Monitoring of EPBM tunneling at Lot2 of Turin metro

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MONITORING OF EPBM TUNNELLING AT LOT 2 OF TURIN METRO

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Introduction

The preliminary knowledge of the lithologic stratigraphy and of the groundwater conditions, combined with the mapping of the existing structures along the alignment of the tunnel, represent the basic elements for the tunnelling phases organisation.

Earth Pressure Balance Machines (EPBM) have been successfully used worldwide in urban tunnels. However, several records of accidents can be found in literature. A correct excavation management and real time data streaming, together with subsidence monitoring, are effective tools to prevent such undesirable situations from happening. This paper aims at a better understanding of the procedures to correctly manage and supervise EPBM tunnelling activities. Moreover, special attention is devoted to performance and production, muck extraction and backfill grouting. The case study of Turin Metro Lot 2 Project is used to highlight some of the features of these procedures and in order to raise the importance of work supervision, namely through its quick and effective action. Finally some recommendations are made for real time monitoring excavation control of EPBMs' parameters.

Project Main Features

On late April 2008 a Herrenknecht's EPB shield machine started the excavation of Turin Metro Lot 2. The Project will extend the already existing line towards the Southern part of the city, connecting Porta Nuova and Lingotto railway stations. For this new line a double track single tunnel of 6.8 m internal diameter, with a total length of approximately 2.9 km is being built.

Turin area extends in semi-flat plains formed by alluvial fans at the end of the Alpine valleys. These fans of fluvial-glacial deposits have been remodelled by the rivers that cross the area (Stura, Dora Riparia, Sangone). The prevailing units along the tunnel alignment are recent formations composed by sand, gravel and disperse pebbles in a silty matrix. These coarse formations present a high permeability (10^{-3}–10^{-4} m/s) and different degrees of cementation, as a result of a random sedimentation process (some lenses of natural conglomerates can exhibit UCS values of about 7–15 MPa). Tunnelling beneath urban areas in such geology is a challenging task, in particularly with an EPB shield machine.

TBM Excavation Monitoring and Data Analysis

Monitoring of EPBMs operation can be divided in six main groups: performance and production, boring parameters, muck extraction, earth pressure, backfill grouting and soil conditioning parameters. Some of them are discussed in the paper.

Performance and Production

Like in any other project, some problems and low production were experienced at the initial stage. During the above mention period a total of 213 m of tunnel was excavated, resulting in an average production of 2 m per day (20% of the estimated). The referred low production can be explained by the numerous stops and breakdowns during this period. In Fig. 4 (left hand side) we can see a pie-chart with the average time per ring for boring, ring erection and breakdowns. Two immediate conclusions can be drawn: the machine spent much of the time stopped (utilisation factor of 9.5%) and for long periods (more than 13 hours in average). The stops and breakdowns had different origins and reasons, namely: disassembly of the steel reaction frame; assembly of remaining backup cars (major stop); problems with the availability of muck disposal areas; several stops to partially empty the excavation chamber and clean the cutterhead; blockage of grouting lines.

Muck extraction

The muck extracted weight (or volume) is one of the most important parameters to control. Modern TBMs are capable of extracting big quantities of material in a short period of time. If muck extraction control is not dealt with care, over-excavations can easily occur and cause surface subsidence or even sinkholes. When controlling this parameter is very important to evaluate the soil in-situ unit weight, as well as to cross-check the measurements by different instruments. In the present project this control was done by means of only one conveyor belt scale.

Backfill grouting

Backfill grouting is essential to guarantee that the annular gap, between the excavation profile and the lining extrados, is completely filled. It has been recognized that the backfill grouting plays an important role on the magnitude of surface settlements. In that sense it is as important as face pressure in controlling surface subsidence. Hence, it should be controlled with the same care. It should be done directly from the tail of the shield and concurrently with the excavation cycle, using a reasonable number of lines to ensure a homogeneous filling. Control should be done both in terms of pressure and volume to ensure the complete filling of the gap. The pressure is normally set slightly higher (around 0.5 bar more) than the face pressure to guaranteed that the water and/or slurry inside the annular gap are repelled and substituted by grout.

Soil conditioning

Concerning soil conditioning it's important to mention that a strong conditioning was carried out, practically only with the use of dry foam (FIR = 136% and FER = 9, average values). As a result of that, some operational problems regarding muck extraction, conveyance and disposal took place. In addition, the face pressure was hard to maintain due to the muck segregation inside the chamber. The muck segregation originated the aggregation of the coarser fraction in the bottom part of the chamber generating high effective stresses, and consequently high torque and wear. On the upper part, due to its fluidity the muck could easily infiltrate in the permeable ground, and therefore making it difficult to apply the required effective pressure.

Conclusions

The ground conditions of the metro line in Torino are particularly difficult because of the heterogeneous grain size distribution, the gravel fraction, the conglomeratic levels and the groundwater level (about −13 m from ground level). Despite the amount of preliminary grouting, the ground conditions have made the EPBM driving difficult to learn.

TBM monitoring involves processing a huge amount of data, with complex correlations. This requires continuous and effective contacts between supervision engineers and a collaborative attitude between all parties (Engineer, Contractor and Owner). Interpretation of data can allow fast answer in potentially critical situations. Surface subsidence monitoring should also be continuously correlated with excavation parameters.

Over-excavation and improper grouting, like it was recorded for example in rings 85 and 86, can be a dangerous combination, as they can be the source of uncontrolled surface subsidence or even chimney type collapses. In the present case, due to the prompt action further complications were avoided.