Technical Report on TC 28 – Underground construction in soft ground

Compte rendu technique sur la CT N° 28 – Constructions souterraines dans les sols mous

R.J. Mair – *Geotechnical Consulting Group, London, UK*

1 INTRODUCTION

Following the successful one-day Symposium in New Delhi just before the start of the 13th International Conference, plans were made for a second Symposium. This was held at City University, London, in April 1996. A total of 116 refereed papers were accepted from 23 countries, and these were published in the Proceedings of the Symposium by Balkema (Mair and Taylor, 1996), together with the session reports and some written discussion contributions. The Symposium was attended by 235 delegates from 27 countries. The first two days were dedicated to 5 session reports and discussion sessions, and the third day was spent visiting construction sites of the Jubilee Line Extension project in London. Two papers summarizing aspects of the Jubilee Line Extension Project were included in the Symposium Proceedings. Brief summaries of the 5 session reports are given in the following sections.

2 BRACED EXCAVATIONS AND SHAFTS

The session report (Kusakabe, 1996) grouped the 31 papers in this session as follows:
1. Failure or near failure case records and failure mechanisms.
2. Detailed monitoring data.
3. Proposals for design.
4. Use of FEM analysis.
5. Project descriptions.
6. Miscellaneous topics.

Six papers were grouped under category (1). Two of these described cases of complete wall failure; three reported excessive deformations of either the wall or the bottom of the excavation, or both. One paper concerned failure mechanisms of braced walls in laboratory model tests. It was concluded that more case records are needed in residual soils and very soft clays (the latter in conjunction with soil improvement methods). The recent availability of FEM codes allowed sophisticated analysis to be undertaken, but the levels of site investigation and laboratory testing should be of comparable sophistication. More research was needed in the area of three-dimensional excavation behaviour such as rectangular shaft excavations.

3 CONSTRUCTION ASPECTS OF BORED TUNNELS

The session report (Negro, 1996) grouped the 17 papers into three categories:
1. Case histories.
2. Summaries of local experiences.
3. New techniques and developments. It was concluded that many of the papers illustrated certain construction features that affect the geotechnical performance of bored tunnels. There was a need to understand more clearly how ground loads are transferred to the tunnel lining both in the short and long term, taking into account the different ways the lining was built. More advantage should be taken of modern monitoring systems, currently available in shield machines, to assess the response of the ground and thereby achieve better control.

4 GROUND TREATMENT

The session report (Shirlaw, 1996) divided the 15 papers into the following topics:
1. Compensation grouting.
2. Jet grouting.
3. Permeation grouting.
4. Ground freezing.
5. Pre-lining/bolting. Most of the papers concerned topics 1-3, with almost half dealing with topic 1. All of the papers on topic 1 were case studies of the use of fracture grouting for compensation grouting. It was concluded that the grout 'efficiency' (defined as the ratio of volume of ground loss to the volume of grout injected) was typically between 0.25 and 0.4. Differences in the primary contractual responsibility for various aspects of compensation grouting (grouting and monitoring operations) were highlighted.

The three papers on jet grouting presented widely contrasting case histories. In one of the case histories the common problem of heave in soft clay was overcome by a combination of pre-treatment of the overlying fills and precutting, the latter involving an initial phase of jetting with water instead of grout.

5 MODELLING AND PREDICTION FOR BORED TUNNELS

The session report (Leca, 1996) noted that almost one third of the papers presented to the session were related to the numerical analysis (principally finite element analysis) of case studies. Three construction techniques were mostly considered: shield tunnelling, the New Austrian Tunnelling Method (NATM) and tunnelling in grouted soil. Most analyses were undertaken with a two-dimensional model, even though the three-dimensional nature of the ground response to tunnelling had been clearly recognised. Either a stress release technique (similar to the "convergence-confinement" method) was used, or soil displacements were imposed around the tunnel boundary (particularly in analyses of ground movements occurring into the tail void).

It was concluded that both numerical and physical modelling can be of benefit in analysing specific aspects of tunnelling, for example the influence on the settlement distribution of a layered soil profile or a structure. Further research was required to improve the representation of such aspects as soil anisotropy, time dependent effects and three-dimensional geometry.

6 SETTLEMENT EFFECTS OF BORED TUNNELS

The session report (Mair, 1996) reviewed 35 papers concerning settlement effects of bored tunnels. Many of the papers on open face tunnelling described case histories of tunnels in London Clay. For these the volume loss was generally between 1% and 2%, although in one case a value of around 3% was observed. Construction with sprayed concrete linings (NATM) was found to be effective in controlling ground movements. Significant post-construction settlements may occur above tunnels in clays, but often with only very small increases in deflection ratio and horizontal strain. Large settlements could occur above tunnels in unusual ground such as gypsum-bearing or collapsible soils.

It was concluded that closed face tunnelling techniques (slurry or earth pressure balance shields) offered potential for a high degree of settlement control, and volume losses were often as low as 0.5%. Provided face pressures were closely controlled, the principal causes of ground movement were the shield passage and the tail void. An additional cause could be grouting of the tail void causing excess pore pressures in the ground. There was often a significant learning curve in achieving appropriate control of face pressure, particularly in the case of earth pressure balance shields.

The importance of soil-structure interaction and the rôle of building stiffness was demonstrated in a number of papers. Despite the importance of potential effects on structures, services and other tunnels in the urban environment, it was noticeable that of the 116 papers submitted to the Symposium, there were very few case records of the detailed performance of structures, services or other tunnels when affected by tunnelling.

REFERENCES

Kusakabe, O. (1996). Braced excavations and shafts. Session report. Proc. Int. Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, London (eds R. J. Mair and R. N. Taylor), Balkema, 3-10

Leca, E. (1996). Modelling and prediction for bored tunnels. Session report. Proc. Int. Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, London (eds R. J. Mair and R. N. Taylor), Balkema, 27-41.

Mair, R. J. (1996). Settlement effects of bored tunnels. Session report. Proc. Int. Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, London (eds R. J. Mair and R. N. Taylor), Balkema, 43-53.

Mair, R. J. and Taylor, R. N. (1996). on Geotechnical Aspects of Underground Construction in Soft Ground. (Proc. Int. Symposium, (eds R. J. Mair and R. N. Taylor), Balkema, 786 pp.

Negro, A. (1996). Construction aspects of bored tunnels. Session report. Proc. Int. Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, London (eds R. J. Mair and R. N. Taylor), Balkema, 11-18.

Shirlaw, J. N. (1996). Ground treatment for bored tunnels. Session report. Proc. Int. Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, London (eds R. J. Mair and R. N. Taylor), Balkema, 19-25.