

INTERNATIONAL EDITION

February 2015

Tunnels

AND TUNNELLING



ITA'S INFLUENCE

Underground solutions to natural disasters

Asia • EPBMs • Settlement

Client:
› Southern Nevada Water
Authority (SNWA)

Contractors:
Vegas Tunnel Constructors
› Salini Impregilo S.p.A.
› S.A. Healy Co.

15 Bar

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Worldwide

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HIGH TIDE

IT'S AN exciting time for the International Tunnelling Association (ITA) leadership. With growing international acceptance that climate change is affecting the world, there are two outcomes. Firstly, governments try to change the habits of the planet to slow the pace of a changing biosphere. This is a boost to the demand for tunnelling on the larger scale; governments looking for low-carbon per capita means of transportation, for example. Metro networks rather than private car ownership.

The second is an acceptance that natural disasters induced by a warming globe are likely to increase in frequency and intensity. This is a problem the ITA can really help with on a project planning level.

In a Q&A session released by the ITA and featured in this issue, President Soren Degn Eskesen looks at the role that tunnelling, and the clever use of underground infrastructure in general, has to play in protecting people and structures from disasters. There is, he says, a growing recognition that the costs of not acting (reacting) are now outweighing the costs of being prepared for such events. In the most straightforward sense, the costs of efforts to rebuild look more and more prohibitive when compared with defences.

Efforts in recent years to show the clever uses underground space can be put to are paying off, Eskesen says, as it appears the relevant UN bodies are consulting ITA more and more to learn the possibilities tunnelling has to offer in this regard. Multifunction tunnels such as Malaysia's SMART project are a good example of this, and are an efficient use of capital and space.

Eskesen references early investment in metro projects in some of the world's major cities, and the benefits enjoyed by several generations of urban populations.

He doesn't point out the enduring problems that can be caused by poor planning. On, for example, the early London Underground lines. While the benefits of infrastructure investment are felt by generation after generation, poorly planned – or just not optimal – projects can create problems

editor@tunnelsonline.info

What do you think? Send your views to the editor and join the debate



Alex
Conacher
Editor



for future engineers trying to solve a problem that could have been identified earlier.

A few years ago, a lot of the excitement from the ITA centred on underground master plans. Helsinki was held up as the golden example – reserving areas underground and placing current infrastructure in such a way that wastage of space could be minimised.

Unfortunately for some of the older cities with extensive networks of underground infrastructure, placing new infrastructure with maximum efficiency is impossible.

Even without strategic placement considerations, individual projects sometimes have to take a less than optimal route to avoid even defunct, small-diameter tunnels.

But for a lot of newer cities in Southeast Asia, the underground is less spoilt, and engineers have options, if they look for them.

It's lucky when you think of another of Eskesen's points: that Southeast Asia seems to be taking the brunt of the flooding.

And tunnelling can help treat the symptoms of a warming world

This month...

20 YEARS AGO

The 10km New Southern Railway connecting Sydney, Australia with the international and domestic terminals at Sydney airport will be finished for the 2000 Olympic Games. The USD 448M project will ease traffic and rail congestion, provide a vital link to the airport, create employment and revitalise Sydney's inner suburbs. After it opens, the railway will carry 46,000 passengers every day. The government will fund the track and tunnel construction.

*Tunnels and Tunnelling, March 1995, p.7**

30 YEARS AGO

The Swiss are working hard to complete the construction of nuclear fallout shelters for the entire population by the end of the century. Although the country has managed to keep out of two world wars, their geographical position wedged between likely nuclear targets makes it unlikely that their neutrality will protect them in any future European nuclear conflict. The country has been developing a civil defence system for the past 25 years and now has one of the best in the world. Hundreds of subterranean concrete and steel shelters designed to protect against explosive shock, nuclear fallout and pollution from chemical weapons have now been constructed.

*Tunnels and Tunnelling, March 1985, p.7**

*No February issue in this year

Cover

The front cover shows the ITA president, who is enjoying increased influence at UN climate talks.



Next issue

In the next issue of Tunnels and Tunnelling we focus on the Latin American market, with other sections of the magazine looking at conveyor developments for mucking out, and the developments made by metro projects tackling the risk of fire.

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Left: TBM breakthrough on Italy's Sparvo Tunnel project. This machine was previously the largest diameter EPBM. Page 31

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What do you think? Send your views to the editor and join the debate

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Nicola Della Valle, Tunnelconsult
Sara Bech Padrosa, Tunnelconsult
A paper exploring the prediction of tunnelling induced settlements in urban areas

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Contributors

NICOLA DELLA VALLE
Nicola is a Doctor in Mining Engineering (1987) from the Politecnico di Torino, Italy, who has spent his career actively working in challenging underground projects. His key experience applies to construction & technical management, mechanised tunnelling, feasibility studies and equipment selection, as well as segmental lining design. He is presently dedicated to his engineering company Tunnelconsult providing worldwide tunnelling designs and consultancy services.

SARA BECH PADROSA
Sara graduated in Civil Engineering from the Universitat Politècnica de Catalunya, Barcelona (Spain) in 2009. Since then she has been intensively working on the design of international tunnels and underground structures within the Tunnelconsult team. Her principal duties are focused on segmental lining and conventional excavation support design, including settlement and risk analysis.

Moriah

Jerusalem Development Company, Ltd.*



MORIAH
The Jerusalem Development Co.

1. Moriah – Jerusalem Development Company, Ltd. (hereinafter: "Moriah") hereby provides notification of the publication of a public tender for the performance of excavation works as preparation for the construction of an underground parking facility at the Shazar Boulevard compound in Jerusalem, Israel.

2. Only bidders in compliance with the prerequisites as determined in the tender booklet, including the conditions specified below, may submit offers in this tender:

2.1 Sole corporations:

- 2.1.1 Corporations that have registered and incorporated lawfully in Israel.
- 2.1.2 Bidders shall have proven experience in the execution of tunneling works using the NATM method both inside and outside of Israel having a cumulative minimum value of NIS 300 million during the period between January 1, 2007 and December 31, 2014.
- 2.1.3 Among the works executed by bidders in the cumulative value as stated in Subparagraph 2.1.2, at least one project shall have been completed having a cumulative minimum value of NIS 100 million, even if executed in the framework of a project having a higher monetary value.
- 2.1.4 Bidders shall have executed, during the period between the years 2004-2014, the excavation works of underground halls within an urban environment, having a width greater than 15m, height of 15m or more and minimum length of 300m or; shall have executed tunneling works at a single excavation face having a surface area exceeding 200m² and volume exceeding 70,000m³.
- 2.1.5 It is hereby clarified that the professional experience must be that of the bidders themselves and not that of companies that are shareholders of the bidders ("parent companies") or companies the shareholders of which are the bidders ("subsidiaries") or companies the shares of which are held by an entity that is also the shareholder of the bidders ("sister companies"). However, proven experience accumulated by the bidders as stated above in the framework of membership in a previous joint venture may be submitted and that on the condition that the share of the bidder as a member of the previous joint venture that executed the works was at least 40%. It is further hereby clarified that, for purposes of compliance with the conditions of this clause, it is irrelevant whether the bidders have accumulated the professional experience required in performing tunneling works as main contractors or as subcontractors.
- 2.1.6 Bidders incorporated in Israel must be registered in the Contractor Registry as "grade C-5 contractors" in Branches 100 or 200.
- 2.1.7 Equity in the bidders' audited annual financial reports for the year 2013 shall be at least NIS 25 million.
- 2.1.8 The bidders' cash flow from current activities during the years 2011-2013 shall have been positive.
- 2.1.9 The bidders' average annual turnover during the years 2011-2013 shall have been at least NIS 160 million.
- 2.1.10 Bidders shall have implemented the terms of Article 2B(b) of the Public Bodies Transactions Law 5736-1976.
- 2.1.11 Bidders shall lawfully manage their account ledgers.
- 2.1.12 Bidders shall have issued a bank guarantee to secure their bids as required under the terms of the tender.

2.2 Joint ventures

- 2.2.1 A joint venture comprised of two member corporations, one of which is a corporation registered and incorporated in Israel and complies with the other prerequisites as determined in this tender with respect to a member of a joint venture (hereinafter: "the Joint Venturer") and the other has professional experience in the execution of the excavation works of underground halls within an urban environment as specified in Subparagraph 2.1.4 above (hereinafter: "the Specialist Corporation"). It is hereby clarified that the Specialist Corporation may be a corporation that has incorporated and registered in Israel or a corporation that has incorporated outside of Israel (hereinafter: "Foreign Corporation").
- 2.2.2 Members of the joint venture shall have proven cumulative experience in the execution of tunneling works employing the NATM method having a cumulative minimum value of NIS 300 million (Three Hundred Million New Israel Shekels) during the period between January 1, 2007 and December 31, 2014.
- 2.2.3 From among the cumulative works performed by members of the joint venture as stated in Subparagraph 2.2.2 above, the execution of at least one project having a minimum value of NIS 100 million (One Hundred Million New Israel Shekels) shall have been completed fully by the specialist corporation. In the matter of this clause, it is hereby clarified that the specialist corporation shall also be considered as having complied with the above conditions if it shows proven experience in the execution of tunneling works using the NATM method of the aforesaid value, although in the framework of a project having a higher total monetary value for which the works have not yet been fully completed.
- 2.2.4 It is hereby clarified that the professional experience must be that of

the members of the joint venture themselves and not that of companies that are shareholders of either of the members of the joint venture ("parent companies") or companies the shareholders of which are either of the members of the joint venture ("subsidiaries") or companies the shares of which are held by an entity that is also a shareholder of either of the members of the joint venture ("sister companies"). However, proven experience accumulated by either of the members of the joint venture as stated above in their capacity as members of a previous joint venture may be submitted and that on the condition that the share of that same member in the previous joint venture that executed the works was at least 40%. It is further hereby clarified that, for purposes of compliance with the conditions of this clause, the question as to whether either member of the joint venture has accumulated the professional experience required as a main contractor or as a subcontractor in performing the tunneling works is irrelevant.

- 2.2.5 In the case of a joint venture between an Israeli corporation and a foreign corporation, the foreign corporation shall be the Specialist Corporation.
- 2.2.6 The share of the Specialist Corporation in the joint venture shall be at least 51%.
- 2.2.7 The share of the corporation that is not the specialist corporation in the joint venture shall be not less than 26%.
- 2.2.8 The Israeli corporation member of the joint venture shall comply with all of the other requirements as determined with respect to a sole Israeli corporation participating independently in the tender as specified in Subparagraph 2.1 above, other than the requirements related to the specialist corporation, if the Israeli corporation does not serve in this role.
- 2.2.9 Each member of the joint venture shall fully comply with the financial requirements imposed on a corporation that independently participates in the tender, other than the requirements in Subparagraphs 2.1.7 (equity) and 2.1.9 (turnover) above. In lieu of them, in the case of a joint venture, the following requirements shall apply:
 - 2.2.9.1 The equity of each member of the joint venture as determined in the annual financial reports of that same member for the year 2013 was NIS 250,000 for every 1% participation in the joint venture, but in any case, not less than NIS 12,500,000.
 - 2.2.9.2 The average turnover of each member of the joint venture during the years 2011-2013 was at least NIS 80 million.
- 2.2.10 The joint venture shall have issued a bank guarantee to secure its bid as required by the terms of the tender.

Nothing in the aforesaid shall be construed as substituting for that stated in the tender booklet and the conditions specified therein are those that shall pertain to the tender and to participation in it.

3. The tender documents may be viewed beginning on December 31, 2014. Such inspection may take place at Moriah's offices at 2 Safra Square, Jerusalem, First Floor on Sundays through Thursdays between the hours of 9 AM and 2 PM. Prior coordination is required by calling 972-2-629-7608 or 972-2-629-7613. The full tender booklet will be published on Moriah's Internet site: www.moriah.co.il beginning on the aforementioned date. To remove any doubt, it is hereby clarified that the binding instructions in the matter of the tender that is the subject of this notice are those instructions determined in the tender booklet only and they supersede the information published in this notice.
4. The tender documents will be sold in exchange for an amount of NIS 20,000 including VAT at the times and dates as specified in Paragraph 3 above. Payment for the tender documents shall be made by check to the benefit of "Moriah – Jerusalem Development Company, Ltd."
5. Participants may submit questions of clarification with respect to the tender. Such questions shall be submitted by March 19, 2015 at 12 Noon. Inquiries shall be forwarded in writing to "Moriah – Capital Gateway Administration" by facsimile: 972-2-6455591. The title: "Questions of Clarification for Tender No. 387/2014" shall be explicitly indicated on the inquiry. Only responses that will be transmitted in writing by an authorized agent of Moriah will obligate Moriah.
6. A bidders' conference and site tour will be held on January 14, 2015 at 10 AM. The site tour will be convened at Moriah's offices at 2 Safra Square Jerusalem. Participation in the bidders' conference and site tour is mandatory and constitutes a condition for participation in the tender. In the case of a Joint Venture comprised of an Israeli bidder and foreign bidder, participation of the Israeli representative at the bidders' conference and site inspection will be sufficient for participation in the tender.
7. Moriah is not obligated to accept any proposal whatsoever, and will be entitled to cancel the tender wholly or in part at its sole discretion.
8. Tender bids shall be submitted in the tender box, which will be stationed at Moriah's offices at 2 Safra Square Jerusalem through April 15, 2015 at 12 Noon and no later. Forwarding of the bid by Postal Service or by any other means that does not involve the placement of the envelopes in the tender box will not be in conformance with the requirements of the tender. A bid that for any reason whatsoever is not placed in the tender box by the aforementioned date will not be included in the bids participating in the tender.

Sincerely,
Doron Noiwirt, CEO

* This is a translation of the Hebrew notification, which was published on 26/12/14. The delay of this publication was due to the Holyday season. Moriah would like to state, that all changes to the tender, if any, will be published, in Hebrew, in Moriah's web site.

Leighton-China State joint venture awarded Shatin-Central work

HONG KONG — A joint venture of Leighton Asia and China State Construction Engineering (Hong Kong) has been awarded a contract for works on the Shatin to Central Link. Works required include construction of the underground Exhibition Station and 300m of cut and cover tunnel along Convention Avenue (the western approach tunnel). The station will serve the convention centre, and the North Wanchai area, completing the new rail link and connecting New Territories and north Hong Kong. The value of the contract is USD 727M, Leighton Asia receiving a 51 per cent share. Leighton Holdings executive chairman and CEO Marcelino Fernandez Verdes said, "Securing the largest civil works contract within this project is an excellent achievement." Shatin to Central Link is a 17km-long rail expansion undertaken by MTR Corporation.

Eppenbergl Tunnel contract awarded to joint venture

SWITZERLAND — Wayss & Freytag Ingenieurbau, Royal BAM Group's German tunnel specialist has bagged a deal in joint venture with Swiss contractor Marti to build the Eppenbergl Tunnel in Switzerland. The two-lane tunnel will measure 2.6km in length and form a significant part in the Olten-Aarau railway (halfway between Basel and Zurich). At present, the railway is being widened to four tracks by the Swiss government and the Swiss rail company SBB. A 12.8m-diameter Herrenknecht Mixshield TBM will bore through the expected hard rock and wet soil conditions. Under this contract, the joint venture will also complete the construction of three emergency and escape tunnels, five shafts for technical areas and niches for M&E installation. The Eppenbergl tunnel project is scheduled for completion by the second half of 2019.

News briefs

ITALY

Driving and lining works have been completed in the 530m-long Basci tunnel, on the new Aurelia road section from Albisola to Savona in Liguria, Italy. The Consortium Letimbro, headed by CMC, started TBM excavation at 13.72m-diameter in April, 2014. The TBM will be transferred from the west end of Basci tunnel to the east end of the 2,010m San Paolo tunnel, where it will be launched this month. The final tunnel to be driven will be the 1,125 m Cappuccini tunnel in 2016.

GREAT BRITAIN

Engineers have developed a snake-like industrial robot that can be used to inspect and clean large construction machines, such as TBMs. The robot consists of a series of short, stiff tubes connected by cables and actuators to form a 2.2 metre-long, snake-like appendage. This serpentine arm is controlled by a set of motors and actuators at the base of the robot that manipulate each of the joints by means of the attached cables. The robot is capable of even greater agility and range of motion than a human limb, possessing an arm bend of over 225° and moving with all the lithe precision of a real-life snake. This enables it to enter environments or spaces that are either hazardous or impossible for human maintenance workers.

TFL APPOINTS MAJOR CONSULTING GROUPS FOR CROSSRAIL TWO

GREAT BRITAIN — Transport for London (TfL) has appointed four major consulting groups that will help develop more detailed plans for Crossrail Two, the proposed major new metro line in London.

TfL is developing proposals for the new line and will be working with the consultants on their areas of expertise. Further public consultations will take place before an application for powers to build the line is submitted in 2017.

The consultants chosen formed part of TfL's Engineering and Project Management Framework (EPMF) and were selected following a competitive tendering process.

The winning bidders along with their project area are:

- Arcadis Hyder (in partnership with Weston Williamson, VINCI Construction, Interfleet and First Class Partnerships and Dr Sauer & Partners) - engineering/technical aspects;
- CH2MHill/Atkins (CAST) - strategic modelling, route development; planning, appraisal and evaluation;
- MTEW (Mott MacDonald, Temple Group, ERM, and WSP) - environment and sustainability;
- Aecom, Weston Williamson and Turkington Martin - town planning, economic development, socio-economic and urban design.

Each set of consultants has been commissioned to offer specialised advice and will work closely with TfL to deliver these plans.

Mayor of London, Boris Johnson, said: "There is now real momentum behind Crossrail 2 and a growing sense that we can get it off the drawing board. We're seeing strong recognition from the business community [of the project's benefits]."

Crossrail tower crane operators prefer hook camera systems

GREAT BRITAIN — As Crossrail tunnelling works advance, crane operators are assessing the success of 'hook cameras' used on the project. These cameras deliver a live video stream to the cabin, mitigating communication issues faced when operating blind. The use of hook cameras is not common in the cranes industry as a whole, but tunnel jobs with shaft access offer a prime environment for their use.

Hook camera provider, HookCam Europe, has supplied several Crossrail contracts, including the C305 eastern running tunnels and C435 Farringdon eastern ticket hall projects.

Lee Bartley, senior appointed person for lifting

operations on C305 said: "Our tower crane operators think it is beneficial to working safely and are not looking forward to working elsewhere on other projects which have not invested in [the system]."

Ben Windass, managing director of HookCam Europe, said: "Tower cranes are widely regarded as the single most important and potentially dangerous piece of machinery on site. "We started working with Crossrail in 2013 and we are very proud to be associated with their 'Target Zero' safety policy."

In a 2000 study, from the US' Occupational Safety & Health Administration, 20 per cent of accidents were attributed to lack of communication.

Cameras give a clear view of signallers, as well as obstacles.



Lake Mead's lowering water level is clearly visible

NEW LAKE MEAD CONTRACTS TO BE AWARDED IN 2015

USA — The Southern Nevada Water Authority (SNWA) board of directors adopted in December a recommendation to design and construct a new Low Lake Level Water Pumping Station (L3PS) at Lake Mead, “within the swiftest feasible timeframe.”

Although the tunnelling for Intake No. 3 has successfully completed, and the project will soon transmit higher-quality water to existing pumping stations, SNWA said declining lake levels resulting from an ongoing, severe drought in the Colorado River basin “have raised concerns about the future operability of the existing intake pumping stations.”

The L3PS project will comprise a 525ft (160m) vertical shaft, 20ft in diameter; two discharge aqueducts of 144in and 108in; an underground forebay tunnel and connection to existing stub tunnel, among other elements.

“The underground excavation and pumping station mechanical and electrical components are anticipated to be accomplished under a contract that allows the constructor to work together with the designer in crafting design features that are both economical and compatible with efficient construction methods,” according to information from SNWA.

With requests for qualification-based proposals in February, the authority expects to award a pre-construction services contract in May, and a construction contract for underground excavation in September.

Delhi Metro tunnelling begins at worksite near Naraina Vihar

INDIA — Last month the Delhi Metro Rail Corporation (DMRC) started tunnelling near Naraina Vihar on the ring road Metro stretch, which is approximately 2.2km long, running between Mayapuri and Delhi Cantonment.

The total tunnelling required for the section stands at a 1,103m length.

The geology of the area is mixed, with quartzite rock as well as silt soil.

As a result, the 6.6m diameter TBM mobilised for the work is capable of tunnelling in soil as well as rock and has a mixed cutterhead.

The tunnelling will be carried out primarily under the densely populated areas of the Naval Staff Quarters, Naraina Village and Naraina

Vihar at a depth of 14.3m below the surface.

DMRC's managing director, Mangu Singh, inaugurated the initial TBM drive at the underground site in the presence of other DMRC directors and officials, as well as representatives of the contractor, a joint venture of J. Kumar and CRTG.

This section forms a part of the 59km-long Majlis Park – Shiv Vihar Metro corridor, which is slated to open to the public in 2016.

According to the Detailed Project Report, the expected daily ridership at the Naraina Vihar station will be 13,831 in 2016. The work forms part of the third phase of the Delhi Metro. For this phase, 45km of underground lines will be built with 31 stations.

A DMRC spokesman said this will be almost as much as the underground work from the two phases previous undertaken.



UNDERSTANDING UNDERGROUND

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SANDVIK

In memory of John King

OBITUARY — John was best known for the time he spent on the Channel Tunnel Project as tunnels director for TML. His contribution to the project was a source of great pride to him. John arrived on the project when the team was coming under real pressure, and his firm leadership and direction changed the mood, giving everyone renewed belief and purpose. John was highly respected for his hard work, and yet still his door was open to everyone who wanted advice.

John's work on the



John King

Channel Tunnel was recognised through his Honorary Doctorate from City University in 1994, and his OBE, which he was proud to

EGLINTON-CROSTOWN TUNNEL MAKES MILESTONE

CANADA — Two TBMs mining the western segment of the Eglinton-Crosstown's 10km tunnel, officially reached the half-way point of their journey on January 21 as they broke through the headwall at Allen Road.

A total of four TBMs are employed on the project, which requires 5.75m diameter tunnels. The TBMs boring the western portion of the tunnel each completed a 3,547m drive to arrive at Allen Road. Each TBM installed 14,124 precast concrete tunnel liners, which formed 2,354 rings.

Over the next several weeks, crews will prepare the TBMs to be moved to the other side of Allen Road to bypass an existing subway line. Once they are relaunched on the east side, both machines will continue their tunnel drives east toward Yonge Street to complete the 6.5km western segment of the Crosstown tunnel.

"It's great to see progress on this important transit project that will benefit Toronto riders," said Steven Del Duca, Minister of Transportation.

"This project is proof of our government's commitment to making the daily commute and quality of life better for Ontario families."

The Crosstown project costs approximately CAD 5.3bn (USD 4.25bn) in 2010 dollars.

"The incredible progress we're seeing on this project is the realisation of important investments in transit made in the Greater Toronto and Hamilton Area," said Bruce McCuaig, President and CEO of Metrolinx.

"The Eglinton Crosstown LRT is a significant undertaking and it will transform the transit landscape in Toronto when it's complete in 2020."

Crosstown Transit Constructors, a joint venture of Obayashi Canada, Kenny Construction, Kenaidan Contracting and Technicore Underground, won the contract to build the 6.2km tunnel in 2012.

A second contract, awarded to an Aecon-Dragados Joint Venture, will construct approximately 3.25km of twin tunnels using the other two TBMs, which are expected to launch this fall, according to Metrolinx.

receive from The Queen in 1991. He was also awarded the BTS' James Clark Medal.

John worked from 1946 until his first retirement in 1986 for John Mowlem and Co. Starting under the mentorship of perhaps his idol, Sir Harold Harding, he rose to become managing director of the civil engineering business. He worked in the '50s in London on GPO tunnels and the Post Office Railway at Rathbone Place, and after a Section Agent role in Sheffield on a steelworks factory, returned in 1961 to be Agent on the Strand Underpass and then the Victoria Line between Victoria and Oxford Circus from 1962 – 1966.

In 1967 and 1968 he was involved in the reconstruction of London Bridge before becoming director of Mowlem with special responsibility for their Tunnelling Business. Mowlem projects throughout this period included the Piccadilly Line Extension to Heathrow; the Fleet Line stations and tunnels at Baker Street; the access adits at Dinorwic; Medway cable tunnel; Redcar sea outfall and numerous sewer tunnels.

In 1977 John became managing director of Mowlem Civil Engineering until 1983. He then went to America for three years to develop Mowlem's business overseas, as a Director of Mowlem International before retiring in 1986 and becoming a consultant.

After the Channel Tunnel, John jointly established Pemberwell Services which proved a successful consultancy and included work for London Underground on Jubilee Line and Crossrail.

John was a founding member and a Past Chairman of the BTS.

He will be sorely missed, but remembered as a first rate engineer and director who was always willing to share the benefit of his experience with others.

Construction apprentice numbers worse than thought

GREAT BRITAIN —

Construction union UCATT claimed last month that new figures it had obtained showed that construction apprenticeship numbers were worse than expected.

The union said that a Freedom of Information request made by it to the Department of Business painted an even worse picture.

A UCATT spokesman elaborated on the specific numbers: "Provisional figures for the 2014/15 academic year record that there are just 24,850 undertaking construction apprenticeships."

Of these the vast majority, 19,830, were participating in intermediate level apprenticeships (Level 2), with just 5,190 apprentices undertaking advanced level apprenticeships (Level 3), and 130 apprentices on higher apprenticeships (Level 4).

Last month it was revealed that in 2013/14 just 8,030 apprentices completed construction apprentices, when the industry needs nearly 45,000 new entrants every year.

Steve Murphy, the general secretary of UCATT, said: "These figures are abysmal. The total number of apprentices being trained is 20,000 lower than the number of new entrants the industry needs every year."

Murphy added: "The lack of apprentices being trained to Level 3 is a result of employers deskilling courses and a failure to think long-term. Employers are locked in a short-term mindset. If they are forced to train apprentices they want to do it as quickly as possible, teaching the bare minimum."

"Fully trained apprentices are more productive and have a greater range of skills, which is in the long-term interest of the industry and the economy."

ITAWTC 2015

41st General Assembly and Congress of International Tunnelling Association ITA-AITES



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BREAKTHROUGH AT COPENHAGEN

DENMARK — The two Copenhagen Cityringen TBMs broke through last month. The site, located some 30m below an existing historical train station, hosted a visit by Danish prime minister Helle Thorning-Schmidt.

The driverless metro project will be completed in 2019. The 15.5km-long, TBM-excavated route has an internal diameter of 4.9m.

The contractor responsible for civil construction work is the Copenhagen Metro Team JV comprising Salini Costruttori, Tecnimont and Seli. The client is Metroselskabet. Cowi, Arup and Systra handled vibration analysis as well as all other design and engineering works.

The client, Metroselskabet, recommended the contract award in late November 2010, pending approval by its owner, and the EUR 1.7bn (USD 2.38bn) contract was confirmed in January 2011. Ansaldo was awarded the separate contract by the client for the control systems and driverless trains.

The ground conditions along the alignment of Cityringen comprise a quaternary sequence of meltwater sands and tills resting on Danian limestone. The quaternary deposits are overlain by fill as well as post- and late-glacial deposits. Deposits belonging to the Selandian (Middle Palaeocene) greensand formation are also found locally subjacent to the quaternary deposits. Cityringen is an extremely complex project since the Danish capital is at sea level, groundwater levels are high and large numbers and volumes of excavations are required. And, not least, environmental regulations for groundwater protection are extremely important.

Israel declares victory in war on tunnels as Hamas vows to rebuild

ISRAEL — Israel's armed forces have demolished the last remaining tunnel from the besieged Gaza Strip into its own lands.

Some 31 tunnels have been destroyed in the recent efforts and while the army admits that there is a margin for error, it believes the task is done.

The Times of Israel, quoting army sources, said a cache of weapons and explosives were found in the tunnel, which was "demolished in order to prevent its rehabilitation in order to safeguard the security of the civilians of southern Israel".

The tunnel had an opening near Nahal Oz, a kibbutz in southern Israel, and reached the Shejaiya neighborhood east of Gaza City, according to Israeli news site *Ynet*. The army said it was discovered during the summer operation,

but did not explain why its destruction was delayed.

The Times of Israel also quotes unnamed security sources, which said that Hamas is working to rebuild its tunnel infrastructure.

As *Tunnels and Tunnelling* goes to press, it is nearly six months since the Israeli armed forces completed a 50-day asymmetric bombing campaign against the territory, 'Operation Protective Edge', which left thousands of Gazans killed or wounded, and resulted in international condemnation.

Israel argues that the Gaza ruling organisation, Hamas, is responsible for the estimated 70 per cent civilian casualties as it operates military activities from residential areas.

The Israeli armed forces also announced a commendation for one of its soldiers who volunteered to step into the 'terror tunnel' alone to facilitate its destruction.



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Concept image of NorthConnex's northern portal

LEND LEASE AWARDED NORTHCONNEX TUNNEL

AUSTRALIA — Lend Lease has won the contract for the AUD 2.6bn (USD 1.99bn) NorthConnex motorway in Sydney. According to a report by the Australasian Tunnelling Society (ATS), giving the group its second controversial tunnel project in six months.

Canada Pension Plan Investment Board (CPPIB) will provide AUD 525M (USD 402M) for the project that will provide a link between the southern end of the M1 Pacific motorway at Wahroonga to the Hills M2 motorway at its existing Pennant Hills Road interchange.

The investment gives CPPIB a 25 per cent stake in the road. The pension fund also owns a 25 per cent interest in the Westlink M7 toll road in Sydney, through its acquisition of Intoll Group in 2010.

Lend Lease is in a joint venture with Bouygues Construction to deliver the project on behalf of client Transurban, which will operate the road. Transurban will own 50 per cent of the project while Queensland Investment Corporation will hold the remaining 25 per cent.

ATS reported: "The contract comes as Lend Lease and its consortium partners are locked in discussions with the new Andrews Labor government, which abandoned the controversial East West Link project promoted heavily by the Napthine Liberal government.

"It is reported that Lend Lease and its consortium partners are willing to cut a deal to cover their bid costs for the East West Link

as well as other costs the consortium had notched up. However, the consortium led by the Commonwealth Bank is believed to be holding out for a much larger deal after the outgoing Liberal treasurer Michael O'Brien included a poison pill in the contract that was signed just days ahead of the state election the party was widely expected to lose.

"There are at present no plans to abandon the NorthConnex project, despite wide community concerns."

Spanning 9km, NorthConnex will be the longest road tunnel project in Australia. Construction of the tunnel will begin in early 2015 and should complete in 2019.

"We are excited to be part of this important motorway development project, which is in line with our strategy to invest in attractive global infrastructure opportunities," CPPIB head of infrastructure Cressida Hogg said.

"The NorthConnex tunnel will create a vital link in Sydney that will play a significant role in alleviating traffic congestion.

"We look forward to working together with an experienced toll road operator in Transurban and a well-aligned, long-term investor in QIC."

The project win will come as a boon to Lend Lease, which has been looking to build its infrastructure business. Ahead of winning the NorthConnex contract, Lend Lease was working on five infrastructure projects with an estimated capital spend of AUD 4.1bn.

Atlas Copco president comments on fourth quarter results

SWEDEN — Machinery manufacturer Atlas Copco reported record revenue and operating cash flow for the fourth quarter of FY 2014/15, and therefore proposed an extra capital distribution.

A spokesman stated that the overall near-term demand for the company's services is expected to increase somewhat.

Fourth-quarter orders rose 24 per cent year-on-year from the previous financial year to reach a level of SEK 24bn (USD 2.87bn), supported by acquisitions and a strong service business.

The organic increase was two per cent.

Revenues in the quarter reached a record of SEK 25bn (USD 3bn). The adjusted operating profit was SEK 4bn (USD 480M), corresponding to a margin of 19.3 per cent.

The cash flow was the highest ever at SEK 5bn (USD 600M).

"The year ended with very strong cash flow and with a good working capital development," said Ronnie Leten, president and chief executive officer of the Atlas Copco Group.

"Demand [...] was stable for equipment and strong for service. The service business for mining continued to grow."

Events during the quarter included the acquisition of Titan Technologies International, a USA-based provider of bolting tools.

An Atlas Copco spokesman added: "Atlas Copco launched several new products in the last year which included a range of oil-free scroll compressors, a complete range of quality assurance equipment for the motor vehicle and general industries, and a range of medium sized face-drilling rigs for the both the underground mining and the civil tunnelling industries."

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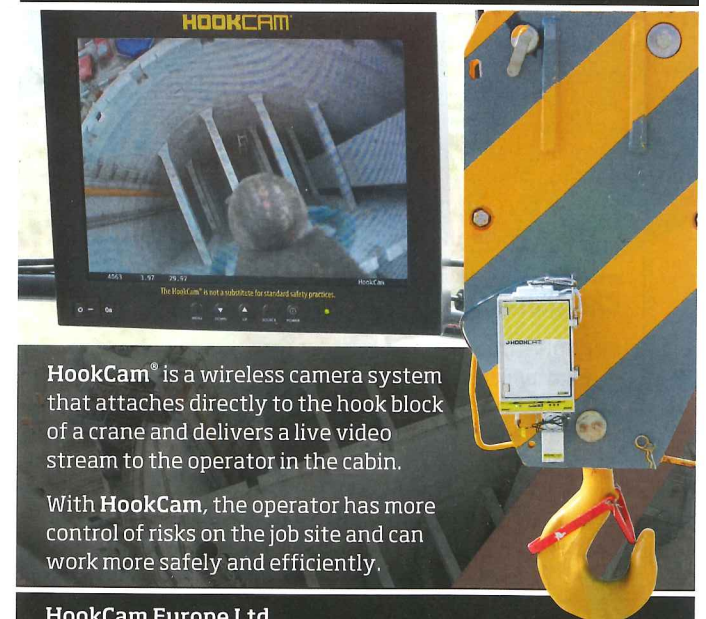
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FRONTLINE EXPERIENCE INSPIRES AWARD-WINNING APPS

GREAT BRITAIN — A team member on a Costain Skanska Crossrail project in London has had success in an international competition to find the best idea for construction-related apps.

Costain's Andrew Irwin was the developer of five of the top 10 apps chosen by an international panel of experts.

The Construction App Challenge was organised as one of the final events under the MobiCloud project. MobiCloud is a European Union-funded scheme to develop a European 'corporate appstore' as part of the EU's Competitiveness and Innovation Framework Programme, in collaboration with Apear (Sweden), EsperantoXL (Netherlands), Nettropolis (Germany) and COMIT Projects (Great Britain).

Irwin, a section engineer on the Crossrail C360 contract – Eleanor Street and Mile End Park Tunnels and Shafts – submitted six ideas over a period of weeks last year. "My frontline role enables me to continually identify real site problems or areas for improvement," he said.

"The challenge provided me with the opportunity to submit my innovative ideas to develop solutions to these problems. My ideas looked to enhance and improve the effectiveness and safety of working on major civil engineering projects in the industry and within the Costain business."

Irwin attended a live webinar in which the top 10 app ideas were announced, with the expert panel having judged the 47 worldwide entries.

"When one of my ideas was announced as coming in at number eight, I thought, 'Brilliant, I'm in the top 10.'"



Andrew Irwin

"I was then delighted on hearing that another of my ideas had achieved fifth place."

Judges then announced that the top three places were also Irwin's ideas, to which he admitted being both astonished and proud.

His winning idea is an app that will improve the management of machinery and powered tools, "currently a paper-based system, taking a lot of engineers' and foremen's time."

Irwin's winning idea uses electronic identification, attached to equipment and scanned using a smart device equipped with his app.

The app displays and records vital information including maintenance certificates, to manage requirements under LOLER and PUWER regulations and health and safety information such as the safe period of use for vibrating hand tools.

For his winning entry, Irwin will attend the MobiCloud consortium meeting in London to receive a EUR 1,000 (USD 1,130) prize and will now have the opportunity to see his app realised, taking the project forward with developers.

Senior civil engineer Katie Swanick, who is MobiCloud project lead at Costain and was one of the judges on the Construction App Challenge, said her fellow judges and she marked entries on several criteria, such as feasibility, simplicity and effectiveness. All the entries were examined on a completely anonymous basis, so judges had no idea whose entries they were scrutinising.

MobiCloud's EU funding ends early next year and the project will be wound up.

NWRL ahead of schedule and budget

AUSTRALIA — New South Wales Premier Mike Baird and Minister for Transport Gladys Berejiklian announced last month that the North West Rail Link is running ahead of schedule and AUD 300M (USD 234M) under budget, as the landmark project reached another major tunnelling milestone.

Baird and Berejiklian were onsite as the first TBM, Elizabeth, broke through into the future Norwest Station area – just days after the fourth (and final) machine started digging.

"This is an exciting day for locals and another clear sign that construction of this critical rail link is powering ahead," Baird said. "It was only in September that we launched this first massive machine at Bella Vista – in that time it has tunneled 2.1km to reach today's historic breakthrough at Norwest."

Berejiklian added, "The project is now running AUD 300M (USD 234M) under budget and I am confident there will be further savings for taxpayers as the project progresses."

In tunnelling to Norwest from the Bella Vista site, the TBM has had 40 hardened steel cutters replaced, worn down from the harsh forces of cutting the Sydney sandstone and shale.

Over the coming weeks, the TBM will be moved through the station, before setting off again.

Channel Tunnel fire causes heavy delays but negligible damage

GREAT BRITAIN/FRANCE — Eurotunnel services were disrupted for three days following a fire last month, but only slight damage was caused to the tunnel.

All services were stopped on Saturday 17 January after a lorry fire broke out towards the French end of the north tunnel.

While services resumed

the following day through a single tunnel, delays persisted.

Empty trains were sent through the affected tunnel as a safety precaution to ensure it was clear, while customers were offered ferry transfers.

A Eurotunnel spokesman later said of the incident: "There was a smouldering

load on board a truck we were carrying on board one of our shuttles.

Supposedly there were also power supply problems as a result. There were no injuries.

Initial concerns were that the incident would be a repeat of the 16-hour 2008 lorry fire, which exceeded 1,000°C.

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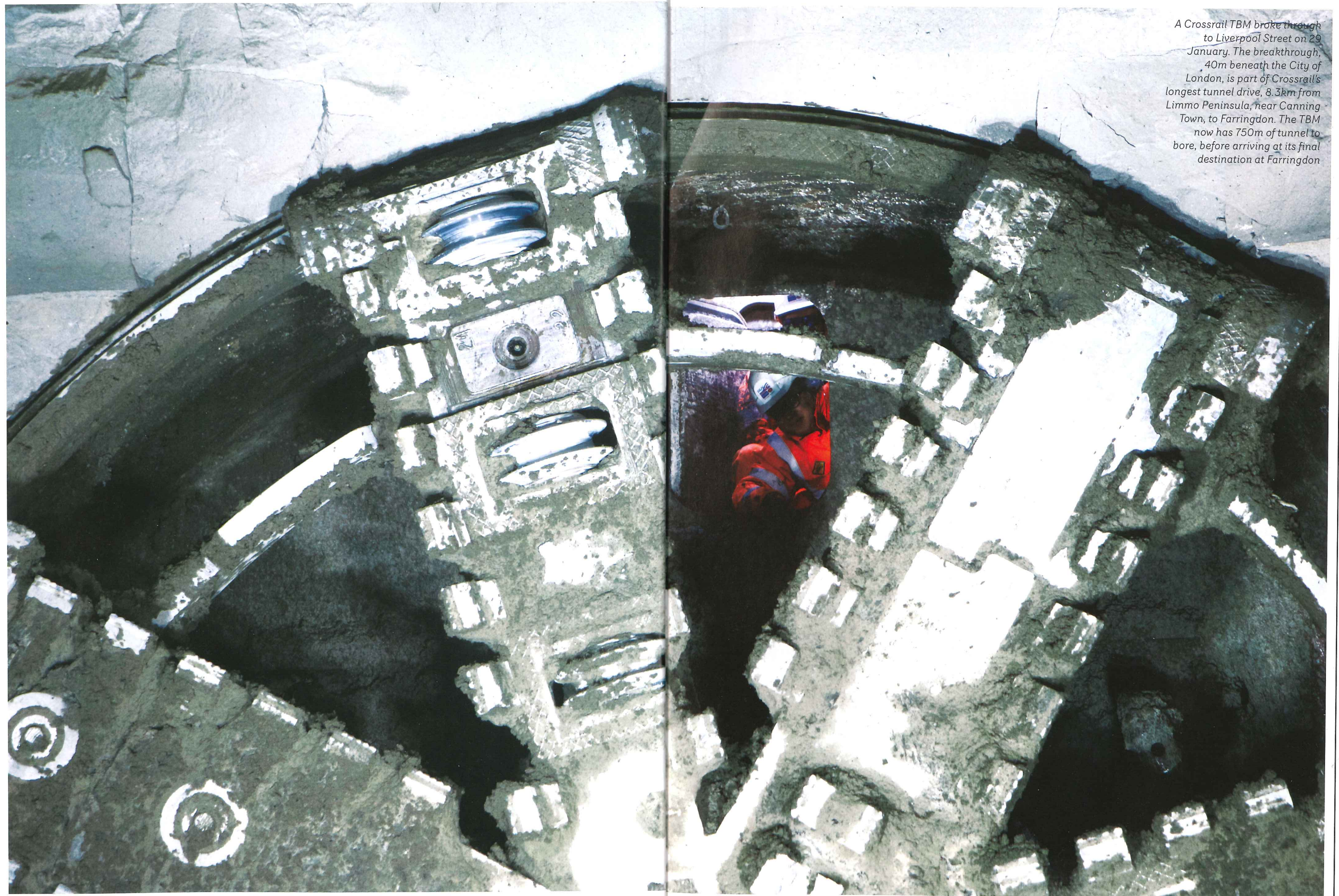
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A Crossrail TBM broke through to Liverpool Street on 29 January. The breakthrough, 40m beneath the City of London, is part of Crossrail's longest tunnel drive, 8.3km from Limmo Peninsula, near Canning Town, to Farringdon. The TBM now has 750m of tunnel to bore, before arriving at its final destination at Farringdon

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ITA PRESIDENT SEES INCREASED INTERNATIONAL AWARENESS

In a Q&A session released by the *International Tunnelling Association (ITA)*, president **Soren Degn Eskesen** outlines what can and is being done to mitigate the effects of climate change through underground infrastructure. Eskesen also reports an increased appreciation from the international community for the benefits tunnelling can bring

The effects of climate change are now widely visible throughout the world. Regarding these phenomena, what solutions could underground infrastructure provide?

Eskesen: Cities around the world are challenged by rapid urbanisation, climate change, and the need to become more resilient. The ITA believes that underground space in urban areas can be used for meeting many challenges cities face. If done in a planned manner, the development of underground space can contribute to sustainable development of urban areas and help them adapt to climate change effects.

The solution falls into two categories. Firstly using the underground can assist in reducing the carbon footprint that big cities today recreate. There are several options [to accomplish] this – by moving transport into underground systems [that are not powered by carbon-generated energy sources], and by changing [the means of energy production] to ‘green energy’ sources such as hydropower, of which the use of the underground is an integral part; providing tunnels for water transport and underground caverns for the power house.

Secondly, solutions using the underground may be used to create flood protection for cities by providing tunnels for flood control. This can be accomplished either by diverting flood water through tunnels instead of surface rivers, which will be overflowing, or by creating underground storage facilities for the retention of flood waters. Such solutions have been used in several cities, [an example being] Buenos Aires in Argentina.

Are states fully aware of the potential of underground infrastructure for population and structure protection?

Eskesen: The ITA has for some years been reaching out to decision makers and urban planners to promote the use of underground space. During our annual World Tunnel Congresses in Helsinki 2011, Bangkok 2012, and Geneva 2013, we organised open sessions where the subject was the use of underground space in a changing world.

Cities everywhere are under pressure to support their growing

populations, and to meet their future energy and transportation needs in far more sustainable ways. Decision makers and organisations are now talking about underground space and how to include the underground in city planning to make cities more resilient. We at the ITA support them and are being acknowledged and being invited to activities driven by UN global agendas. The ITA was named as one of the partners in the Expert Group on Urban Drainage, set up by UN Habitat. An excellent example of this is the SMART project in Kuala Lumpur, Malaysia.

The UN Habitat has recently identified the five basic principles on Urban Drainage, and one of the five is that “effective use of tunnelling and underground space is appropriate where required”. Tunnelling and underground space is now becoming part of UN policy. So yes, the international community is aware of the matter. This is only a first step, but it is significant, and it does show our work in ITA is achieving what we set out to do.

ITA participated in a New York summit last September. What were its successes?

Eskesen: The ITA was represented by the chair of our Committee on Underground Space, Han Admiraal, and myself at the

Below: Soren Degn Eskesen is ITA president and tunnelling specialist for Cowi of Denmark



UN Climate Summit in New York in September 2014. At the historic meeting, many governments and organisations pledged to an alliance to combat climate change. From this moment on, it became clear that investors were increasingly backing green projects geared towards a low carbon economy. This is caused by three reasons outlined by the speakers. Firstly it became clear that no longer is there any doubt as to the fact that climate change is altering our world, and that it is being caused by human activity. Secondly, that the costs of not doing anything are now outweighing the costs of acting. Thirdly, that governments alone are not going to change anything, and involvement of the private sector is needed. That involvement is not about individual companies, but about companies willing to act together based on a common interest and on the simple fact that if they don't act now, there soon will be no world left.

In the closing session, UN Secretary Ban Ki-moon announced a 'Global Geothermal Alliance' in the field of energy, which made it clear that the ITA's efforts to develop underground space in a planned manner need to continue. Other fields that the ITA shall remain focused on are transportation, and cities. The reduction of carbon emissions and transitioning to a low carbon economy are vital and can be delivered through these fields. Tunnelling and underground space can play an important role in delivering solutions in these areas.

The participants acknowledged that underground space can contribute to numerous urban challenges and they now acknowledge the ITA as a global leader on tunnelling and underground space.

Floods are likely to increase in frequency and strength. How can the industry foster greater investment in underground infrastructure to limit the effects of these disasters?

Eskesen: Our industry has solutions for flood control by diverting water into tunnels to avoid floods at the surface. We have proven the solutions exist already, demonstrated by a number of projects. We need to spread the message, and inform people that it is cheaper, safer, and more resilient to provide the solutions prior to the disaster occurring. We need to convince states and governments to invest to avoid the disasters. The capital is better spent investing for disaster risk reduction, than to spend a similar amount or even more in rebuilding efforts.

Cities everywhere are under pressure to support their growing populations, and

to meet their future energy and transportation needs in far more sustainable ways in order to reduce the carbon footprint and the climate change effect. Moving people efficiently is critical to the livability and economic success of cities. Success depends on how well cities utilise their underground space, because what happens below greatly enhances what is possible above. By investing in the underground you create room at the surface to develop the city into an economic powerhouse.

Are there any significant ongoing construction projects that aim to reinforce the security of populations and goods located in flood prone areas?

Eskesen: Southeast Asia is probably the area of the world where the risk of flooding is highest. In Jakarta, the capital city of Indonesia, flooding is too frequent in recent times. Several projects exist to cope with immediate remediation, such as the tunnel that will connect the Ciliwung River in the Bidaracina district of eastern Jakarta, with Jakarta's East Flood Canal. But for the longer term an important project is the Jakarta multi purpose tunnel, based on the example of the Kuala Lumpur SMART project.

After the mega flood that occurred during the autumn of 2011 in Bangkok, Thailand; the Bangkok Metropolitan Administration (BMA), as well as the local ITA member association (TUTG), proposed various solutions including tunnels to prevent such flooding. TUTG proposed the construction of a long multi-purpose tunnel from the north of the city to the sea, and BMA is reinforcing its network of drainage tunnels. The construction of such a tunnel began a few weeks [prior to Tunnels and Tunnelling going to press]. It will be a 6.4km-long tunnel some 5m in diameter. Other projects exist in various countries and parts of the world. Even in my hometown of Copenhagen in Denmark, we are considering the construction of a tunnel that would serve as a combination of drainage tunnel and a six-lane road. At the moment, the heavily congested surface road follows the alignment of a river that now runs through drainage pipes. By moving the road underground and combine it with a drainage tunnel to control heavy rainfall, we will free the surface area and make room for reinstating the river to create a recreation area to the benefit of the city's inhabitants.

In 2015 Paris will host the World Climate Conference, an occasion that will put climate disorders at the heart of discussions. What key messages does ITA plan to convey?

Eskesen: During our work with UN Habitat, we will inform delegates of the role underground space can play in urban drainage and disaster risk reduction. We are now part of a process that wants to bring together cities and private partners to really start projects that will do this. No more concepts, the real thing and especially in those fast-growing cities that need it but have never considered it. We are challenged to come up with solutions to solve the challenges these cities have. These being, among others, drainage and flood control.

The benefits of the urban decisions we make today will be valued by generations to come, exactly in the same way as we in our older cities see the benefit of the investment our grandfathers made, such as building underground metro systems in cities such as: Paris, London, New York etc. Today's urban population is still benefiting from the investments made more than 100 years ago.

ITA has never before been so close to getting the attention of the world, and ensuring that tunnelling and underground space are seen as vital to meeting the biggest challenges this world has ever faced. We are committed, and ITA will show leadership to carry the solutions through

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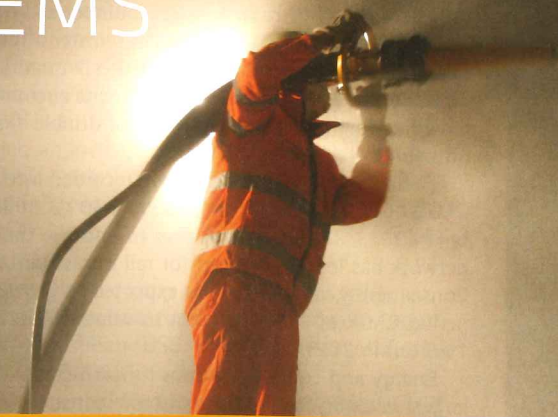
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INVESTMENT IN ASIA

Danny Richards, a senior economist for the market analysis arm of *Timetric, Tunnels and Tunnelling's* publisher, gives an overview of infrastructure investment in select Asian countries during a review period of 2009–2013, and presents the results of market analytics to predict the value performance of infrastructure sectors in a forecast period up to 2018

TIMETRIC HAS published its latest range of national economic reports. Looking at the smaller construction markets of Asia (when compared with the giants of India and China) the economists analyse industry performance and future indicators to give an idea of growth to guide investors over the next few years.

HONG KONG

Infrastructure construction was the largest market in Hong Kong's construction industry in 2013, accounting for 47.0 per cent of the total industry value. It grew steadily to reach a value of HKD 82.6 bn (USD 10.7 bn) in 2013. Growth will be supported by the need to invest in the water infrastructure network, to reduce dependency on China for water resources. The market is therefore expected to hit a CAGR of 9.56 per cent and reach a value of HKD 130.4 bn (USD 16.8 bn) in 2018.

Aside from water, rail is a significant factor. In the 2013–2014 budget, the government included plans to extend Hong Kong's rail network to Kennedy Town and Sai Ying Pun in 2014, with extension to Ap Lei Chau Hang and Wong Chuk, and Ho Man Tin and Whampoa in 2015. Construction of a rail line from Shatin to Central Link is expected to be completed in phases in 2018 and 2020. The category is therefore expected to record a CAGR of 9.64 per cent to value HKD 21.2 bn (USD 2.7 bn) by 2018. The road construction industry is dominated by the Hong Kong–Zhuhai–Macau Bridge is one of the main infrastructure projects: worth HKD 83.3 bn (USD 10.7 bn), its construction started in 2009 and is scheduled to complete in 2016. The category is expected to enjoy a CAGR of 9.71 per cent, reaching a value of HKD 33.0 bn (USD 4.3 bn) by 2018.

INDONESIA

Owing to high investment, the construction industry posted a review-

Danny Richards

Danny works for the market analysis and reports arm of *T&T's* publisher



period compound annual growth rate (CAGR) of 27.11 per cent to value IDR 2.6 quadrillion (USD 254.5 bn) in 2013. Industry growth is expected to remain strong over the forecast period (2014–2018), as a result of the government's focus on infrastructure and industrial construction, and the implementation of the multiyear Master Plan for the Acceleration and Expansion of Indonesia's Economic Development (MP3EI). Consequently, industry output is expected to rise at a forecast-period CAGR of 15.90 per cent to value IDR 5.5 quadrillion (USD 436.5 bn) in 2018.

The infrastructure construction market valued IDR 1.6 quadrillion (USD 156.7 bn) in 2013. The CAGR of 29.94 per cent can be attributed to significant government investments and the participation of the private sector through public-private partnerships (PPPs) in infrastructure developments. The market is expected to have a CAGR of 17.79 per cent to value IDR 3.7 quadrillion (USD 291.5 bn) in 2018.

Road infrastructure was the largest category in the infrastructure construction market in 2013, accounting for 47.5 per cent and valuing IDR 773.1 trillion (USD 74.5 bn). The category recorded a CAGR of 29.54 per cent during the review period, driven by the government's encouragement for road infrastructure construction as the number of vehicles continues to rise. The category is expected to register a forecast-period CAGR of 17.73 per cent to value IDR 1.7 quadrillion (USD 138.2 bn) in 2018 based on government encouragement for road-building projects in the wake of double-figure percentage growth new vehicle sales.

The rail infrastructure category recorded a review-period CAGR of 26.66 per cent to value IDR 109.3 trillion (USD 10.5 bn) in 2013. The long-term plan to improve the country's rail network has led to the need for rail infrastructure upgrades. Consequently, the category is expected to grow at a forecast period CAGR of 17.72 per cent to value IDR 247.2 trillion (USD 19.5 bn) in 2018.

Energy and communications infrastructure was the third-largest category in the infrastructure construction market in 2013, with a 14.3 per cent share of the market's value. The category recorded a review-period CAGR of 28.60 per cent to value IDR 233.2 trillion (USD 22.5 bn) in 2013. According to the Ministry of Energy and Mineral Resources (MEMR), electricity demand in the country is projected to increase by 10.1 per cent annually.

The category is expected to grow at a forecast-period CAGR of 18.88 per cent to value IDR 553.7 trillion (USD 43.8 bn) in 2018.

JAPAN

After coming to power in 2012, the government announced an emergency stimulus package of JPY 10 trillion (USD 110 bn) in January 2013, with a primary focus on public work infrastructure. Public work subsidies increased to JPY 5.3 trillion (USD 0.1 trillion) in 2013. The package focuses on reconstruction projects including repairs and the construction of earthquake-resistant roads, bridges and tunnels.

The Japanese construction industry recorded a compound annual growth rate (CAGR) of 0.14 per cent during the review period (2009–2013) and valued JPY 54.1 trillion (USD 558.8 bn) in 2013. The country's economy contracted following an earthquake, subsequent tsunami and nuclear disaster in 2011. In a bid to reconstruct and revitalize the economy during the review period, the government introduced economic reforms, such as an increase in subsidies and tax breaks for companies that invest in factories.

The construction industry outlook is favorable, as a result of the government's focus on reconstruction activities. According to the Ministry of Economy, Trade and Industry (METI), indices of construction activity increased from 87.5 in the fourth quarter of 2012 to 99.4 in the fourth quarter of 2013, registering growth of 13.6 per cent. The construction industry's output is expected to increase at a CAGR of 3.19 per cent over the forecast period (2013–2018), to reach a value of JPY 63.4 trillion (USD 682.1 bn) by 2018.

The infrastructure construction market was the largest in the Japanese construction industry in 2013; it accounted for a 47.4 per cent share of the industry's output and valued JPY 25.7 trillion (USD 264.8 bn).

It was also the fastest-growing market during the review period, registering a CAGR of 0.24 per cent. The market is expected to register a forecast-period CAGR of 4.05 per cent to reach a value of JPY 31.3 trillion (USD 337 bn) in 2018, driven by investments in public infrastructure, such as the construction of a maglev train line, and developments in transport and energy infrastructure.

Road infrastructure accounted for a 25.3 per cent share of the market value in 2013, equal to JPY 6.5 trillion (USD 83.3 bn) and representative of a review-period CAGR of -0.45 per cent. The earthquake in Tohoku in 2011 damaged the majority of the region's road infrastructure, creating the need for road works, and the collapse of the Sasago tunnel in December 2012 demonstrated the infrastructure's aging condition. In order to fund reconstruction activities in the country, the budget framework was increased from JPY 19 trillion to JPY 25 trillion over 2011–2015. The government has also proposed, in its 2014 budget, an increase in spending on public works by JPY 680 bn (USD 8.5 bn) to reach JPY 5.9 trillion (USD 0.1 trillion). The road infrastructure category is anticipated to post a forecast-period CAGR of 3.74 per cent to value JPY 7.8 bn (USD 83.8 bn) in 2018.

The rail infrastructure category accounted for a 16.2 per cent share of the infrastructure construction market in 2013 and valued at JPY 4.2 trillion (USD 43 bn), representative of a review-period CAGR of -3.93 per cent.

The category is expected to record a forecast-period CAGR of 4.20 per cent to value JPY 5.1 trillion (USD 55.1 bn) in 2018.

SINGAPORE

The infrastructure construction market valued SGD 6.5 bn (USD 5.2 bn) in 2013. The Singapore government has invested heavily in rail and road infrastructure, and has a strong pipeline of various rail transit projects nationwide. Moreover, 80 per cent of the country's total electricity is

10.7

billion USD is the value of the Hong Kong infrastructure construction market

245.5

billion USD is the value of the Indonesian infrastructure construction market

110

billion USD is the value of the Japanese infrastructure construction market

5.2

billion USD is the value of the Singaporean infrastructure construction market

62.4

billion USD is the value of the South Korean infrastructure construction market

generated using natural gas fuels. According to the Energy Market Authority (EMA), the government is expected to add 3GW to the country's total power capacity through natural gas by 2017. Increased investments in energy infrastructure in order to meet rising energy demand, and transport infrastructure to enhance the country's connectivity will also support the market's expansion. The market is therefore expected to record a CAGR of 4.96 per cent to value SGD 8.3 bn (USD 6.5 bn) by 2018.

The Ministry of Transport (MoT) launched a new Land Transport Master Plan (LTMP) in 2013, which replaced the LTMP 2008. The MoT plans to expand the country's rail network with the construction of two new rail lines, and extensions of three more. The length of the rail network is expected to double from the present 178km to 360km by 2030.

SOUTH KOREA

Infrastructure construction is the largest market in the South Korean construction industry. The market posted a review-period CAGR of 1.20 per cent, to value KRW 68.4 trillion (USD 62.4 bn) in 2013. The market is projected to continue expanding until at least 2018, driven by investments in road, rail, and energy infrastructure. The government has placed a high emphasis on infrastructure construction, and KRW 124 trillion (USD 108.6 bn) worth of infrastructure projects are in the pipeline. The market is consequently expected to record a forecast-period CAGR of 4.04 per cent, to value KRW 83.4 trillion (USD 80.3 bn) in 2018. This is a result of increased government investment and participation of the private sector through public-private partnerships (PPPs), which will support infrastructure construction activity over the forecast period.

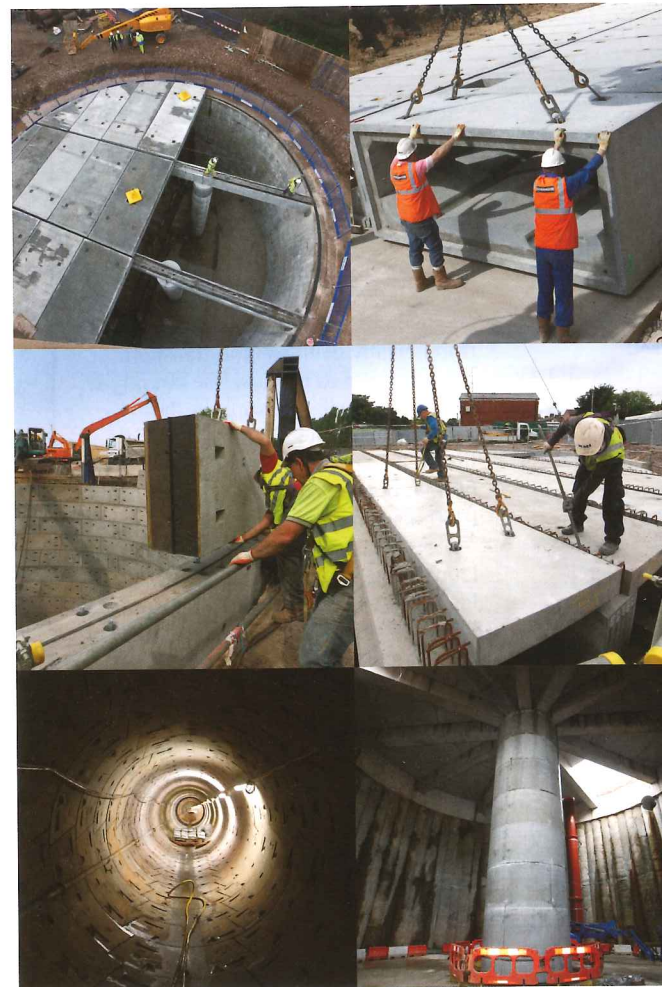
The long-term plan to improve the country's rail network has led to the need for rail infrastructure upgrades. Consequently, forecast-period growth in the category will be supported by various rail construction projects, such as the Wonju-Gangneung high-speed rail project, the Kimpo rapid transit project, the Jinjeop metropolitan rail line 4 extension project and the Daegok-Sosa metropolitan rail line expansion project.

The category's value is expected to increase from KRW 7.2 trillion (USD 6.6 bn) in 2013 to KRW 9.1 trillion (USD 8.8 bn) in 2018, at a forecast-period CAGR of 4.81 per cent

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A boom in investment over the last half decade has seen meteoric changes for Central China's unofficial capital, Wuhan. One of the fruits of the investment is the Sanyan (or Sanyang) Road tunnel project. A combined road-rail crossing of the Yangtze River that is the first multifunction tunnel in China

Alex Conacher

The *Tunnels and Tunnelling* editor has been with the magazine since 2010



WUHAN CAN

WUHAN IS the most populous city in Central China and a transportation hub for the wider area. But with a population just shy of 10 million people, it falls short of true megacity status, and a long way behind the country's top-tier metropolitan areas of Shanghai and Beijing. With infrastructure investment over five years totalling approximately USD 300bn however, it is looking to reshape both the political landscape, and its own environment. ▶



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The city's centre is being 'reimagined' – in typically bold Chinese style – with a colossal programme of demolition and reconstruction. All this is being financed through the state taking on a massive debt burden, and the explosion of the Chinese credit sector from a total value of USD 10tn in 2008 to USD 25tn in 2014 (a size increase equal to the entire US commercial banking sector). It has been an attempt to mitigate the effects of the global financial crisis that has seen investment soar to 50 per cent of GDP.

But economic rationale and impacts aside, the result is a windfall to engineers. A high tech commercial city centre is being swiftly built along with the associated skyscrapers, a second airport, rail routes, road networks, and an entire metro system.

RIVER OBSTACLE

The Yangtze River, the longest in Asia, has been a hazardous natural obstacle for locals for thousands of years.

Bottom left: A bridge crossing of the Yangtze River

Bottom right: The Wuhan Metro network, delivered in less than a decade

Below: Wuhan in China, capital of the central region



Splitting Wuhan in half, its span is approximately 1km at its narrowest point inside the city. While traditionally crossed by ferries, several permanent crossings, bridges and tunnels, now exist.

And now a new crossing is to be added. A multipurpose tunnel combining road and rail transport will be built as part of Wuhan's Metro Line Seven, and Sanyang Road, located in the city centre.

In August 2013 the National Development and Reform Commission approved the feasibility study for the first phase of Line Seven. This phase includes the Sangyang Road tunnel, which will run as a twin tunnel with tubes 2.5km long and an excavation diameter of 15.76m. The large diameter allows for an upper deck with a three-lane road, and a lower deck for the metro service, as well as safety and other electrical and technical networks.

It is the fourth rail line, after Lines Two, Four, and Eight, to run across the Yangtze River. The route starts at the Oriental Lucky City in Hankou, passes Fazhan Avenue, Jianshe Avenue, Aomen Road, Sanyang Road, the Yangtze River, Qinyuan Road, Youyi Avenue, Zhongshan Avenue, and Lizhi Road, and terminates at Yezhi Lake in Wuchang. The entire length of Line Seven will be 30.9km, with 19 stations.

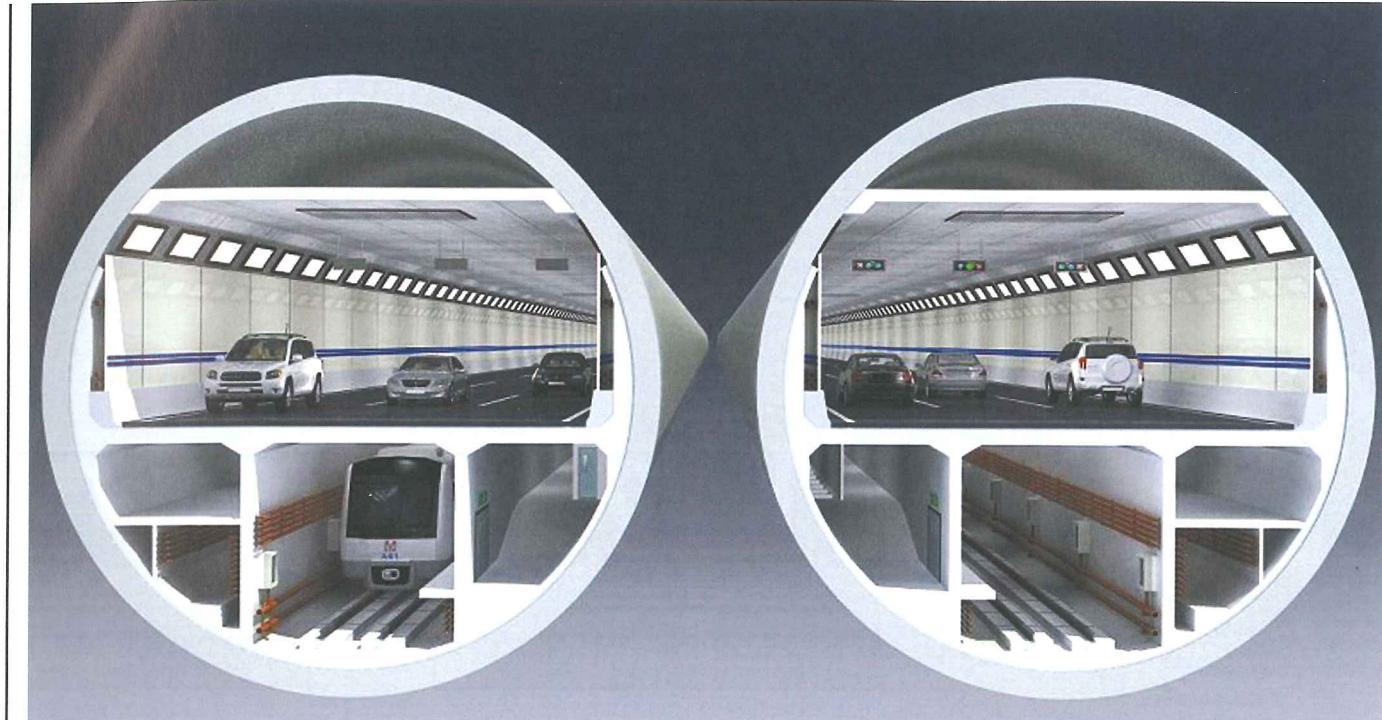
Analysis has predicted that of 640,000 journeys per day, some 250,000 will cross the river through the tunnel.

CROSSING THE RIVER

The contract was awarded to Shanghai Tunnel and Engineering Company (STEC), a soft soil tunnelling firm, which began construction in 2014 and expects to be finished on schedule in 2017. The tunnel alignment passes through complex, varying geology consisting of sand and clay in places, and elsewhere a mixture of mudstone, conglomerates and sand. The tunnel will pass 39.5m beneath the river, and water pressure up to 5.3 bar is expected.

Around seven years ago, nearby road tunnel bores by 11.38m-diameter NFM slurry TBMs experienced pressures up to 7 bar through silt and sand with clay and large boulders. Daily progress of 15–20m was achieved.

Excavation this time will be carried out by two 15.76m



Herrenknecht Mixshield TBMs, STEC having previously constructed large-diameter road tunnels in Hangzhou and Shanghai with the German manufacturer's equipment. At Hangzhou a single 15.43m-diameter Mixshield made two passes under the Qiantang River for a 3.25km total distance at a depth of 27.6m. And at Shanghai a 14.9m Mixshield bored 3.4km at 59m below the Huangpu River.

The machines this time will have cutterhead power of 5,600kW, and nominal torque of 27,720kNm. The cutterhead will have 80 single cutting discs that are exchangeable under atmospheric pressure, and 52 scraper that are also exchangeable under atmospheric pressure. This is to deliver time and cost-saving access to the excavation chamber for maintenance work under pressurised conditions.

LINING THE LINK

The tunnel will be lined with precast segmental ring, forming an internal diameter of 13.9m, and an external diameter of 15.2m. The thickness of the segments is 650mm and they have a width of 2m. Each ring will be composed of 10 segments, comprising seven standard, two counter-key, and one key segment. The 30 static moulds were provided by CBE, which designed them in France and manufactured them in Yangling, China to reduce transportation costs.

CBE general director, Pascal Clerc added, "The complete mould design is based on the technical specifications and tolerances defined by our customer – a local precast company, as is often the case in China – and are confidential. But regarding the design and fabrication process, there really is no difference between this project and other large diameter tunnels, such as the Alaskan Way project, which we also supplied. In addition, the multi-function nature has no influence on segment or mould design. The ring is as it would be in any other 'classic' tunnel.

"However, every project is unique and we do individual pre-project studies regarding the specific design, taking into consideration dimensions, accessories and equipment such as sockets, shear cones, guiding rods etc. We pay special attention to the quantity of vibrators and their distribution at every

Above: The cross section of the multi-function tunnel, road below, rail above

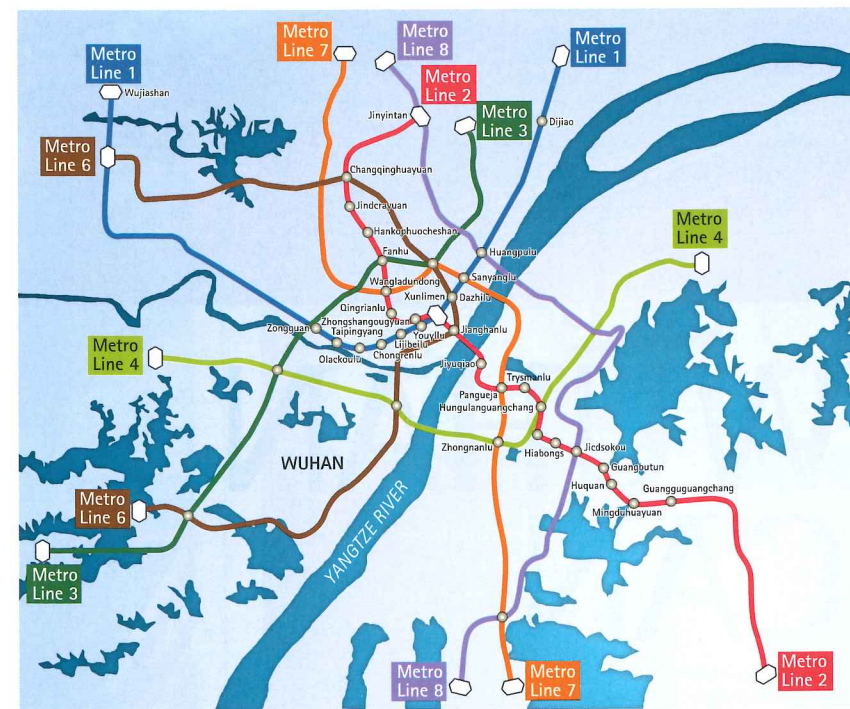
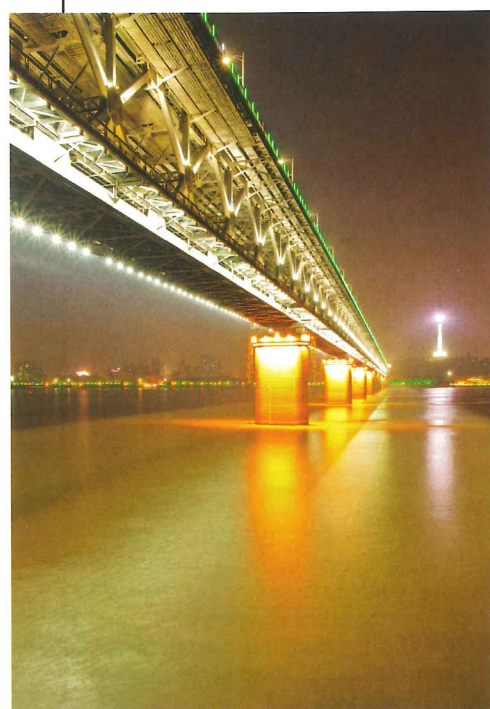
project." The local precast company uses a vacuum system to demould the 28,000 segments required by the project, which are then placed in a water basin during the later curing process. Gaskets are traditionally glued, as cast-in-place technology is not yet applied in China

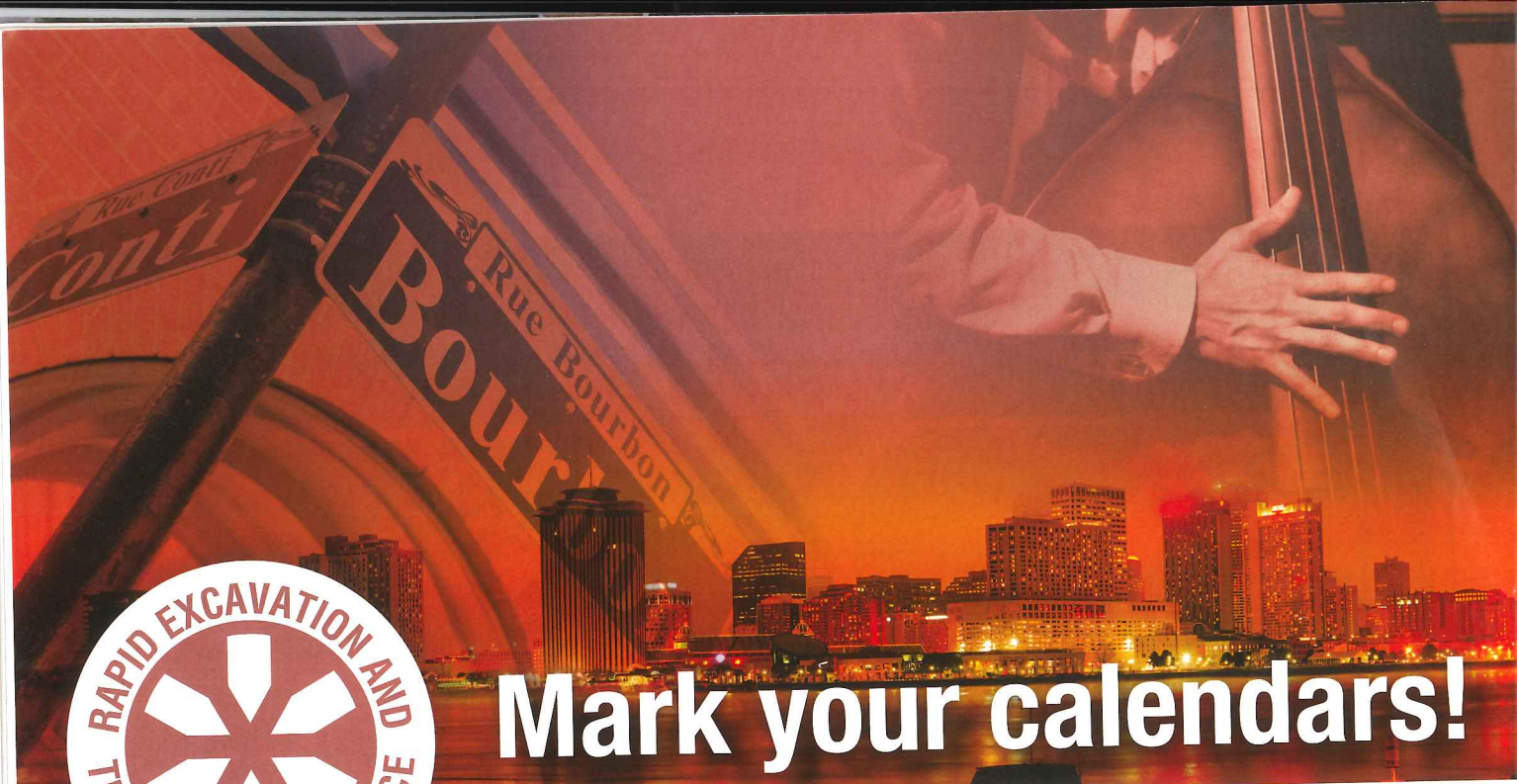
For a more in-depth look at the design of the project and the challenges facing the engineers, readers might want to get hold of a translation of the Chinese-language paper listed in the references box. The English abstract is included.

Reference

XIAO Ming-Qing, LING Han-Dong et al., *Key Techniques for the Overall Design of the Rail-and-Road Combined Yangtze River Tunnel on Sanyang Road in Wuhan*, 2014

Abstract: The Wuhan Yangtze River tunnel on Sanyang Road, the first rail-and-road combined shield tunnel in the world, has encountered some difficulties in overall design because of its extra-large diameter, high water pressure, small spacing, complicated geological conditions, and difficult construction conditions. Thus, based on the interactive factors of environmental conditions, relevant construction safety and risk, technical requirements for rail and road, and disaster prevention and rescue during operation, this paper analyses some key design techniques for the tunnel plane, longitudinal profile, cross section, and evacuation and rescue in order to reduce the risks of construction and operation. Additionally, a proper overall design scheme is proposed, providing a good reference for similar projects in the future.





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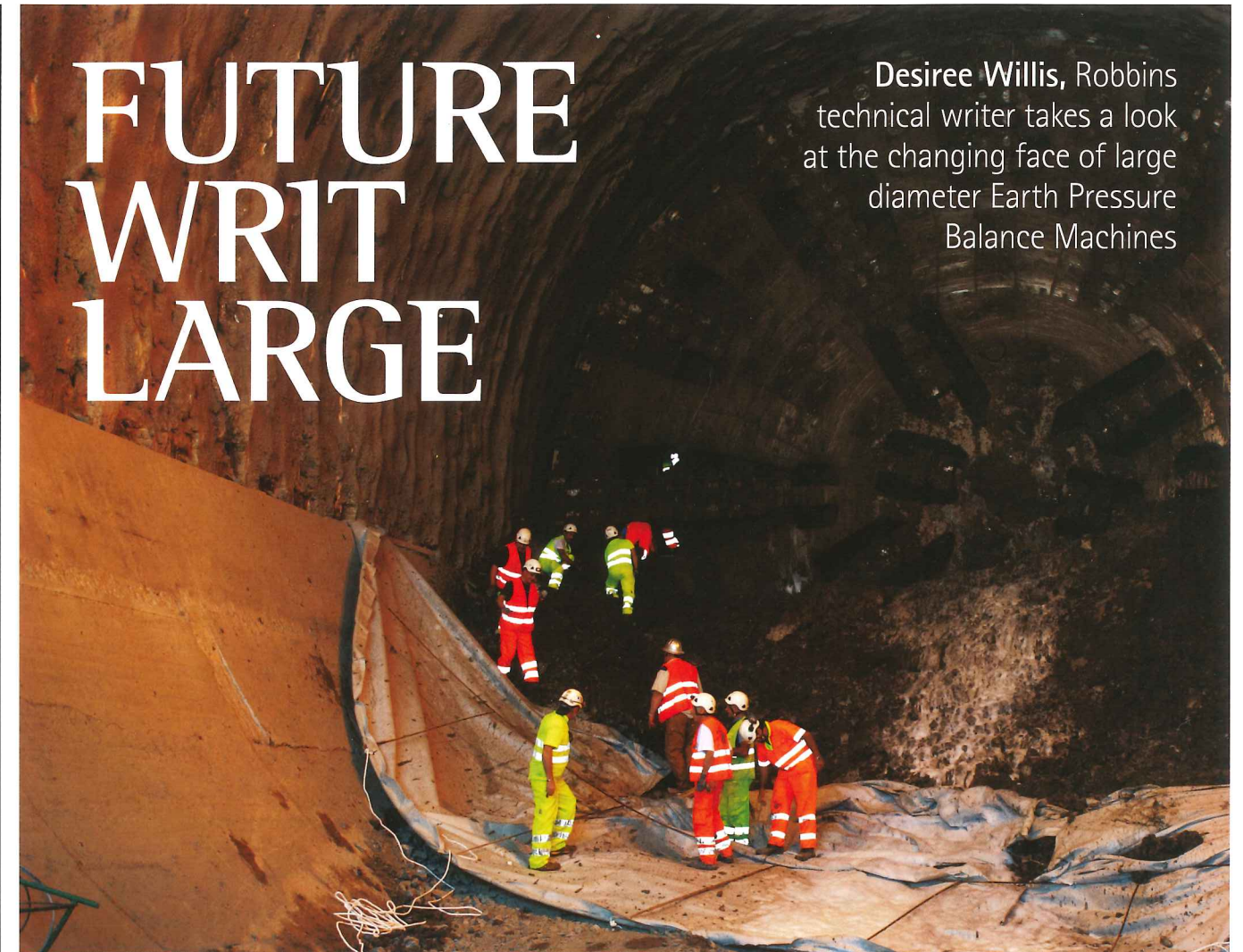
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FUTURE WRIT LARGE

Desiree Willis, Robbins technical writer takes a look at the changing face of large diameter Earth Pressure Balance Machines



SO-CALLED "MEGA MACHINES" populate today's headlines and captivate imaginations with their sheer size and complexity. Viewpoints surrounding the concepts of large diameter EPBs and their trends, together with the politics and logistics involved, can be difficult to gage. The changing face of large-scale EPB tunneling is a complex one: "What is a large diameter machine? Ideas about this are evolving. A 10m machine is a big machine, but it is no longer considered large diameter. Machines in the 12 to 14 m range are now considered large, and machines over 14 m are considered very large," said Brad Grothen, Engineering Manager for Robbins, who has worked on and designed large TBMs worldwide. It is not only industry perception that is evolving, though—new design concepts, logistical considerations, and technologies that push the limits make this one of the most exciting topics in the tunneling industry.

LARGE-SCALE TRENDS

Most in the industry would agree that we are seeing a trend towards larger diameter machines for all types of ground, from hard rock to soft ground under water pressure.

"There appears to be some competition in the industry to make machines bigger and bigger," observed Steve Skelhorn, Project Sponsor for contractor McNally Corporation, who has worked on dozens of EPBs in his career.

Consultants surveyed for the article agreed that with the current suite of projects under consideration, large diameter

Above: Break through on the Sparvo Tunnel project in Italy, the previous largest EPBM

machines (over 14m) would remain a trend. They found this particularly true for road tunnels and combination road/railway tunnels. However, the vast majority of new tunnels being proposed were predicted to remain medium sized (9 to 13m range).

"I believe acceptance of these machines as a tunneling tool is increasing, but there has to be sufficient portal area for assembly and support. In my opinion the main market for them is in highway, rail, and water projects," said Paul Zick, Project Director for Obayashi Corporation.

Shinichi Konda, Robbins' chief EPB engineer, was measuredly optimistic when considering the large diameter trend: "In Japan in particular, they are politically becoming more popular. To

Desiree Willis

Desiree has covered a range of topics for *Tunnels*, as Robbins' technical writer



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manufacture two smaller machines with two shafts is very expensive and can take up a lot of space. In this instance it is beneficial to use one larger machine with one shaft to take up less space." While EPBs over 14m have been used in Japan since the 1990s, they are gaining more traction due to the country's unique land rights regulations.

Konda made mention of a particular project known as Gaikaku, or the Tokyo Outer Ring Road Project. The tunnel can only be constructed below city streets with 16m width, as residents and businesses own land down to a 50 m depth in the country. As such, three different TBM manufacturers are currently building a total of four 16 m EPB machines for the tunnel project, which measures 16.2 km in total length.

OPEN SPACE: DESIGN CONSIDERATIONS FOR MEGA TBMS

The design possibilities that open up with large machines are, like the rest of the machine, bigger. "The larger diameter just provides more overall room—if you have a hybrid machine for example, there is more area to



Above: An EPBM undergoing factory acceptance

Opposite: Large EPBM assembly showing thrust rams

work with in terms of changing out cutting tools in the cutterhead and having multiple mucking options in place, such as both a screw conveyor and belt conveyor," said Grothen. Other advantages of the extra space include the ability to dock with the man lock using a pod, allowing for transport in emergencies and for decompression if saturation diving is needed.

For Grothen, the back-up system is another area that sees dramatic design frontiers open up at large diameters.

"There are road elements that can be brought into the design, such as precast concrete inverts for rubber-tired vehicles. Cast-in-place concrete linings can be used. There are a lot more options for parallel construction."

Other systems are simply sized up—two screw conveyors for example, and double segment erector arms to place segments at a more continuous pace. All of the extra space and technology does require extra crew, more logistical planning, and more action plans in place should equipment malfunction. "Many of the added features are really about risk mitigation. The risk of operating a large machine increases as the area of the excavation face increases," said Grothen.

CHANGING CUTTERS

For most consultants surveyed, a distinct advantage of large diameter EPB design is the ability to enter the cutterhead spokes in order to change cutting tools at atmospheric pressure. Some cutter change systems allow for continuous flow through of the muck, but these types of cutterheads are often deep in their design, and the passage canals for cutting tools face the risk of becoming blocked by excavated material.

Another type of system, touted by Robbins as the RACCS (Robbins Atmospheric Cutter Change System), offers a solution to the problem of clogging. The flow-through design is currently in development, and requires cutterhead spokes that are completely sealed off inside and large enough for a worker to crawl inside. Disc cutters are mounted on moving sled structures that are separated from the inner and outer cutterhead structure using two gates. Gates can be lifted to move the cutter forward or retract the cutter backward. While boring, the cutter is in an advanced position with both gates up. When a crew member wants to change a cutter at atmospheric pressure, the front gate is closed and the cutter is retracted into the chamber. The design is unique in its use of two gates. "We want to eliminate or prevent the chance of cutter structures clogging in tough ground conditions. Our design has an open back behind each cutter that allows muck to continually flow through it," said Grothen. Engineers are currently building a large test fixture for this system, which will analyze how RACCS reacts in sand, gravel, boulders, clay, and mud conditions under pressure.

LIMITATIONS ON LARGE DIAMETER MACHINES

Along with all of the design possibilities on larger machines come some limitations. In some cases these challenges can be mitigated with extra monitoring and equipment, and in other cases they are simply a function of the large-scale excavation taking place. "You can go bigger, but at some point you do start to run into logistical problems, such as bigger, heavier pieces, gaining access to the site, larger cranes, and just finding the precision tools that can make very large parts," said Grothen. He added that the operation of the machine itself was not necessarily affected by the large diameter, and that slurry machines were even less subject to size limits. "In slurry machines, power requirements are not as great, the thrust required is not as much, and the machine is lighter overall. These machines could definitely go bigger."

The larger parts can cause another potential issue, though not with the technology: "Cost is certainly a factor. When you have a very large diameter main bearing, you must split the bearing during the manufacturing process. This can wind up being much more costly than a standard main bearing. You are also limited by the number of suppliers that can manufacture such a large item," said Konda.

Another limitation is the pressure differential as size





Both: TBM assembly and operations in confined space

increases—the earth pressure at the bottom of the cutterhead will be different from the pressure at the top. While the differential in itself is not problematic, and can't really be helped, there are issues with maintaining material flow through the chamber at very large sizes. The challenge, according to the consultants interviewed, is to eliminate “dead” zones where material comes to halt, which reduce the space available for flowing materials and increase wear inside the excavation chamber and cutterhead. Such additional mechanical measures like independent and actively driven mixing devices may be required. To further ensure good muck flow, the consistency of the conditioned material has to be closely monitored and controlled. This requires additional monitoring as well, such as temperature and density monitoring in several sections of the excavation chamber.

Other factors also come into play with a large cutterhead, which may require additional monitoring: “With a very large TBM there exists a very large pressure drop from top to bottom of the face, which in turn will have an impact on the bearing sealing systems. Grease and oil injection to the seals presents challenges due to these large differential pressures and intervention work,” said Skelhorn.

Maintaining good control of foam additive at the face can also be difficult, as the geology often differs across a large excavation face. “A foam system is a good solution for ground conditioning, however the quality of the foam depends on the pressure,” said Konda. “If an operator bases the concentration of the foam on the pressure at the center of the cutterhead, then there will be too much foam at the top and too

little foam at the bottom.” Solving the problem requires an awareness of the pressure differences and can be helped by independent foam lines.

NEW WAVE OF TECHNOLOGY

Despite increased need for monitoring, the future of large diameter EPBs is a bright one.

“Designers are realizing that if you increase the diameter of a tunnel by just a small amount, the cross sectional area can multiply to become quite significant. This is particularly attractive for road tunnels. A large diameter machine in this case can be a good solution,” said Grothen. The machines also offer a quicker construction solution compared with building two tunnels at smaller diameter. “The speed of excavation and ability to control the quality of the finished product with parallel construction are definite benefits,” said Zick.

The technology involved in large diameter EPBs is ever evolving. Japan is again an innovator of new concepts that could help to usher in a robust era of large diameter excavation. Konda mentions new designs being tested out in Japan, which include bolt-less segments that have no bolt pockets on the I.D. of the segment and require no secondary lining—a technology that could potentially make the construction of very large diameter tunnels much quicker.

Also of particular importance in Japan are non-circular machines. In a country where all muck must be sent to a plant to be treated regardless of the type of ground or additive used, eliminating extra muck removal is a plus. In traffic tunnels, which are ultimately rectangular in shape, a method known as the Multi-Micro Shield Tunnel (MMST) has been developed. The method involves excavation by numerous small rectangular shield machines, with adjacent sections being linked together by reinforcing bars. The excavated ground is then filled up with concrete to form the outline of a large rectangular tunnel. Afterwards, the soil within the internal section is excavated. The net result is a large tunnel of rectangular or square shape with no extra muck required for removal.

Whether or not non-circular machines make their way outside of Japan remains to be seen. One thing about the future of large diameter EPBs is for sure, however: They will remain a fixture in the tunneling industry, and an option for large scale projects worldwide. For Zick, and for many in the industry, the trend is a positive one: “I think the future is very promising. In the U.S. alone, there are several very large diameter projects in the planning and design phases. The industry benefits from having large diameter machines available as an option”



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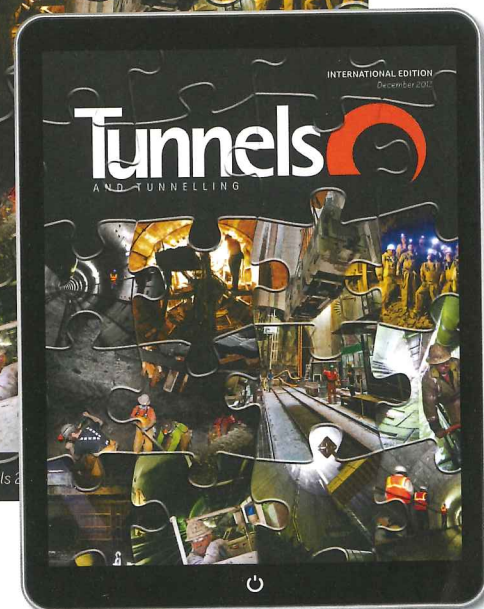
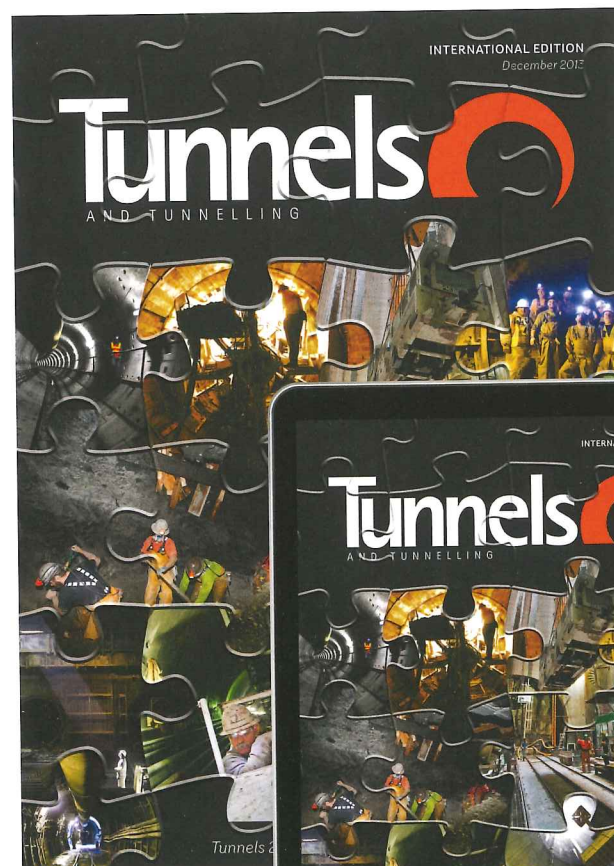
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PREDICTING SETTLEMENTS FROM CONVENTIONAL TUNNELLING

The Üsküdar – Ümraniye – Çekmeköy (UUC) project in Istanbul, Turkey is an extension to the metro on the Asian side of the city, running 17km underneath a dense urban area. Some 8km of tunnels needed to be excavated through weak to medium strong sedimentary rock using conventional methods. In this article based on a paper presented at WTC Brazil, Sara Bech Padrosa and Nicola Della Valle of Tunnelconsult share some of the lessons learned from the settlement prediction methods employed

THE PREDICTION of settlements induced by conventional tunnel excavation on the Üsküdar – Ümraniye – Çekmeköy (UUC) metro project in Istanbul was a great challenge from the start of works.

In any urban tunnelling process, surface settlement estimation becomes a crucial part of the project for assessing the risk of damage to the existing buildings and proposing, whether it is required, specific ground treatments or protective measures to avoid or minimise them, as well application of proper excavation methods.

Due to the number of buildings along the UUC alignment, a systematic and practical approach to estimate the ground

movements induced by conventional tunneling in weak rock was adopted.

PROJECT DESCRIPTION

The UUC metro line is an underground link running beneath a very dense urban area at the Asian side of Istanbul beginning at Üsküdar Station, which connects to the recently opened Marmaray submerged railway link, and ends at Çekmeköy Station. The line is approximately 17km long, and includes the construction of running twin tunnels, cross passages every 250m, several crossovers along the alignment and 16 underground stations.

The twin running tunnels are excavated with two EPBMs in some stretches and with conventional methods used for crossovers. A mixture of mining and cut and cover methods are used for the construction of the 16 stations, cross passages and crossovers are excavated with conventional methods as well, the latter with large tunnel sections with an excavation area of approximately 120m².

The overburden along the alignment ranges between 20 to 40m, with minimum at the beginning of the line, at Üsküdar station, with 13m, and maximum of 80m, where the tunnels underpass a hill relief, whose peak reaches the +189.0 elevation.

Geology

The prevalent geology along the UUC line is formed by weak to medium strong sedimentary rocks belonging to the Paleozoic and Cenozoic era

Below: Figure 1, Platform tunnel section geometry

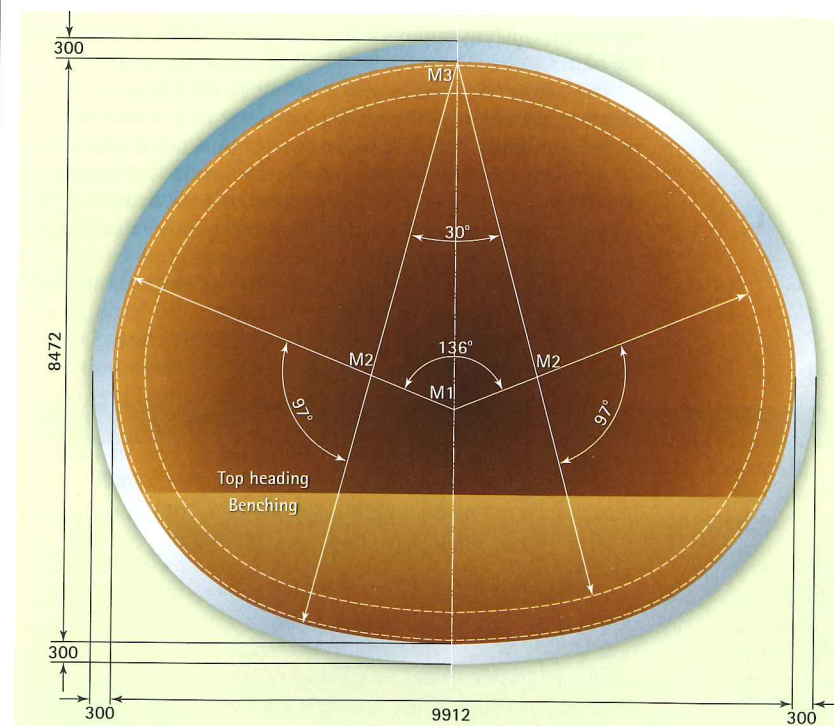


Table 1. Main mining sections in UUC project

Section	Excavation area [m ²]
Platform section (P1)	75.6
Main running section (A)	36.8
Crossover section (T2)	119.6
Inter platform section (B12)	50.1
Equipments section (P2)	81.6

Source: Authors

(i.e. limestone, claystone, sandstone). At specific areas the excavation is performed within weathered terms, at fault zones or in sandy-clayey alluvial quaternary deposits.

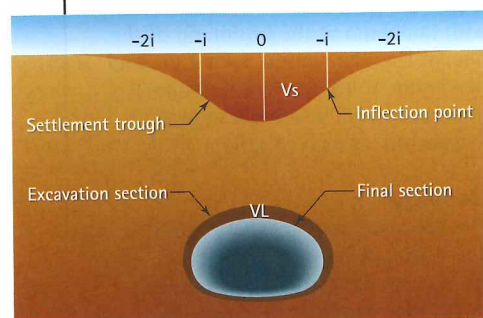
Along the initial sector of the alignment the tunnels are excavated through claystone-sandstone formations (3.5km). A second stretch is basically formed by limestone and conglomerate (4km) and then by intercalation of mudstone-claystone and Arkosic sandstone (5.7km). In the last kilometers, the tunnels are excavated within sandy-clayey soil and limestone (3.7km). Along the alignment several faults are being intercepted as were identified in the geotechnical campaign.

The rock mass quality, defined in the GBR, varies basically from poor to good rock mass, with RMR from 30 to 70, although lower values are expected at the faults zones.

In terms of hydrogeology, the investigations indicated that the encountered geological formations show low to very low permeability (from 10⁻⁶ to 10⁻⁸m/s). Despite that, it is noticeable that the lithologies are also characterised by secondary permeability because of the high rate of weathering and fracturing, and low water inflows are actually occurring (recorded water inflows < 5 l/s through tunnel face).

Sections types

Eleven different mining sections were designed for the UUC project for running, platform and crossovers tunnels. The geometry of the mining sections was defined with an optimal polycentric section in regards of the



Left: Figure 2, Gaussian curve for the settlement trough and ground loss definition

required tunnel clearance (see Figure 1).

The main tunnels sections along the alignment are the platform tunnels excavated at the stations (75.6m² excavation area), the running tunnels excavated for the main line (36.8m²) and the crossover tunnels which are enlarged sections (119.6m²).

Five classes of support were designed for each section type according to the geomechanical conditions in terms of RMR. On site, depending on the encountered rock mass condition the adequate support type is installed. The difference between the classes of support remains on the shotcrete thickness, lattice girder dimension and spacing, number and length of crown bolts and spilling or pipe umbrella installation.

Final lining

A cast in situ lining is always applied at mining sections after the installation of a waterproofing system consisting in a geotextile and a PVC membrane. The thickness of the final lining was determined according to the section area. Three types of final lining reinforcement were designed according to the rock mass quality.

SETTLEMENTS PREDICTION

The tunnels of the UUC are excavated underneath a very populated area of the Üsküdar municipality, at the Asian side of Istanbul. More than 3000 buildings were surveyed before commencing the works, located within 50m at both sides of tunnel axis. Actually, the tunnelling influence zone was defined in the UUC Technical Specifications as the zone where the settlements are expected to be greater than 10mm. After the first prediction of the tunnelling settlements, the maximum influence zone width was 80m, which is lower than the 100m of the initial surveyed area.

The prediction of induced movements is a very crucial process of the project since it enables the identification of the stretches where the maximum settlements are expected, and consequently analyse the possible damage to the existing buildings and structures.

Due to the extension of the project, the variability of tunnels size, and the different geotechnical conditions, a systematic analysis approach was conceived at the beginning of the works to habilitate the settlements prediction task.

The procedure consists of the definition of a formula and the estimation of the input parameters to compute the settlement basin. The adopted expression for the calculation of vertical ground movement was the semi empirical normal distribution curve, and its input parameters were defined according to the available geometrical and geotechnical information, general references and complementary computations (e.g. the convergence-confinement method).

Peck curve adoption

The semi empirical method to estimate the surface settlements in the UUC project was based on the Peck approach that assumes a Gaussian curve for vertical ground movements in soft ground. This method for calculating transversal settlements was firstly described by Peck in 1969, who proposed that the shape of the settlement trough could be well represented by a normal distribution curve. Later on, a Gaussian model was developed considering that the ground loss could be represented by a radial flow of material to the tunnel and the trough could be related to the ground conditions through an empirical width parameter (BTS/ICE, 2004). Therefore, several semi empirical equations were developed based on soil excavation case studies giving a suitable procedure of the surface settlements behavior.

The vertical settlement formula adopted in the UUC project

is a Gauss distribution in accordance to the equation (1):

$$(1) \quad s(x) = s_{max} e^{-\frac{x^2}{2i^2}}$$

S(x) is the settlement at x distance from the tunnel axis; Smax is the maximum settlement at tunnel axis, expressed as:

$$(2) \quad s_{max} = \frac{V_s}{\sqrt{2\pi}i}$$

Vs is the volume of the settlement trough per unit length of tunnel and VL is the ground loss, which is the volume of soil excavated in excess of the theoretical volume of the tunnel (see Figure 2). These two volumes are considered equal for shallow tunnels in cohesive and incompressible ground formations, as in the UUC project (ITA/AITES, 2006).

i is the distance of the inflexion point to the tunnel axis. It can be calculated as i = ZOK. With ZO being the depth of the tunnel axis and K the trough width parameter.

The use of semi empirical methods, such as the Gaussian curve, based on soil settlements was considered applicable in this project although the tunnels were excavated through weak to medium strong rock. Nevertheless, in the 'Back Analysis' part of this paper, the applicability of the Gaussian curve in the UUC weak rock is validated.

Trough width K parameter

The empirical K parameter describes the settlement basin width and depends on the geotechnical characteristics of the ground, the tunnel depth and, in some cases, excavation method.

Following the research from O'Reilly and New (Aoyagi, 1995) the K parameter can be estimated depending on the tunnel depth (ZO) and the cohesion of the soil as:

$$(3) \text{ for non cohesive soils } k = 0.28 - \frac{1.2}{Z_0}$$

$$(4) \text{ for cohesive soils } k = 0.43 + \frac{1.1}{Z_0}$$

Similarly, other studies reveal that the K parameter varies from 0.2 to 0.3 in granular soils and from 0.4 to 0.5 in stiff clayey soils and even reach 0.7 for very soft silty clays (Burland, 2008).

Taking into account the rocky nature and frictional behavior of the excavated geological formations along the UUC tunnels, the adopted K parameter was calculated from the tunnel depth using equation (4), which corresponds to the cohesive soils formula. Taking into account the minimum and maximum overburden of the UUC alignment, 13m and 80m respectively, the estimated K parameter varies from 0.495 to 0.443.

Volume loss estimation

The cause of the settlement is the volume loss generated due to excavation, which mainly depends on the geological formations and their stress state, excavation rates, tunnel size

Table 3. Stations geotechnical characteristics

Station	Geology	Expected RMR range	Recorded average RMR*
Bulgurlu	Limestone, andesite	60-80	75
Ümraniye	Claystone-mudstone	40-60	51
Çarşı	Limestone, andesite	20-40	30
Kısıklı	Andesite, Fault	<20	12

Source: Authors

*Average value recorded in the construction site

Table 2. Rock mass parameters at Ümraniye station

Parameters	Favourable scenario	Unfavourable scenario
RMR class	III	IV
Angle of friction [°]	50.0	41.2
Rock mass strength [MPa]	3.16	1.63
Deformation modulus [MPa]	950	195
Poisson ratio [-]	0.31	0.31
Unit weight [kN/m ³]	27.2	27.2

Source: Authors

and installed support type. Hence, the adopted conventional construction methods were designed to minimise the volume loss during excavation.

The volume loss, VL is commonly defined as the percentage of the volume of ground excavated in excess to the theoretical tunnel volume divided by the theoretical tunnel volume, as per equation (5):

$$(5) \quad V_L(\%) = \frac{V_L}{V_{tunnel}}$$

In the UUC project the expected volume loss for the settlement curves computation was systematically and quickly estimated with the convergence-confinement method. The result of the convergence-confinement method is the radial tunnel deformation which easily allows the computation of the volume loss.

The convergence-confinement method, also known as the stress-deformation curve, considers the weak rock mass deformability and strength and the installed support capacity and characteristics (AFTES, 2002). An equivalent radius was considered for the mining sections according to their excavation areas.

For each geological stretch of the alignment, two sets of parameters were identified corresponding to the maximum and minimum expected RMR. Thus, two stress-deformation curves could be computed to obtain the tunnel deformation in a favourable and unfavourable scenario at each section. Consequently, the settlement curve could be defined under favourable and unfavourable conditions, expecting the actual ground movements to fall into these two scenarios.

Settlements curve

In order to describe the applied method for settlement prediction on the UUC project, the computation of the settlement curve at chainage 7+640

is presented, with the corresponding parameters assumptions and estimations. The section at chainage 7+640 corresponds to two platform tunnels with an equivalent radius of 4.91m each located at Ümraniye station. The average overburden is 22m, identified in the available alignment profile.

Two platform sections with axial distance of 29.1m are excavated and the corresponding settlement curves are summed up. Moreover, from the authors' experience, twin tunnel reciprocal interference is to be considered in the calculations where the distance between tunnel axes is less than three diameters. Hence, an increase of 10 per cent to the second tunnel volume loss is considered due to the previous ground relaxation induced by the first tunnel, resulting in an asymmetrical settlement trough.

The adopted K parameter is in this section 0.471, considering equation (4), for 27m of tunnel depth.

The stress-relaxation curve is computed for the geotechnical parameters indicated in the GBR for claystone-mudstone rock mass present at Ümraniye station. The relevant geotechnical properties are summarised in Table 2.

The result of the stress-deformation curves is a radial displacement of 6.4mm and 17.5mm in the favourable and unfavourable scenarios respectively, which brings equivalent volume losses of 0.18 per cent and 0.68 per cent. Therefore, two different settlements curves can be computed for each rock class, as shown in Figure 3.

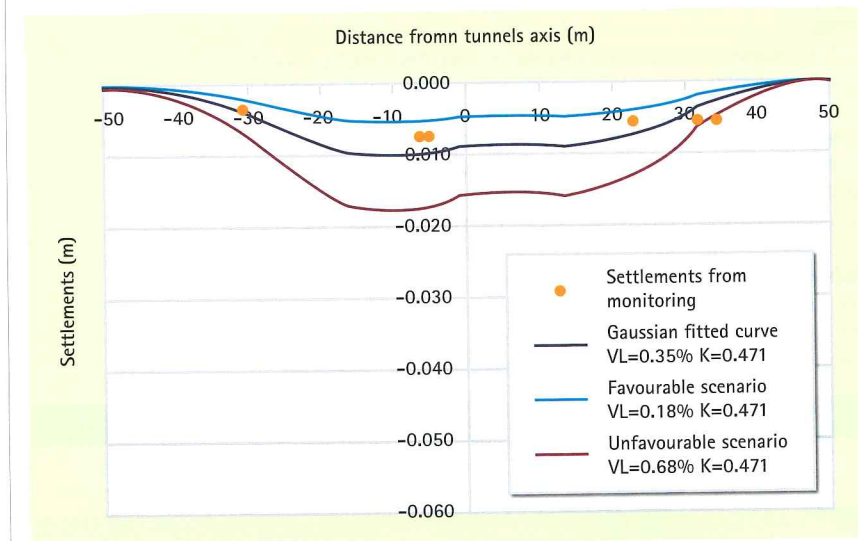
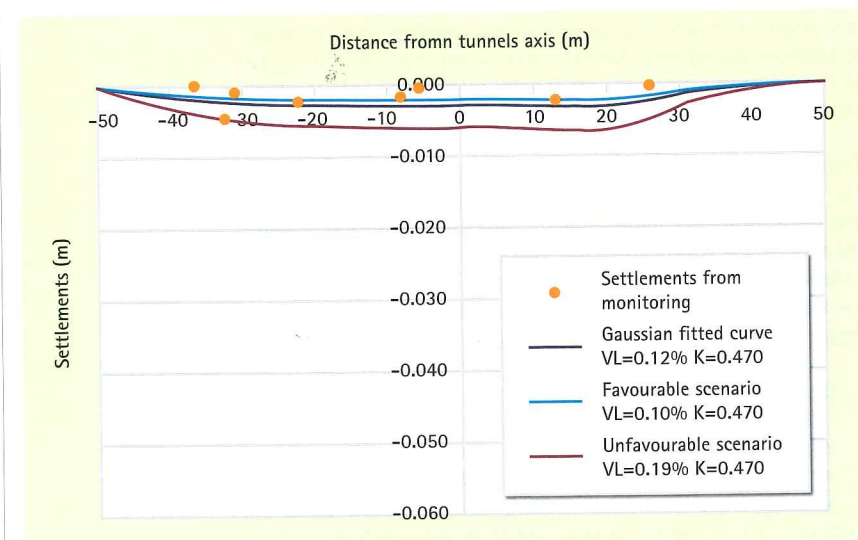
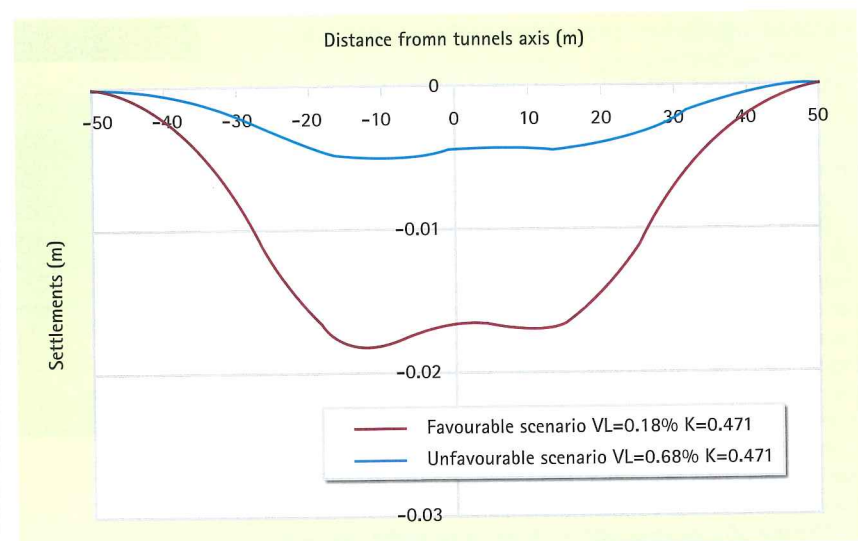
The process of volume loss estimation is repeated for every homogeneous stretch of the tunnel with similar geometric and geological conditions, enabling the systematic computation of the settlement curve.

BACK ANALYSIS

Back analysis is performed on the settlements analysis prediction to refine the K and volume loss parameters and verify the applicability of the Gaussian curve for the overall conditions of UUC project. The back analysis is based on the available monitoring data from the installed transversal section leveling pins along the alignment.

The computed back analysis at four settlement stations with varying geological conditions is presented from here on. The selected stations, together with their geology and actual RMR values are summarised in Table 3.

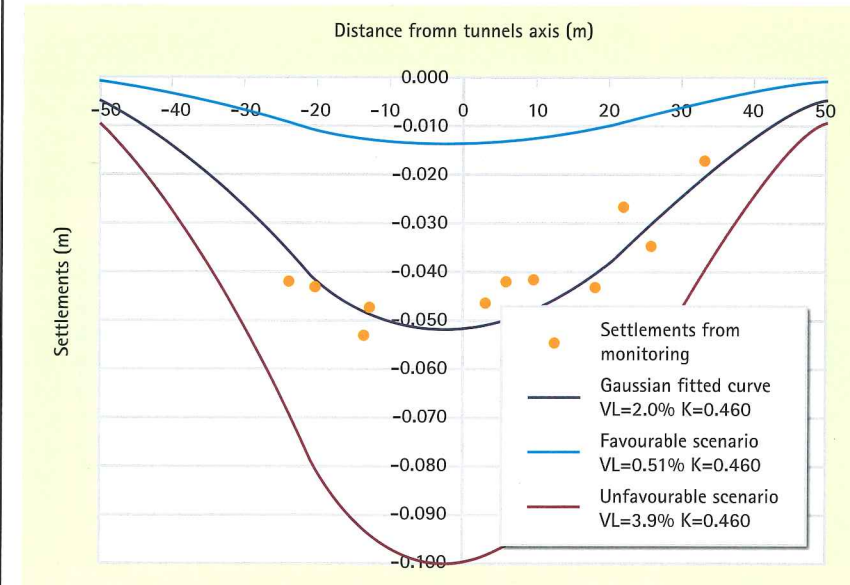
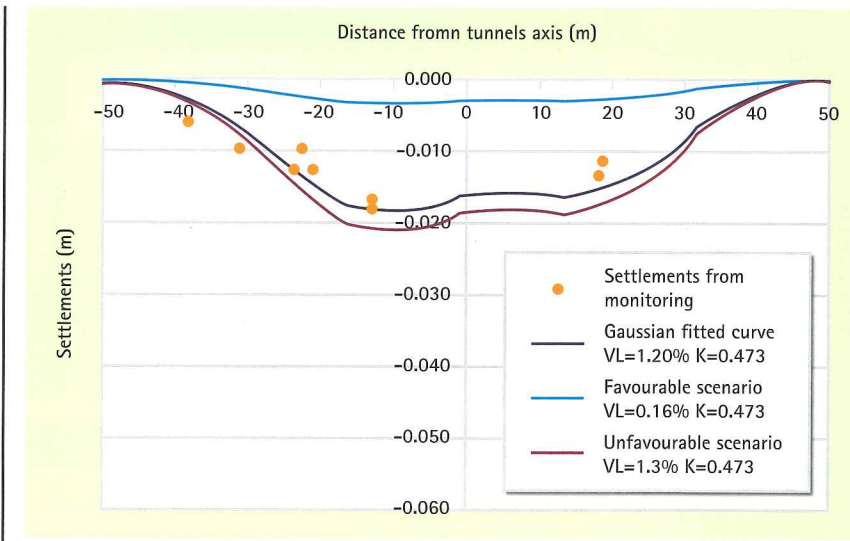
The computed back analysis at four settlement stations with varying geological conditions is presented from



Above: Figure 5, Levelling pins data and Gaussian curve for 40<RMR<60 (Ümraniye)

here on.

The platforms are excavated as two tunnel sections (75.6m² of excavation area) and separated 29.1m. The average tunnel depth along each station has been also considered in the analysis (specifically: 27.7m at Bulgurlu station, 25.6m at Çarsi station, 37.1m at Kisikli station and 26.9m at Ümraniye



station). The K parameter has been estimated with the cohesive ground formula (4).

The expected settlement basins computed with the volume losses for the favourable and unfavourable scenarios are plotted together with the recorded ground movements. A Gaussian curve has been fitted to the actual ground movements, which has been compared in shape and depth to the previous estimated settlement troughs (see Figures 4 to 7).

Analysis of the back analysis results

The first conclusion of the back analysis is that the measured ground movements for the four stations follow a settlement shape consistent with a Gaussian distribution. It is noticed that for lower RMR values (worse rock mass condition) this is even more evident, as in Figure 7, where the registered ground movements follow quite precisely a Gaussian curve.

On the other hand, according to the results of the back analysis, the K width parameters calibrated from the monitoring data fitted curve is equivalent to the K parameter estimated with the cohesive soils formula as per equation (4). Hence, the approximation on the K parameter calibration with the cohesive soil expression can be considered fairly successful.

Regarding the calibrated Gauss curve for the four stations, the estimated volume loss using the convergence confinement

method gives matching results because the back computed volume loss falls, for all the cases, between the expected limits of the favorable and unfavourable scenario.

At Çarsi station (Figure 6) the excavated volume loss is close to the unfavourable scenario. This might have an explanation, since this station was the first one to be excavated and a learning period could partly be responsible for it.

The calibrated volume loss from the four analysed stations has been plotted together with the recorded RMR values on site from Table 2. From the Figure 8 it can be inferred that the volume loss decreases approximately linearly while the RMR values increase. It is noted that this assumption of linearity is only based on four stations and that further sections should be studied to verify the lineal equation. However, as an estimation method, it can be used for the prediction of the volume loss depending on the RMR values when platform sections are excavated. It could be also interesting to perform the same back analysis with a large tunnel size, for which excavation is not yet completed.

FEM analysis verification

During the systematic prediction approach, for crossover sections (excavation area larger than 100m²) the expected settlements computed using semi empirical methods were verified with 2D FEM analysis.

The tunnel excavation FEM analysis with Plaxis 2D v8 enables the simulation of actual geotechnical conditions, the section geometry, and reproduces the excavation method with the designed tunnel support system.

The results of the analysis carried out simulating the excavation of two crossover sections under fair to poor rock conditions (30<RMR<50) are presented from here on.

The model considers the construction of two crossover sections separated 24.2m, which are excavated in multiple drifts at the top heading and then the benching. The model takes into account the corresponding tunnel support, and the crown and lateral rock bolts installation.

The vertical displacements computed in the FEM analysis can be then compared with the predicted semi empirical settlements and the surface settlements registered from the monitoring. In Figure 9 the vertical displacements basin from the FEM analysis is plotted together with the curve fitted to the monitoring data

Above: Figure 7, Levelling pins data and Gauss curve for RMR<20 (Kisikli Station)

Above, top: Figure 6, Levelling pins data and Gaussian curve for 20<RMR<40 (Çarsi Station)

Top left: Figure 3, Predicted settlement trough at Ümraniye

Middle left: Figure 4, Levelling pins data and calibrated Gaussian curve for 60<RMR<80 at Ümraniye

and the curves from the semi empirical analysis under the favourable and the unfavourable scenario.

The predicted volume loss using the convergence-confinement method and the Peck formula is 0.10 per cent and 0.47 per cent for the favourable and unfavourable scenarios. The K parameter has been calculated with equation (4) for cohesive ground giving a value of 0.468. A Gaussian curve is fitted to the monitoring data with a volume loss of 0.19 per cent and a K=0.468. Thus, the prediction of the settlements induced by the crossover mining sections with semi empirical methods is considered applicable for large sections too.

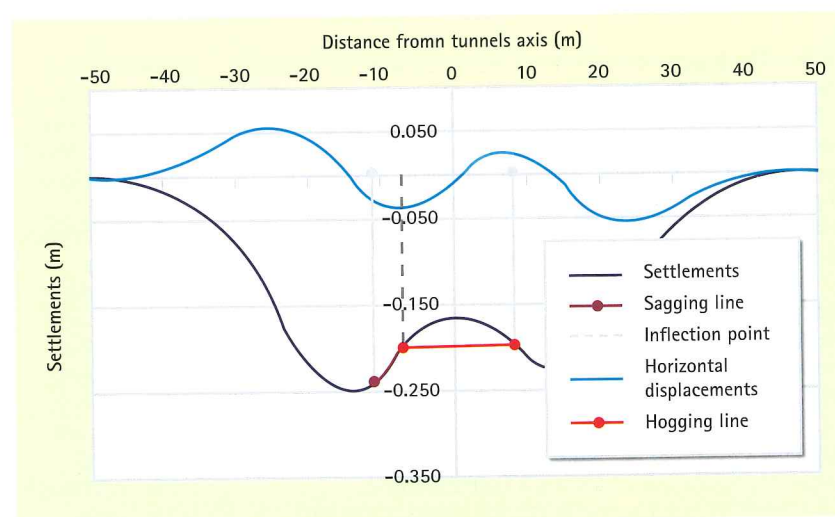
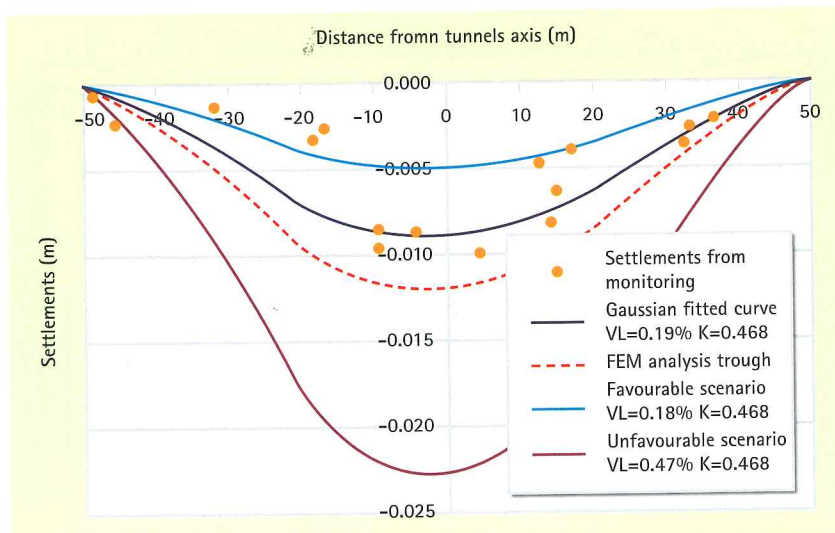
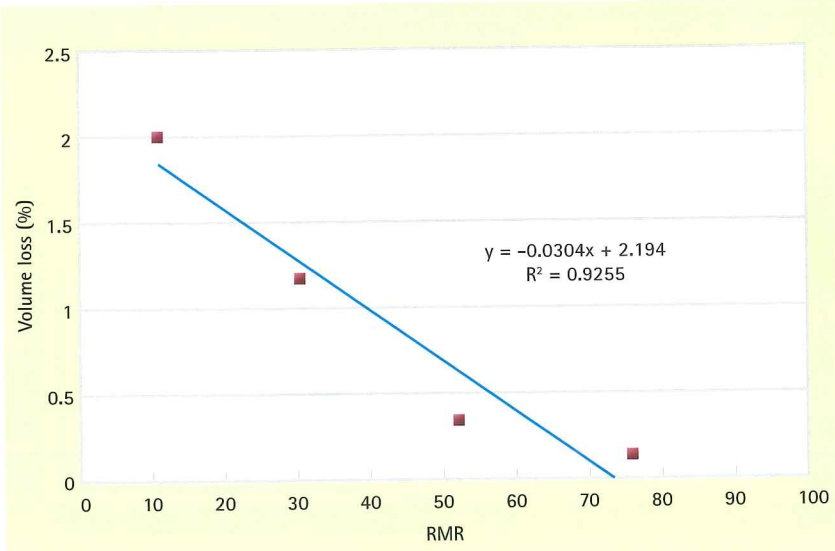
The FEM analysis confirms the normal distribution of the vertical movements for large mining sections under fair to poor rock conditions. The FEM analysis curve is slightly wider, which means a higher related K value. Thus, to sum up the back analysis and the FEM analysis reveals the good approximation of the settlements predictions with a Gaussian curve in weak to medium rock.

BUILDING DAMAGE ASSESSMENT

The systematic settlements prediction approach is completed in the UUC project with a building risk assessment that analyses the impact of the predicted settlements to the existing buildings and structures.

Basically, three types of damages can occur to buildings, which are defined as: aesthetics, functional or stability. According to these types of damage and its ease of repair, six categories of damages are defined in order to classify the buildings into them. The adopted building risk assessment follows the three stage assessment recommended by Mair (1996). The stage one assessment is based on the predicted settlements curve and the corresponding angular distortion. The computed surface settlements are plotted along the alignment in a plan drawing including the buildings location as in Figure 10. Hence, the predicted settlements for each building are identified.

The stage two assessment is carried out for all the buildings that are in the slight to very severe category of damage in the previous stage one according to the admissible limits from Table 4. The stage two analysis is based on the calculated maximum tensile strain. The methodology to compute the tensile strain in the buildings follows the commonly implemented equivalent beam analysis (ITA/AITES, 2006) and follows the expression of Burland (Burland et



Above: Figure 11, Building S-176 stage 2 assessment

al., 2004). This model represents the building by means of a simple rectangular beam, undergoing sagging and hogging modes of deformation. This approach easily gives an idea for the mechanisms of cracking and enables the calculation of the critical tensile strain, which is the maximum between the tensile strain due to bending (ϵ_b) and the tensile strain due to

Table 4. Admissible settlements in the stage 1 assessment

Category of damage	Maximum settlement (mm)	Maximum angular distortion
0 - 1 Negligible to very slight	<10 mm	< 1/500
2 Slight	10 - 50 mm	1/200 - 1/500
3 Moderate	50 - 75 mm	1/50 - 1/200
4 Severe	> 75 mm	1/50 - 1/200
5 Very severe	> 75 mm	> 1/50

Source: Authors

Table 5. Admissible settlements in the stage 2 assessment

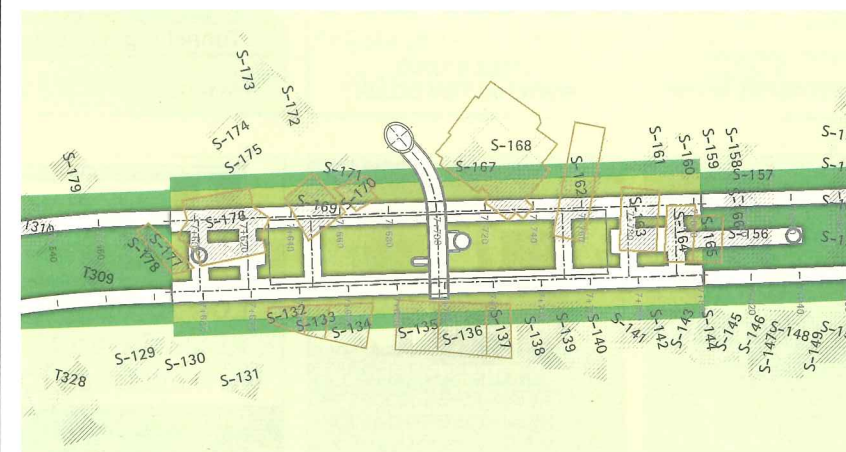
Category of damage	Maximum tensile strain (%)
0 Negligible	< 0.05
1 Very slight	0.05 - 0.075
2 Slight	0.075 - 0.15
3 Moderate	0.15 - 0.30
4 - 5 Severe to very severe	> 0.30

Source: Authors

shear (ϵ_d). Figure 11 exemplifies the second stage assessment of the building with reference number S-176 identified with settlements greater than 10mm in Figure 10. The maximum computed tensile strain in hogging is 0.055 (very slight damage) and in sagging is 0.032 (negligible damage) according to the admissible limits of Table 5. The stage three assessment is expected to range from moderate to very severe in stage two. The use of FEM analysis is considered to simulate the effects of tunnelling to the existing buildings. The accuracy of the calculations gives more precise and reliable settlement and strain predictions. If the results of stage three assessment indicates that the category of damage for the buildings is moderate or higher, protective measures need to be considered.

CONCLUSION

The defined systematic approach evaluating ground movements has given successful results in the settlement prediction of excavation on UUC. The estimated settlement trough using the semi empirical method has been compared with ground movements from the installed leveling pins, with



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Opposite top: Fig 8, Correlation on site RMR-calibrated volume loss for platform sections

Opposite, middle: Fig 9, Crossover sections settlement prediction and monitoring data

Below: Fig 10, Settlement and existing buildings plan

a back analysis showing fine similarities in shape, width and maximum settlement basin. Hence, although the semi empirical Gaussian theory was conceived for settlement estimation in a continuous and homogeneous soil, its application in weak rock excavation proved to be successful, as in UUC project, with a significant gain in prediction speed and accuracy.

Regarding the systematic approach described in this article, the attempt to narrow down the volume loss with the convergence-confinement method under the favourable and unfavourable geotechnical scenario gives well approximated thresholds since the actual volume loss falls for all the studied sections within these limits. Moreover, the calibrated volume loss from the monitoring data has shown a linear relation with the recorded RMR. Thus, a linear relation from the RMR and the excavated volume loss under the same section geometry has been found out. This regression can be then used in the systematic approach for the volume loss estimation in other stretches with the same tunnel section according to the expected rock mass conditions.

Finally, the empirical K parameter formula for cohesive soils has been verified and resulted applicable for the weak rock classes encountered along the 17km of the UUC project

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What's on

2015

ICETUS 2015

3-5 March 2015
 Subang Jaya, Malaysia
 Following the successful International Tunnelling and Trenchless Technology Conferences held in Malaysia in 2006 and 2011, the Tunnelling and Underground Space Technical Division of The Institution of Engineers, Malaysia, is holding its third conference to coincide with KVMRT developments.
www.icetus2015.iemtc.com

ISRM Congress 2015

10-13 May 2015
 Montreal, Canada
 Held in conjunction with the CIM Convention for 2015, the International Symposium on Rock Mechanics is an international conference every four years.
www.ISRM2015.com

World Tunnel Congress 2015

22-28 May 2015
 Dubrovnik, Croatia
 WTC 2015 heads to the Dalmatian Coast as the event returns to Europe. Further details to be confirmed.
www.wtc15.com

RETC

7-10 June 2015
 New Orleans, Louisiana
 The Underground Construction Association's biennial conference.
www.smenet.org

49th US Rock Mechanics / Geomechanics Symposium

28 June-1 July 2015
 San Francisco, California
 The 2015 program will focus on new and exciting advances in rock mechanics and geomechanics and encompasses all aspects of rock mechanics, rock engineering, and geomechanics.
www.armsymposium.org/

Eurock 2015 & 64th Geomechanics Colloquium

7-10 October 2015
 Salzburg, Austria
 The ISRM Regional Symposium EUROCK 2015 Future Development of Rock Mechanics, is to be held in conjunction with the 64th Geomechanics Colloquium
www.eurock2015.com

25th World Road Congress

2-6 November 2015
 Seoul, South Korea
 The World Road Congress has been held every four years for more than 100 years. Since the first meeting in Paris in 1908, it has toured the member countries of the non-government organization, Permanent International Association of Road Congresses (PIARC).
www.aipcrseoul2015.org

Post-2015 Framework for disaster risk reduction

14-18 March 2015
 Sendai, Japan
 UNISDR is facilitating the process of developing a post-2015 framework for disaster risk reduction. This process will culminate at the 3rd United Nations World Conference on DRR
unisdr.org/we/coordinate/hfa-post2015

Stuva Conference

1-3 December 2015
 Dortmund, Germany
 Held every two years, this conference sees 1,500 participants and visitors from about 20 countries. It is numbered among the world's leading get-togethers for underground construction experts. In 2015 the chosen venue for this premier event is Dortmund.
www.stuva-conference.com

2016

World Tunnel Congress 2016

22-28 April 2016
 San Francisco, USA
 WTC 2016 heads to the Golden State as the event heads to North America. Further details are to be confirmed.
www.wtc2016.us

Underground Construction Prague 2016

23-25 May 2016
 Prague, Czech Republic
 Past conferences confirmed that the Prague conference, thanks to its scientific programme, venue and social programme found a firm position among similar European conferences. The 2016 event will also be enhanced by the Third Eastern European Tunnelling Conference (EETC 2016).
www.ucprague.com

British Tunnelling Society

The BTS has a membership of almost 700 individual and 60 corporate members. It is one of the most vibrant gatherings of professional tunnellers in the world and traces its history back to its founding in 1971. Regular BTS monthly meetings are hosted at the Institution of Civil Engineers in London from 5.30pm every third Thursday of the month. In recent years, the BTS Young Members have also begun hosting a programme of evening lectures.

UXO - CIRIA guide and the practical application

19 March 2015
 UXO (unexploded ordinance) can arise from both hostile and defensive military activity and is often related to World Wars I and II. This presentation looks at how UXO can pose a risk to sub-surface engineering activities and how risk can be managed and mitigated to 'As Low As Reasonably Practical', in accordance with the law and best practice.
 Speaker: Simon Cooke

Harding Prize

16 April 2015
 The annual Harding Prize competition is named in honour of Sir Harold Harding, the founder Chairman of the BTS and is open to young engineers aged 33 or under at the end of 2013. Entrants must submit an original paper relating to any aspect of tunnelling they consider of interest to the industry. The winner will be chosen by the BTS Committee.
 Speaker: Harding Prize finalists

East Side Access project

21 May 2015
 Speaker: Andy Tompson

Tunnelling in the Lambeth Group: how can we stop it going wrong?

18 June 2015
 Speaker: Jackie Skipper

Innovation and technology in segmental lining design

17 September 2015
 Speaker: Anthony Harding

If you have a topic or project you feel would be suitable for a BTS evening presentation, please contact:

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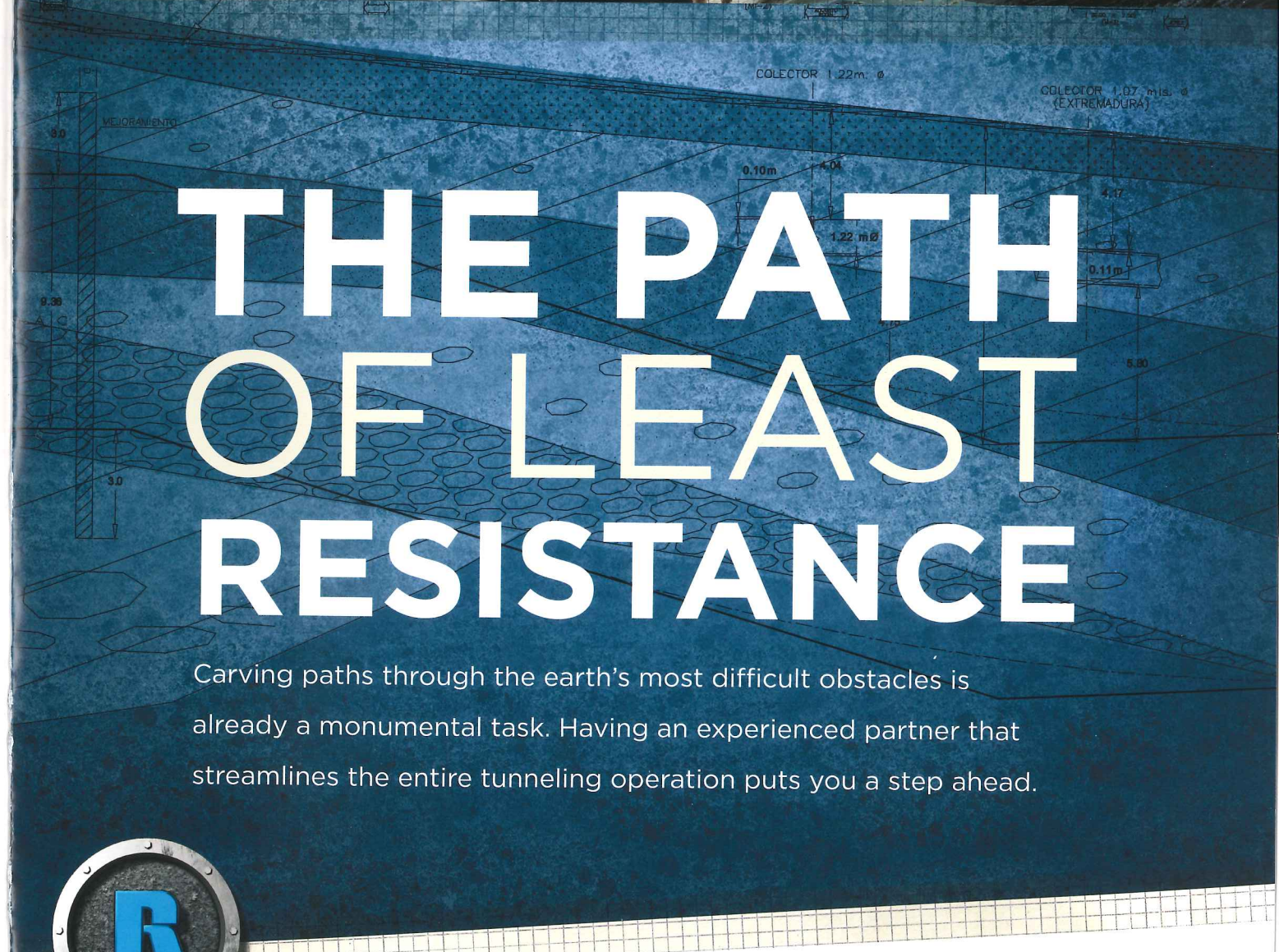
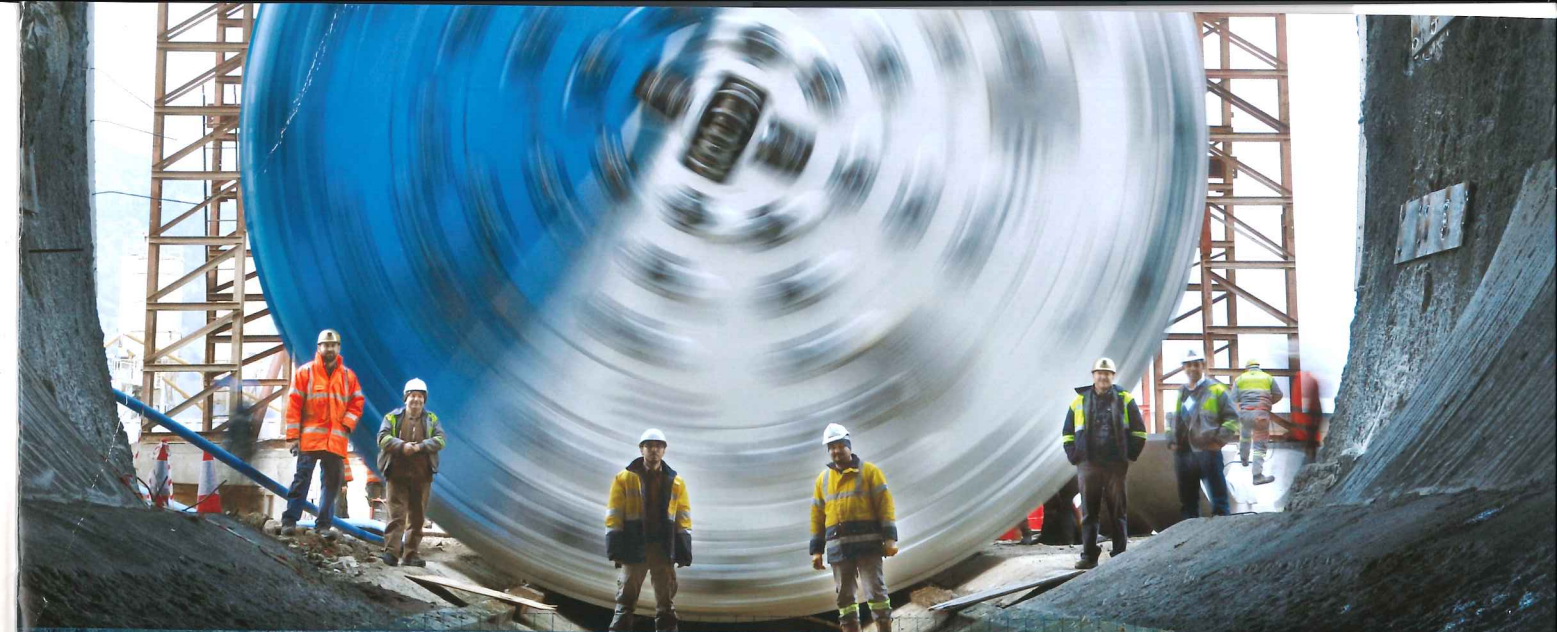
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