Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering

doi:10.3233/978-1-61499-656-9-3181

Technical session 2d: Tunneling

Séances techniques 2d: Tunnelisation

V.P. Petrukhin
NIIOSP, Russia

R. Mair
University of Cambridge, UK

S. Akutagawa
Kobe University, Japan

1 INTRODUCTION

Technical Session 2d : Tunneling was held on the afternoon of September 14th, Wednesday, 2005 in Special Conference Room on the 12th floor with approximately 100 attendants. The session was opened by the Chairman, Prof. V. P. Petrukhin (Russia), who addressed the following points as characteristic issues to be discussed in modern tunneling engineering:

- Tunneling with greater diameters, depth and length.
- Tunneling in complex geological, hydrological and hydrogeological conditions.
- Tunneling in urban areas near historical buildings.
- Tunneling near rivers, canals, lakes etc.
- Tunneling with modern observation techniques.

2 GENERAL REPORT

The contents and trends of the issues covered by 22 papers submitted to the tunneling session from 15 countries were assembled, organized and presented as General Report by Prof R. J. Mair (UK). He categorized these papers into the following 6 groups.

- Excavation and construction process 7 papers
- Tunnel stability 3 papers
- Ground movements and their effects 6 papers
- Tunnel lining behaviour 3 papers
- Extraction of geothermal energy 1 paper
- Pipelines 2 papers

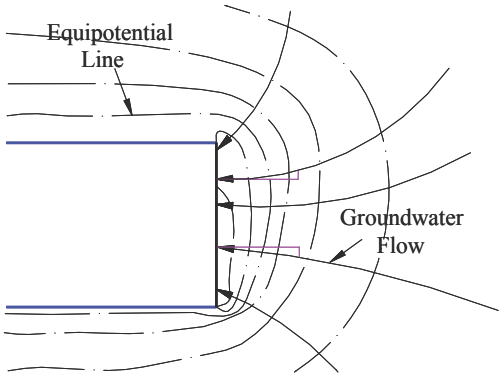
After introducing these papers, Prof. Mair raised three points as discussion topics for the 2nd half of the session, which will be stated in detail in Section 4.

3 PANEL PRESENTATIONS

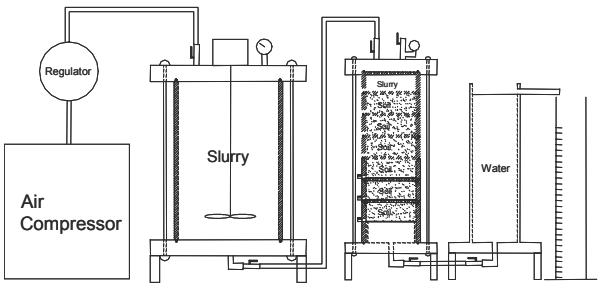
After the General Report, four panel presentations were made as follows:

- I. Lee (Korea) – Seepage and tunnel stability
- C. Sagaseta (Spain) – Geotechnical problems in a tunnel portal
- T. Nakai (Japan) – Effects of tunneling on pile foundations
- D. Adam (Austria) – Design aspects of tunnels at shallow depth

Lee acknowledged firstly an increase in tunneling practices in complex hydro-geological conditions and addressed 1) the effect of seepage forces on the tunnel face stabilityand 2) the effect of slurry penetration phenomena on the face stability of slurry-shield tunnels. Lee stated that the stability of a tunnel face is one of the most important factors in tunnel excavation. Especially, if a tunnel is located under the groundwater level, groundwater may flow into the tunnel face and seepage forces acting on the tunnel face due to groundwater flow may seriously affect the stability of the tunnel face (Figure 1a).



(a) Concept of seepage force near tunnel face.

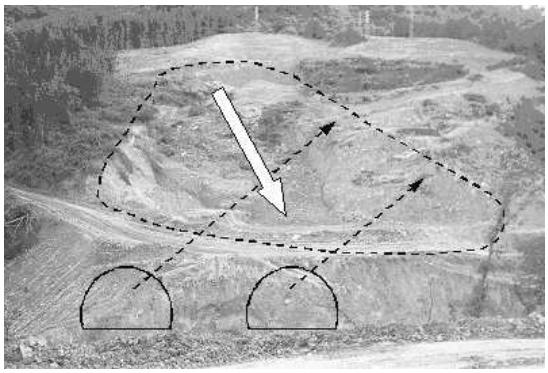


(b) Overall view of the experimental apparatus for investigation of slurry penetration.

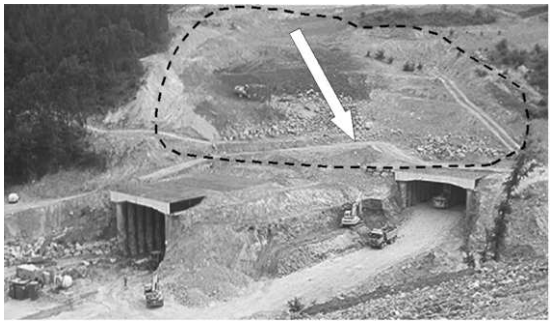
Figure 1. Concept of seepage force and experimental apparatus (from Lee).

Lee added that in the slurry shield method, the stability of the working face depends essentially on the rheological characteristics of slurry penetration into the ground, and introduced experiments in which the slurry penetration was assessed by soil-filter clogging theory to understand the rheological characteristics (Figure 1b).

Sagaseta presented an example of designing a tunnel portal in the presence of a sliding soil mass (length ~100m, max. width: ~80m, depth: ~15m) just above (Figure 2a). The slide took place during the excavation of the portal. The ground consisted on a thick colluvium over a bedrock of limestone and marl. The installation of a rigid concrete structure at the portal was chosen to assure stable excavation (Figure 2b) and avoiding the need of anchoring, while taking advantage of an "intact" toe. The total tunnel length in colluvium was 150 m. Of them, the first 50 m were excavated directly below the slide area. In this part, the excavation was done in heading and bench, with excavation advance of 0.80 m, and supported with 250 mm of fiber-reinforced shotcrete, steel ribs HEB-160 spaced 0.80 m, and an umbrella formed by a double row of micropiles. This support was gradually reduced after passage of the slide area. The construction of the tunnel was performed with no further problems.



(a) Sliding mass and location of tunnel portals.

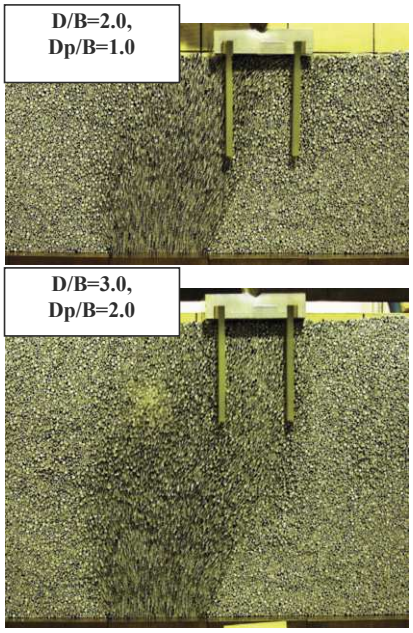


(b) Installation of rigid concrete structures just beneath the sliding mass.

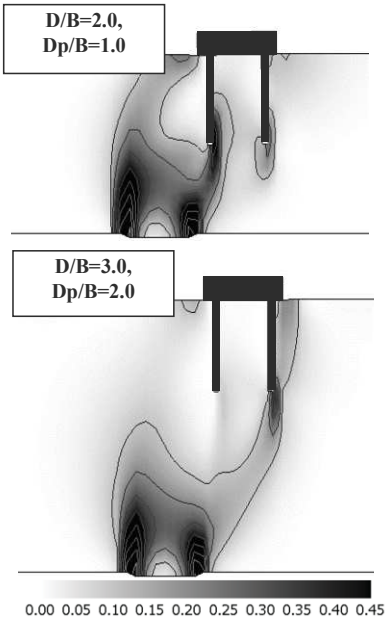
Figure 2. Engineering solution for tunnel portal at an unstable slope (from Sagaseta).

Nakai presented the results of an investigation on the influence of existing pile foundation on the earth pressure and ground movement due to tunneling. Figure 3 shows part of the results from 2D trapdoor model tests (Figure 3a) and the corresponding elastoplastic finite element analyses (Figure 3b). According to the results of his investigation, the distance between the pile tip and the crown of the tunnel was found to be more important than the pile length in the interaction problem of tunneling and pile foundations. It was also found that the vertical load of the front pile that was nearer to the excavation block decreases significantly with the tunnel excavation. In contrast, the vertical load of the rear pile increased with the excavation of the tunnel.

He also showed that on the ground with foundation, maximum settlement occurs not above the tunnel but at the position of the foundation, and the shape of settlement trough does not follow the Gaussian curve that is usually assumed in a greenfield. He emphasized that in order to obtain the realistic results in the analysis on tunnel problems, it is necessary not only to use a constitutive model that can describe typical deformation and strength characteristics of geo-materials but also to take into consideration the existing building loads, the type of the foundation, the skin friction of piles and others.



(a) Ground movement in lab tests.



(b) Ground movement by FEM simulation.

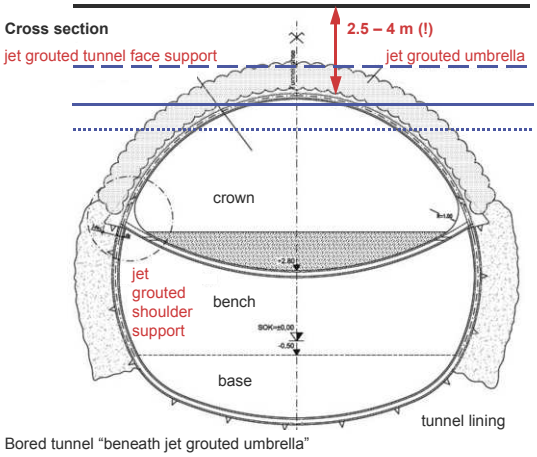
Figure 3. Comparison of deformational mechanism of tunneling near pile groups (from Nakai).

Adam introduced an example of tunneling at shallow depth in extremely difficult ground conditions in terms of dealing with underground water. The tunnel of concern has a length of 4.564 km, which has been currently constructed with basically three different construction methods (Figure 4); as follows.

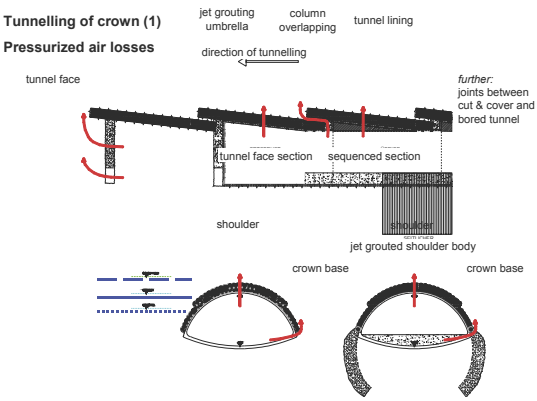
Cut & Cover "bottom up":
Clearance width: 11.30 m
Clearance height: 8.35 m

Cut & Cover "top down:
Clearance width : 11.63 m
Clearance height: 8.35 m

Bored tunnel "beneath jet grouted umbrella":
Clearance height: 9.35 m



(a) Bored tunnel beneath jet grouted umbrella.



(b) Pressurized air losses.

Figure 4. Various tunneling method under difficult ground conditions (from Adam).

To control water and preserve a workable tunnelling environment, heavy grouting and in some cases compressed air had to be used.

4 FREE DISCUSSION

Prof. Mair as Chairman of the discussion firstly identified the following three questions as discussion topics.

- Tunnel stability – continues to be of key importance. What special factors should be considered?
- Ground treatment – the practice is still ahead of fundamental understanding. Can we quantify the effects on stability and ground movements?
- Pile foundations – increasingly important to predict response to tunnelling in urban areas. Can we do this with confidence?

The first question from the floor, concerning seepage rate and its effect on tunnel face stability, was followed by a series of questions and answers, which ranged from relative stiffness of grouting material and soil, required tightness of shotcrete when using compressed air, importance of knowing the distribution of ground permeability, interpretation of small displacement with respect to presence of plastic deformation etc. One particular comment made was rather interesting and shocking that tunnel stability could sometimes be controlled by a piece of wood which is not supposed to be in a concrete lining. The other question was concerned with the model tests and numerical simulations by Nakai. He explained that the imposed tunnel displacement (4mm), which corresponded to 5% volume loss in tunnel, was rather larger than that in usual tunneling practice. He continued that the tendency of the ground movements was the same even in smaller tunnel displacement, and the earth pressure was not influenced very much by the amount of the displacement because active earth pressure decreased sharply with a very little displacement and did not change very much with succeeding displacement.

As Prof. Mair guided the audience's attention to the second discussion point, the room began to gather momentum as if a battle between practitioners and academicians started. Academicians try and wish to quantify the effectiveness of jet grouting, for example, hopefully at the design stage. They keep doing it, but they know that most approaches seldom work. Practitioners know what to do on site and how to construct tunnels to specification. They would welcome if quantitative evaluation of jet grouting works in a simple manner. But they don't really need it for their works to be completed safely. This is possible because by experiences they often know how much ground support is required to maintain minimum safety. But there is still little or no quantitative knowledge as to how ground treatment work such as jet grouting influences ground movements.

If we allow this gap to remain unchallenged, practice will always keeps its superiority to theory. We have known this importance for years, probably for as long as modern simulation techniques have been around, but have not yet come to a point of comfortable understanding of why our prediction or preliminary quantification don't work as well as we hope. As the discussion time was not sufficient for this session, the answer or conclusion, as predictable, did not come up at the end of the session. There were also many other interesting topics to be discussed, but time did not allow us to continue. The session was then closed promising that we shall all meet again at the next professional meeting as tunneling and geotechnical engineers, the closest of which would be the ITA Congress in 2006 at Seoul, Korea.

ACKNOWLEDGEMENT

Authors express special thanks to all the panelists for their presentations and contributions to this report.