », l'axe Est-Ouest était long de 9,6 km et disposait de 15 stations.

Pendant la même période, l'avancement des travaux permit la mise en service d'ouvrages souterrains pour les tramways sur « l'axe de Petite Ceinture » entre les stations ROGIER et PORTE DE NAMUR (3,2 km – 6 stations), sur « l'axe de Grande Ceinture » entre les stations DIAMANT et BOILEAU (2,6 km - 4 stations) et sur « l'axe Nord-Sud » entre les stations LEMONNIER et GARE DU NORD (3 km – 6 stations). Entre 1976 et 1998, les axes « Est-Ouest », « Petite Ceinture » et « Nord-Sud » firent l'objet de plusieurs phases successives de prolongement. L'axe « Petite Ceinture » fut converti en mode « Métro » en 1988; il comptait alors 8,3 km et 13 stations.

Aujourd'hui, le réseau d'infrastructures est long de 45,2 km (dont 39,4 km en sous-sol) et comporte 64 stations (49 stations de Métro, 10 stations souterraines pour tramways et 5 stations mixtes où se retrouvent les deux modes). Un prolongement vers le Sud-Est de l'axe « Est-Ouest » au-delà de la Station BIZET (2,7 km – 4 stations) est en phase d'équipement (mise en service programmée pour septembre 2003). Les travaux de génie civil d'un prolongement vers l'Est de l'axe « Petite Ceinture » au-delà de la station CLEMENCEAU (0,5 km – 1 station) viennent de débuter (mise en service programmée pour septembre 2005).

Outre le métro, la Société des Transports Intercommunaux de Bruxelles (STIB) exploite 207,3 km de lignes de tramways (dont 7,5 km en sous-sol) et 425 km de lignes d'autobus.

LE MÉTRO, LE PRÉ-MÉTRO ET LES PERSONNES HANDICAPÉES.

Dès leur mise en service, l'accessibilité des infrastructures pour le pré-métro et le métro fut l'objet de critiques formulées par les associations représentant les personnes handicapées (se déplaçant essentiellement en voiturettes). A l'époque (1969) ces associations étaient peu nombreuses, peu structurées et il faut admettre que ni le pouvoir politique, ni les techniciens ne leur accordaient beaucoup d'attention.

On ne peut dire pour autant que l'accessibilité des autres catégories d'usagers que l'on qualifie actuellement de « personnes à mobilité réduite » était négligée. Les 64 stations du réseau de Bruxelles sont équipées de 580 escaliers mécaniques. Il est piquant de rappeler que lors de la mise en service des premières stations (1969), ces équipements étaient critiqués par d'aucuns car ils étaient considérés comme « dangereux pour les personnes âgées ». C'est cependant sans surprise que la réduction du nombre d'escaliers mécaniques équipant les stations mises en service ces 5 dernières années a été critiquée comme étant « une non-prise en compte des problèmes des personnes âgées ».

Les quais des stations STOCKEL et ALMA sont accessibles de plain-pied depuis la voirie et les quais de la station HEYSEL sont accessibles via les rampes prévues pour les grandes foules en provenance du Stade Roi Baudouin et du Palais des Expositions, ces stations ne sont pas équipées d'escaliers mécaniques.

Le problème spécifique des personnes handicapées fut partiellement pris en compte en 1978 par le pouvoir politique qui chargeait la STIB de mettre en œuvre un service de mini-bus équipés d'élévateurs. Ce service « à la demande » était spécifiquement réservé aux personnes handicapées. Le parc actuel de mini-bus comporte 18 véhicules.

LE MÉTRO, LE PRÉ-MÉTRO ET LES PERSONNES À MOBILITÉ RÉDUITE

Le concept de « personnes handicapées » a rapidement évolué ces dernières années vers le concept de « personnes à mobilité réduite ». Ce concept, associé à celui de « droit à la mobilité » s'est rapidement révélé plus profond que la simple « définition politiquement correcte ». Cette nouvelle prise de conscience à conduit à mener, en 1997, une étude de faisabilité sur l'accessibilité des quais des stations de métro de Bruxelles par les « personnes à mobilité réduite » par un système d'ascenseurs. Suite à la conclusion positive de cette étude en 1998, le pouvoir politique décidait de faire entamer les études détaillées d'exécution et d'inclure les station de métro dans la liste des bâtiments publics soumis, depuis juin 1999, au nouveau Règlement Régional d'Urbanisme (Titre IV-Accessibilité des bâtiments par les personnes à mobilité réduite).

Ce nouveau règlement impose que toute nouvelle station de métro à mettre en service et toutes les stations faisant l'objet de travaux de rénovation doivent être équipées de dispositifs (essentiellement des ascenseurs) permettant l'accès aux quais par les personnes à mobilité réduite. Il en sera ainsi pour les stations à mettre en service en 2003 et 2005.

Depuis mars 2002, la station MAELBEEK est la première station du métro de Bruxelles à être équipée d'ascenseurs à l'occasion de travaux de rénovation (voir photos).

L'investissement spécifique à l'établissement de ces appareils (gros œuvre, parachèvement, équipement, est de l'ordre de € 450.000.). Etant donné qu'une des salles des guichets de cette station est accessible de plain-pied depuis la voirie, deux appareils relient la salle des guichets et les quais (dénivellation : 5 m). Compte tenu du peu de surface disponible, les appareils sont du type « 8 personnes » ; compte tenu du peu de hauteur disponible au-dessus et en dessous des appareils, ils sont du type « à vis ».

Les stations GARE CENTRALE, GARE DU MIDI, DE BROUCKERE, ARTS-LOI, BELGICA et ST-CATHERINE devraient être équipées d'ascenseurs endéans les deux ans.

Le programme fixé par le pouvoir politique nous impose d'équiper l'ensemble des stations existantes à un rythme minimum de deux par an. Notre espoir est cependant d'atteindre un « rythme de croisière » de 4 à 5 stations par an à partir de 2004 et de clôturer le programme d'ici 12 à 15 ans. L'investissement total prévu actuellement est de l'ordre de € 25.000.000.

IDEAS ON TUNNEL STABILITY

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It is difficult to discuss "Ideas on Tunnel Stability" without their immediate association with the construction methods that apply such ideas, or that were at the origin of such ideas. During tunnelling operations, construction methods always need to be adapted to a natural environment which never is exactly as it was imagined during the design process. Therefore a good supporting method has to fit the changing anatomy and physiology of the rock mass, and should be evaluated for its adaptability to the laws and whims of Nature, rather than for its theoretical qualities.

The following paper discusses tunnels driven with conventional methods and not those made with a shield or tunnel-boring machine.

THE PRINCIPLE OF SELF-SUPPORT

In the beginning, the self-support of holes and cavities went without saying. This basic principle, also named arch effect or arching, gave stable caverns to the prehistoric men, even inside low strength rocks provided they harbour not too many joints.

Another type of self-supporting structures are the caverns dug below a thick bed, like room and pillar mining, which had been widely used for a long time at the border of the limestone plateaux.

Early architects also used self-support in order to build vaults, for bridges as well as for churches or basements. These vaults are stable even without any cement, provided that the building blocks are well fitted. Such arches face the gravity forces by progressive stressing of their elements. Above ground such arches need heavy buttresses to provide for lateral abutments; below the surface, however, full 3D abutments are provided by Nature for free.

What is true for built arches is also true for tunnels and caverns, whether natural or man-made:

If the rock is strong enough to bear the tangential stress along the perimeter (approx.: $R_c > 3\gamma H$ around a circular hole), and if there are no ill-oriented joint surfaces, the hole will stand without any support. Natural caves as wide as 50 m are not uncommon, and the largest known to date spans almost 400 m (Good Luck Cave, Sarawak, Malaysia).

When the strength of the rock is exceeded along the perimeter of the hole, and provided that the rock mass is rather homogeneous, a plastic ring appears around the hole, accommodating the excess of stress. Excessive damage to the rock mass by plastic strain may be prevented by a minimal skin support such as a thin shotcrete cover.

Finally, if the rock mass is too strongly fractured or even soil like, self-support is no longer viable and the only answer is to strengthen the rock mass as a whole, through extensive grouting or rock bolting.

THE TIME OF PASSIVE SUPPORT

During the 19th and the first part of the 20th Century, before the time of shotcrete and rock bolts, tunnel men had no better way than dividing the full tunnel section into smaller ones, bored one after the other, each of them heavily timbered. It should not come as a surprise that the tunnel construction resulted at that time in many "national" methods, known then as English, Belgian, French, German, Austrian and Italian tunnelling methods (see for example Duffaut and Piraud, 1975).

In those methods, the place of self-support was restricted to so-called "good ground", and elsewhere to a few tiny spaces between timber pieces. This timber support was temporary and had to be replaced by thick vaults of masonry or brickwork, likely to stand for many years. The major fault of such structures was that their contact with the surrounding rock mass was both late (it took weeks or months before the vault could be constructed) and discontinuous (a smooth vault cannot fit against a rough rock walls). This delay provided time and space for weathering and loosening of the rock mass, which, little by little, will impose increasing loads upon the vault and justify its thickness a posteriori.

After the Word War I, two major innovations appeared:

As temporary support, steel ribs replaced timber, allowing wider spans to be supported; this method, standardised by Terzaghi (1949), later became known as AMSS, American Method of Steel Support;

As definitive lining, cast-in-place concrete favourably replaced masonry, providing an intimate contact between vault and rock mass, even if somewhat late.

Both innovations introduced a type of industrialisation in tunnelling, allowing faster boring with less manpower. But this progress hid two fundamental drawbacks of the passive support: an excessively long operational delay and a discontinuous contact between the support and the surrounding rock mass before concrete casting. As a consequence the final lining was designed and justified as a bearing structure, submitted to ill-mastered or unknown external loads; hence the structural calculations by the well known "springs method", based on rather rough hypotheses, easily adjustable to any presupposed results...

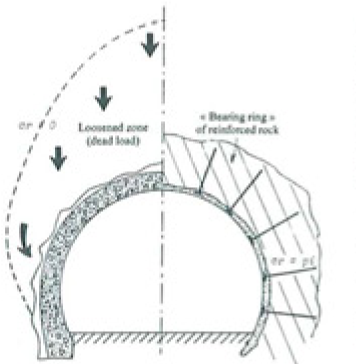
These drawbacks, intrinsic to passive supports, were tolerable for most shallow tunnels, as well as for some deep tunnels in hard rocks like the first Gotthard railway tunnel in 1875. However, they became prohibitive when the Simplon tunnel, about 1900, had to cross crushed rock at great depth. No vault, whatever its thickness, could withstand the thrust of 2000 m of mountain. One had to understand that the only way was "to let the rock mass come", as coal miners used to do: being accustomed to the behaviour of rocks at greet depth, they had learned how to tame soft or crushed rocks like coal.

Such alpine experience was the basis for the Swiss engineers Maillart and Andreae, who had the intuition of the shotcrete efficiency some decades in advance: Maillart, 1922: "masonry must tightly fit the rock-mass contour", Andreae, 1949: "a light support, but quickly installed, is the most efficient mean against rock thrust".

As Rziha wrote in his Handbook for Tunnelling as early as 1874, "the true art of the engineer is to prevent the build-up of rock thrust instead of overcoming it after it has built up". This fundamental target has been forgotten during almost a century, through the lack of technical means likely to achieve it.

THE INVENTION OF NATM

Some years later, around 1960, the same acknowledgements as made in Switzerland led the Austrian engineer von Rabcewicz to put into practice the principles quoted above. He implemented two newly available technologies, i.e. rock bolts borrowed from coal miners and shotcrete coming from America, where such material was used for a long time to repair damaged structures. The target of the method was clearly posted: "help the rock mass to support itself", instead of striving to support the rock thrust with the help of a lot of heavy members



Comparison between a thick, passive support (on the left) and the "bearing ring of reinforced rock" of the NATM (from Louis, 1972).

Austrian engineers pointed out that the cross section shape and the excavation method were crucial in order to avoid, as far as possible, any damage to the surrounding ground. They understood that they had to measure accurately the reactions of the ground with time, just as did for a long time the dam engineers.

So began the "new" Austrian Tunnelling Method, NATM, which was to become the spearhead of the "Salzburg Club", under the aegis of Prof. Leopold Müller. After successful applications to exceptional works such as the Frankfurt metro or the Waldeck underground power station, in central Germany, the method appealed to some interested French engineers, among them Claude Louis. He worked with the authors to make French contractors aware of the major progress brought by NATM, and of the potential savings brought to owners; he showed that in some cases this new method was the only technical answer (cf. Louis, 1972).

Some relevant images were proposed at that time to illustrate the core of the message: the new technologies, shotcrete and rockbolts, could be compared to glue and nails as used in woodwork; the four main points of NATM may be associated with simple formulas:

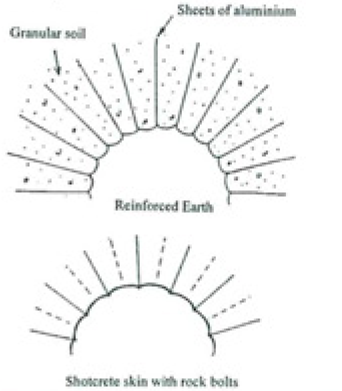
Excavating with care, thanks to a rounded cross section and a smooth blasting, may be compared to carefully dismantling the rock mass (instead of blasting it at full strength);

Protecting the excavated rock surface with a shotcrete skin, equals dressing and bandaging a wound;

Rock bolting equals reinforcing the ground, as usually done in reinforced concrete;

Monitoring the ground behaviour implies relying on measurements rather than on calculations.

The complex formed by rock mass + rockbolts + shotcrete may be compared to a complex of reinforced earth, i.e. a granular soil mass + metallic strips + facing panels. In both cases, the main mechanical role is played by the reinforced ground mass; shotcrete acts like a skin only, whose role is vital for protecting the freshly exposed rock mass, but subordinate from the mechanical point of view.



Analogy between a tunnel support with shotcrete and rock bolts (below) and a vault of reinforced earth (above); experimental set-up studied by Behnia, 1973.

As a conclusion, NATM expressed in the art of tunnelling the paradigm shifts that dominated geotechnics along the second part of the 20th Century: to improve the properties of in-situ ground instead of trying to make up for its weakness through costly artificial structures. Plenty of ground is available around tunnels, providing free 3D abutments; to obtain the best of it, one only needs to inject intelligence. The English word "support" (like the French word "soutènement") is misleading: the action of shotcrete and rockbolts is to maintain, retain, or contain the ground, but never to sustain or support it (Duffaut, 1994).

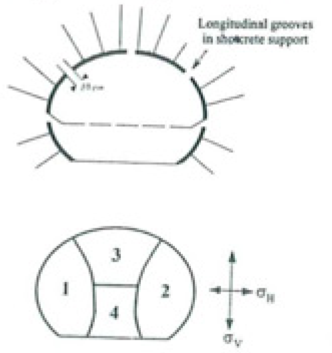
The main reservation, though, is that this method absolutely requires a great rapidity of implementation, a rigorous work organisation, and real-time monitoring. The lack of any one of these three conditions may create a dangerous situation; this is why it can only be operated with highly qualified and experienced staff at all levels.

During the 1970s and 1980s hundreds of kilometres of NATM tunnels were bored successfully, the more in Austria, Germany, Switzerland, Italy, and Japan. Obviously, some failures have been reported. The most famous examples are in Munich (Germany, 27th Sep.1994) and below the Heathrow airport (UK, 21st Oct. 1994). The first case was associated with an unexpected local deepening of the alluvial gravel down to the tunnel crown; the second with a too optimistic design for three parallel tunnels, a method proved valid inside the chalk of the Channel tunnel but no longer so in the London Clay. A French advertising slogan suggests that "one glass of wine is harmless for car drivers, but the damage begins with the second": this ought to be the same rule for tunnels in soils.

THE TRIUMPH OF NATM

During the 1970s and 1980s, the concept of a "bearing ring of reinforced rock" became the essential feature in the world for conventional tunnelling. Still, its applications varied depending upon the thickness of the overburden:

For deep tunnels, the major concern is to accompany the elastic or elasto-plastic stress release of the rock, preventing it from becoming disorganised, or, in military terms, by favouring its ordered retreat rather than a rout. If the expected convergence is such that the shotcrete shell might break, it is necessary to create longitudinal grooves that will close once the rock mass has converged. Such grooves delimit independent parts of the vault that are literally suspended from the rock mass by means of rock bolts, in the same manner as a "Berliner" wall is attached to the soil mass by prestressed anchors. The Tauern, Karawanken, Arlberg and Inntal tunnels number among the most difficult tunnels driven through the Alps in this manner.



Variants of the NATM:above, deep tunnel with longitudinal grooves,below, shallow tunnel with ogival sidewall drifts.

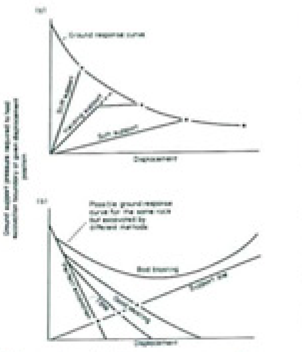
For shallow tunnels, commonly driven through soil or soft rocks, any deformation must be prevented in order to avoid irreversible shearing in the ground and limit surface settlements. In the 1980s, Austrian engineers had the idea of replacing the top heading with two ogival sidewall drifts, whose shape is much better suited to the low horizontal stress that prevails near the ground surface. The subways of Vienna and most German towns, as well as 150km of German high-speed railway tunnels, were constructed in this manner, if necessary after grouting or drawing down the groundwater level. However, in order to avoid having to pay the Austrians an export premium, the German engineers renamed the method as "Spritz betonbauweise" (literally: sprayed concrete lining method).

Outside the Germanic world, the main tunnellers, i.e. Italians and Japanese, adopted NATM practices in the 1970s and China did so in the 1980s. Since then, these countries have used just two tunnelling methods: either TBM, or NATM.

American and English engineers, however, ignored this "continental" invention for a long time. England discovered it belatedly during work for the Channel Tunnel, and brilliantly applied it to excavating an enormous cavern for the tunnels crossover at 40 m below the seafloor. The major British engineering firms have tried to rename NATM as SCL ("Sprayed Concrete Lining"), a name that places undue emphasis on the relatively minor role played by shotcrete.

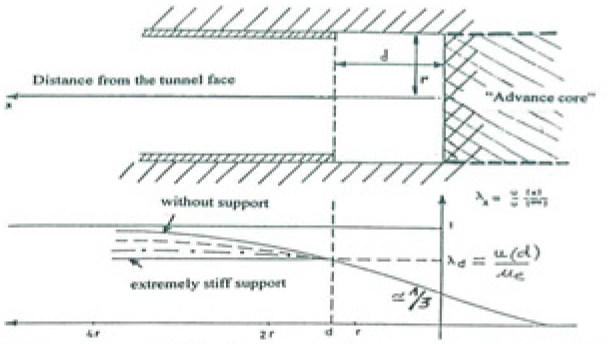
THE FRENCH EXCEPTION

NATM arrived in France at the beginning of the 1970s and was successfully used in soft rocks under low overburden, in particular for highway tunnels at Nice, for the railway tunnel at Grigny near Paris and for many projects of EDF (the French Electricity Board). As had happened in Germany, the French tried to gallicise the name of NATM with the short-lived French acronym PTSS (for Participation du terrain stabilisé au soutènement), introduced in 1982 in the handbook for Government contracts.



Characteristic curves of support and ground response (from Hudson, 1993)

During the same period, French engineers gave an interesting contribution to the tunnel design by developing the "Convergence-confinement" method under the guidance of Marc Panet. This theory uses mathematical terms for expressing the behaviour of the ring of rock around a tunnel: the stresses imposed on the support generally decrease with the continuing convergence of this ring (Panet, 1995). This is the clas-



Variation of the radial displacement u for supports of various stiffness (from Panet, 1973).

sic "Support supply and support demand" comparison. Even though the method uses 2D calculations, it implicitly considers the 3D role played by the tunnel face, using the "unloading factor".

In practice, however, many French engineers continued to ignore the specifics of NATM, banned the term from the French vocabulary, and continued the application of the good old "passive support" system, which is more lucrative in poor ground conditions when the arches are paid by weight (!). This conformism contrasted with the rapid adoption of TBM and shields by the French contractors after 1985.

In fact, the senior author was one of the few in the French Tunnelling Society (AFTES) who persisted not only in defending NATM, but also in calling it by its proper name and in reminding all and sundry of its successes. At the same time, a bizarre controversy arose in some scientific circles concerning the exact definition and even the existence of this method (cf. Kovari, 1994). It is true that its many application variants have disconcerted some theoreticians, but in practice a NATM tunnel is immediately recognised by some common and clear characteristics:

Confidence in self-support and rounded shapes;

Immediate use of shotcrete and rock bolts;

Rapid closure of the section and careful monitoring of deformation.

Curiously, the French engineers have perfectly integrated NATM practices in their international contracts. A striking example is the CERN caverns that are being completed near Geneva by a joint EDF-Knight Piesold engineering venture. A distinctive characteristic of these openings with a span of almost 20 m is that, for the first time, the shotcrete shell is ignored as a structural element in the stability calculations. This is not to say that its role is negligible; on the contrary, thanks to this shell the surrounding rock does not loosen and retains its original properties, or even improved ones thanks to rock bolting (cf. Laigle et al., 2001).

EMERGENCE OF THE NEW ITALIAN METHOD

In soft or weak ground, or under conditions where the rock strength cannot withstand the overburden, experience had taught that not only the tunnel walls but also the face have to be supported. This can be done in various ways (cf. Pelizza et al., 1993):

By keeping a stabilising mass of ground (short bench) in the middle of the face;

By spraying concrete on the tunnel face;

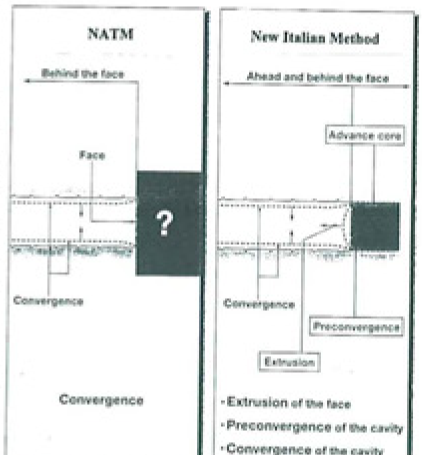
By reinforcing the face with horizontal fibreglass bolts;

By forepoling with steel bars or pipes ("umbrella") along the future tunnel walls;

By creating resistant arches along these future walls, either by mechanical pre-cutting and concrete "pre-vaults"(Perforex method), or by jet grouting.

All these pre-support methods have the same objective: avoid collapse of the tunnel face, which would render useless all further wall support. The above mentioned techniques developed in many countries during the 1980s, but without a global understanding of the mechanisms involved; in fact, practice largely preceded theory. In France, the major step was the Galaure TGV tunnel south of Lyons, which was successfully excavated by a JV led by Bouygues in 1991-93; notwithstanding an exceptional cross section of 150 m², it was dug in full section, after mechanical pre-cutting and face reinforcement by 18-m horizontal rock bolts.

Although the pre-vaults method was patented in France, the development and systematic application of pre-support methods came from Italy, where much of the tunnelling ground is composed of weak or soft rocks, often strongly folded and faulted. Pietro Lunardi had the merit of unifying these techniques by proposing a tunnel-stability theory that is based entirely on the equilibrium conditions of the "advance core". This theory favours an axial-symmetric, rather than transverse, stability approach; the decisive parameter is the axial deformation ("extrusion") of the advance core, which pre-



Comparative analysis of the deformation response of a rock mass, using the Austrian and Italian methods (from Lunardi, 2000) cedes and causes the convergence of the tunnel walls.

This theory is known as ADECO-RS (Analisi delle deformazioni controllate nelle rocce e nei suoli). Like NATM some 30 years before, it proposes a true "cultural" revolution in that:

Everything revolves at the face: a tunnel with an unstable face will collapse, even though its walls may be supported;

The next step is to close the ring as rapidly as possible: the cross section must not be divided, even and especially in poor ground conditions!

Where NATM seeks to create a bearing ring of reinforced rock around the excavated section, the New Italian Method seeks to create good ground ahead of the tunnel face (and if necessary around the future walls), in order to be able to dig a stable tunnel.

This new method can thus be considered as a 3D application of NATM principles, to be used in soft and unstable ground where the latter would be impotent. In retrospect, we can see that the Austrian engineers did somewhat neglect the mechanical role of the tunnel face. However, in both cases we are dealing with a method that helps the ground in accepting the presence of a hole, or prepares it in advance for the presence of a hole in the case of the Italian Method.

In practice, the Italian engineers apply these precepts as follows:

The tunnel is to be driven full face, regardless of ground quality; the main variable of adjustment is the type and "intensity" of the face reinforcement, which is easily modulated without disturbing the tunnel advance;

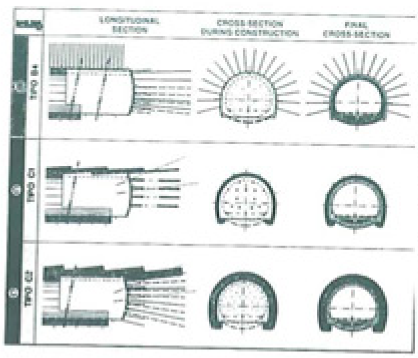
In very poor ground conditions, the face reinforcement is to be completed by pre-supporting means around the future walls, such as pre-vaults, forepoling or jet-grouting,

Most of the ground support and reinforcement is installed horizontally, i.e. longitudinally, every 15 to 20 m only and no longer at each round;

Support of walls after excavation consists of steel ribs linked by small shotcrete vaults; this is a relatively rigid support, as in the case where NATM is used at shallow depths;

The concrete lining is cast in two stages only (first floor and then vault), at less than a few diameters from the face and a few days only after excavation; the concrete ring is almost always closed in the floor.

Italian engineers have invented specially adapted machines for the different types of longitudinal support. Always available on site, they allow a true industrialisation of tunnel construction in soft and weak rocks, with advance velocities and an economy of means that were hitherto unheard of. The new high-speed rail connection through the Apennines, with 9 tunnels of 135 m² cross section for a total length of 73 km, is the most striking example of this new method; within year 2000, the site as a whole saw up to 30 simultaneous advance faces, producing more than 3 km per month of finished tunnels.



Examples of standard cross sections used for the new high-speed-rail tunnels through the Apennines (from Lunardi, 2000)

At the same time, the progress in numerical 3D modelling has clearly identified the real ground-stabilisation mechanisms during excavation, thus confirming the intuitive conclusions of the inventors of the pre-support. Speaking in images, the advance core can be assimilated to an abutment of reinforced earth, with the longitudinal bolts playing the role of metallic strips; the last "spans" of a tunnel are no more than a "provisional link" between this abutment and the last ring of cast-in-place concrete.

There is little doubt that the New Italian Method will become universally accepted for tunnelling in unstable rocks at low and moderate depth, as did the New Austrian Method some 30 years earlier for tunnelling in jointed rock. The reasons are the same: both methods are based on two geotechnical principles that always lead to saving money:

A better mechanical understanding of the ground mass, enabling the optimum mobilisation of its own strength;

A systematic use of easily adaptable techniques for reinforcing the ground as and where necessary, at each step of tunnel advance.

All the references for this article will be available on the ITA web site

NEWS FROM ITALY

TUNNEL & PERFORAZIONI®
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FRIDAY 17th MAY 2002

Conference
" "IMPROVEMENT OF ROCKS AND SOILS "

Great progress has been made in recent years in the fields of survey instruments, calculation tools, tunnel driving techniques and the improvement of rocks and soils in the design and construction of tunnels and major underground works.
Consequently it is now possible to distinguish between the design phase and the construction phase with resultant advantages in terms of construction schedules and greater certainty with regard to the costs of a project.
When the stress state in the ground exceeds its capacity to withstand that stress by an appreciable amount even in the zone around the tunnel face, an arch effect cannot be formed because the ground does not possess sufficient residual strength. In such a case, deformation phenomena are unacceptable because they develop rapidly into the failure range, giving rise to serious symptoms of instability such as the collapse of the face and the cavity, without allowing any time to perform radial confinement.
Under these conditions, preconfinement operations must be performed ahead of the face to develop preventative pre-confinement action sufficient to constitute artificial arch effects.
Often there is the additional presence of water under hydrostatic pressure, which further reduces the shear strength of the ground and encourages plasticisation and a greater deformation response of the cavity. It can trigger phenomena such as siphoning of water which may drag material with it to cause harmful and unpredictable results.
These are the so-called difficult ground conditions, typical of our urban areas, where more and more often new transport services and public utilities are located below ground along profiles and routes that allow design engineers no alternatives.
If the necessary support is available in terms of materials and construction technology and correct design modelling, it is possible to drive tunnels even through particularly demanding geological formations and to guarantee that deformation of both the new tunnel and existing structures is controlled, on condition that design engineers and specialist contractors operate to maximise synergies and employ all their skills in the conviction that joint objective responsibility is essential.
Some of the best known operators in the sector have been invited to this conference, who by taking recent experiences on major projects as a starting point will give their assessment of the most recent design technologies.
The use of underground space as a new resource for the construction of new infrastructures is a necessary choice if development is to be compatible with a decent quality of life in heavily populated areas and it is our duty to make this choice as economical and safe as possible.

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NEWS FROM TURKEY

International Conference & Exhibition on Tunnelling & Underground Space Use
16-18 October 2002 Istanbul/TURKEY

With an increasing need to protect environment and to use space effectively, creating space underground and tunnelling is an attractive solution. Designers, researchers, scientists and engineers concerned by the topics are invited to the conference, to share their knowledge and experience.

Conference Topics
The suggested topics for presentation are given below, both on general trends and recent cases, dealing with the state of art and especially new developments or new creative ideas.

1. Tunnels, Environment and the Public
2. Planning, Research, development and Design Aspects on Underground Structure
3. New Development of Excavation Technology for Rock and Soft Ground Tunnelling; Mechanization
4. Contract Management, Financing and Risk Analysis
5. Maintenance, Rehabilitation, Renovation and Repair of Underground Structures
6. Seismic Design of Tunnels

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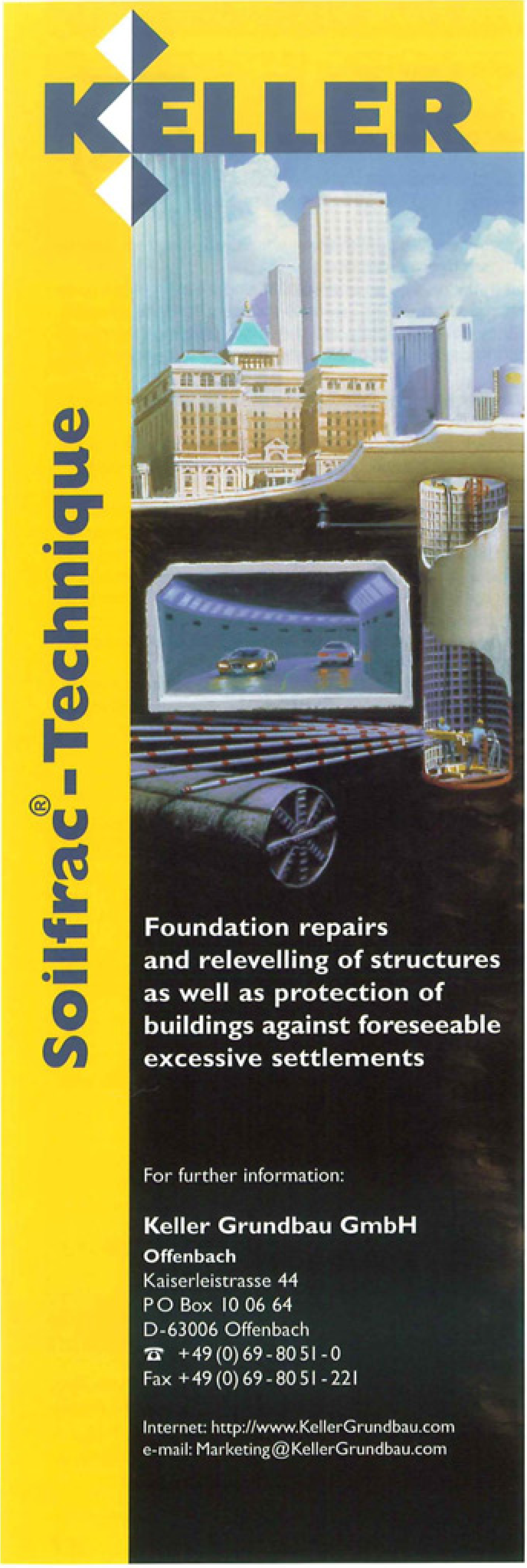
NEWS FROM CHINA

CSUEUS (Chinese Society of Underground Engineering & Underground Space) had its founding ceremony in Xiamen, December 11 & 12. ITA was represented by Prof Jian Zhao who read a letter from ITA President, Prof Andre Assis. CSUEUS is a subsidiary of the Chinese Society of Rock Mechanics and Engineering (CSRME) and also a member of ACUUS. CSUEUS, chaired by Hon President Prof Qian Qi Hu, and President Prof Zhu Wei Sheng, is very active in the underground space development.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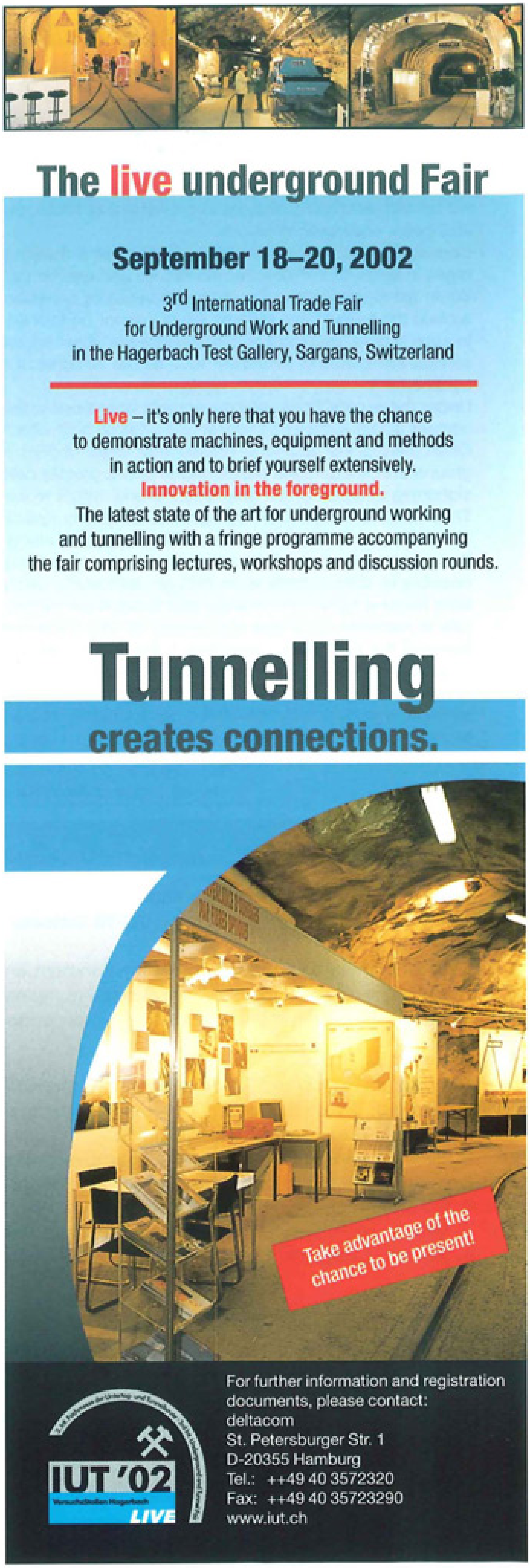
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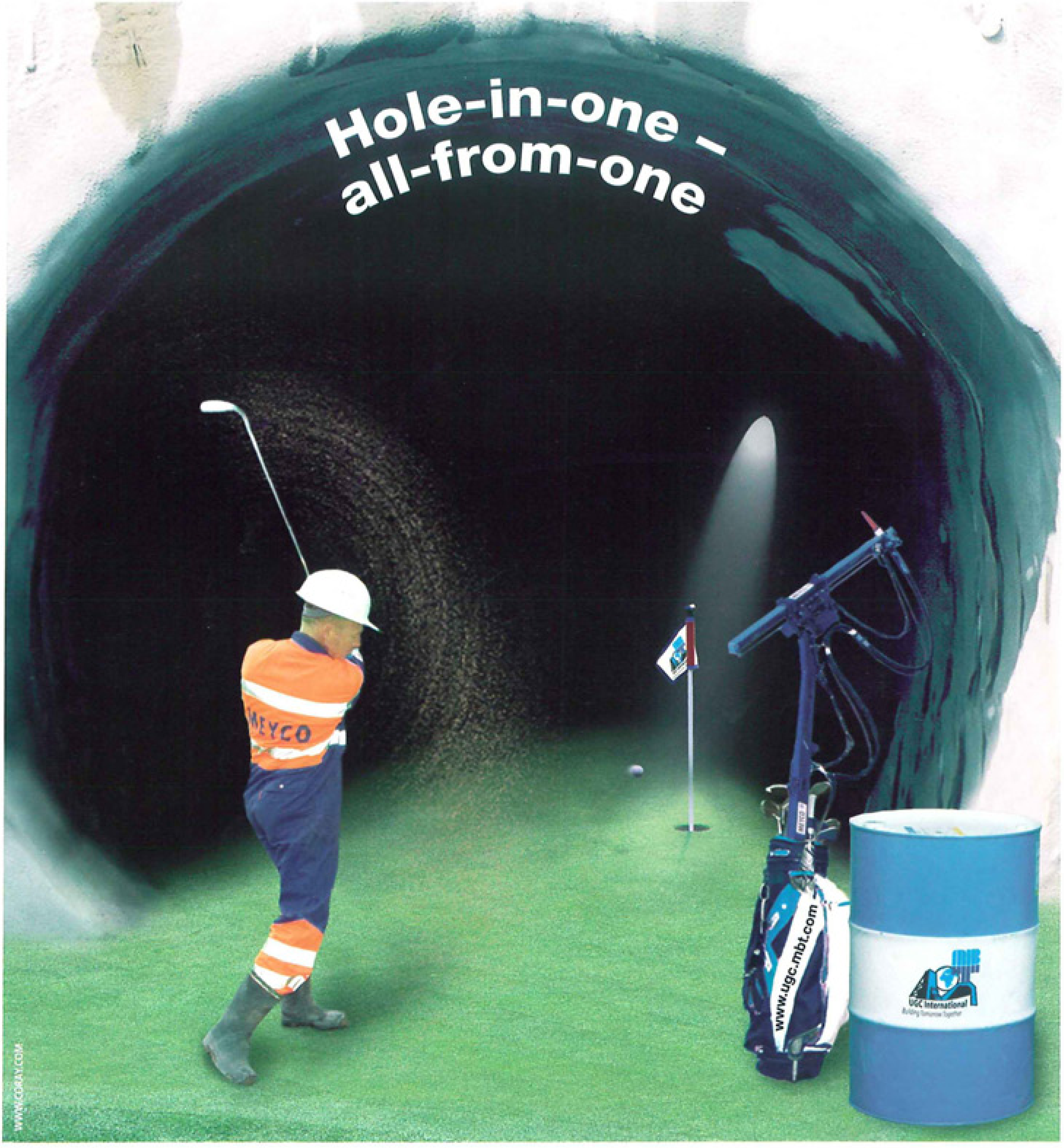

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