Long Drive Microtunneling Excavation in the Alluvium

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1. Scope

As part of the restructuring of the sewage system in LYON - France, CSM BESSAC has just completed the excavation of the "Carré de Soie" main sewer on behalf of the Grand Lyon Urban Community. The 2 m internal diameter tunnel structure was carried out by horizontal pipe jacking with the largest micro tunnelling machine (MTBM) currently in use in France. The tunnel structure, 966 m in length, is a major achievement and was constructed in a single section. This is also a first in France.

The following constitute the main characteristics of this tunnel structure:
- an internal diameter of 2.0 m,
- 966 m in length,
- driven at a constant gradient of 5 mm per metre,
- a route comprising 2 curved bends,
- a depth varying between 6.40 m and 10.6 m along its vertical route from upstream to downstream,
- 2 crossings beneath the tracks of the LEA tramway.

In addition to the mains sewer itself, associated civil works include the construction of an upstream shaft, a downstream shaft connecting into an existing mains sewer (EPE), 3 intermediate inspection shafts and 4 ventilation shafts.

2. Geotechnical considerations

The mains sewer runs entirely through dense Rhone sand-gravel alluvia with a permeability of approximately \(10^{-4}\) m/s. The gravel may also include an erratic boulder distribution. The entire mains sewer is constructed above the water table and, therefore, only occasional infiltration is considered possible.

The district where the new mains sewer is being built is located in the centre of the "Carré de Soie" urban development project. In this district, which is being comprehensively upgraded, it was considered essential to limit the impact and surface disturbance as much as possible to prevent damage to nearby structures such as: presence of the Avenue des Canuts that serves the new "la Soie" metro station, bus routes, the presence of the LEA tramway route etc.
3. The shafts

In view of the limited land areas that were available in this area, the micro tunnelling machine launch shaft had to be located upstream. Accordingly, the tunnel was driven downstream. This shallow rectangular shaft was constructed using metal sheet piles which were first vibrated into the ground and then driven with a diesel pile hammer. After the construction of a reinforced concrete base slab, the micro tunnelling machine was installed in the shaft as shown in figure 1.

![Figure 1: launching shaft](image)

The downstream reception shaft and connection into the deeper EPE main sewer were excavated using the conventional shaft sinking method with temporary support by steel lagging and beams, as shown in figure 2.
The 3 intermediate inspection shafts and sewer links were also constructed using traditional technique. The 4 ventilation shafts were built using vertical drilling technique along the horizontal alignment above the new main sewer.

4. Microtunneling equipment

A Herrenknecht AVN 1800 type micro tunnelling machine was used for this project. However, it is normally used to carry out tunnel structures having an internal diameter of 1.8 m. Therefore, CSM BESSAC, the owner of this machine, designed and manufactured a wider shield skin enabling the MTBM to excavate the tunnel with an internal diameter of 2 m. A new cutting wheel also had to be fabricated to accommodate this new enlarged diameter and designed to cope with the geology envisaged along the tunnel alignment as shown in figure 3.

The tunnel structure, made of reinforced concrete pipes, was carried out by pipe jacking method and built in a single 966 m section.

The micro tunnelling machine was remote controlled from a container located on surface, near the shaft. Workmen were only requested to enter the tunnel occasionally to maintain equipment and overhaul purposes.
5. Excavation

In order to reduce the friction between the tunnel and the alluvium during the MTBM progress, a lubrication mix of bentonite, polymers and water was grouted in the annular space. One every four pipes was fitted with 3 grouting valves on which was connected the lubrication circuit.

Seven 8500 kN intermediate jacking stations were also installed along the tunnel. Only 3 one them were used.

In the most permeable layers of alluvium, bentonite slurry losses were noted in the front.

Some boulders have been met in the tunnel path. They were reduced by the disc cutter of the cutting wheel. Inspections were carried out every week in the excavation chamber of the MTBM in order to check the disc cutters and change the worn ones.

6. Monitoring surface movement

The main sewer is located almost entirely beneath a road with very heavy traffic. Additionally, it crosses twice under the tracks of the LEA tramway. Therefore, the maximum limit imposed on surface movement (settlement or swelling) was the project’s major limitation. This limit was : +/- 10 mm.
Major topographical monitoring was put in place during the works:

- a real time topographical monitoring system using a motorised theodolite was installed by SolData for monitoring the tramway tracks,
- conventional topographical monitoring systems were used for the remainder of the alignment.

Approximately 1 millimetre of maximum movement was recorded (refer to figure 4) which was well within contractual requirements.

![Figure 4: real time monitoring of the tramway tracks](image)

### 7. Guidance

In order to control the tunnel alignment which included 2 curved bends having a radius of 700 m and 500 m respectively, refer to figure 5, the micro tunnelling machine was equipped with a gyrocompass guidance system. This system provides the machine operator with the real time position of the micro tunnelling machine in relation to the mains sewer’s theoretical alignment.

This highly effective guidance method meant that the alignment remained well within contractual limits.
8. Conclusion

The construction of the “Carré de Soie” mains sewer using the micro tunnelling techniques was a resounding technical success. The mains sewer was excavated in just 4 months including the micro tunnelling machine start-up period, and did not affect any of the neighbouring structures.

This project demonstrated that a micro tunnelling machine’s technical capacity can be used for building tunnels with major diameters, extensive lengths and curved routes on condition, quite obviously, that the excavation is carried by a specialized contractor with enough skilled and experienced work force to operate and maintain the tunnel boring machine.