*Towards New Worlds in Tunnelling, Vieitez-Utesa & Montañez-Cartaxo (eds) © 1992 Balkema, Rotterdam. ISBN 90 5410 050 8*

# Highway tunnel crossing of an old river bed in N. Italy while maintaining the hydrogeological balance

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ABSTRACT: The Mompantero tunnel is part of the highway linking Turin (Italy) to Frejus (France). The 900m-long twin tunnel crosses a Mesozoic calcschist under a cover of upto 100m. An unexpected problem occurred during construction of the tunnel when a tectonic lineament (associated with an old river bed) was intercepted just below the Mompantero village. Large water inflows and poor geotechnical characteristics of the ground were encountered in this section and the above aquifer was rapidly drawn down. The solution to the problem required the use of special techniques for supporting the ground as well as assuring the geohydrological equilibrium around the tunnel. These techniques included a complex program of resin injection for water-proofing around the tunnel, which was confirmed by precise piezometric measurements. The methodology used and the results are discussed.

## 1 INTRODUCTION

The twin-bore Mompantero tunnel is part of the works of the motorway connecting Frejus (France) to Turin (Italy). It was completed on behalf of SITAF (owner of the motorway) by the Mattioda-Carena Consortium. Its length is about 900 meters, with maximum coverage of the order of 100 meters. It passes under the built-up area of Mompantero with 40 to 50 meters of overburden.

From the geological standpoint, the tunnel passes nearly exclusively through Mesozoic formations of calc-schists with green stone, mainly consisting of greyish foliated schists, sometimes with large intrusions of basic prasinitic and/or amphibolitic rocks.

During excavation of the tunnel from the Turin side, a sedimentary deposit, presumably of glacial river origin, was encountered. The deposit consisted mainly of different grain size pebbles and gravel, immersed in a yellowish sandy silt matrix with a great amount of water flow; the water level was nearly at the surface, 35 meter above the crown of the tunnel.

This finding coincided with a drastic reduction of the self-supporting capability of the excavation face and collapse of several hundred cubic meters of material, together with heavy inflow of water (see Photo 1), at about 320 meter advance (from Turin portal) in the bore adjacent to the valley.

Considering the intense lamination of the essentially prasinitic rock mass, which also intersected the second bore, the situation was presumably due to a paleo river bed situated along an important tectonic alignment (Figs. 1-2).

The heavy water inflow was also associated with the hydrologic changes that occurred on the

Photo 1: Example of heavy water inflow into Mompantero tunnel

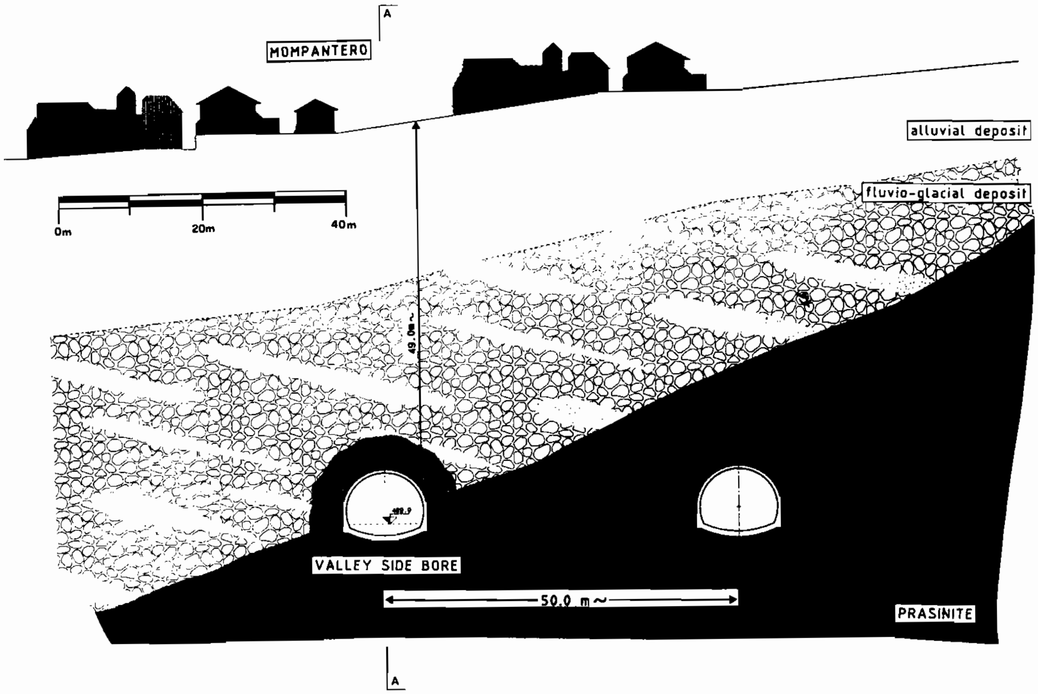


Fig. 1. Geologic cross section of the twin-bore Mompantero tunnel

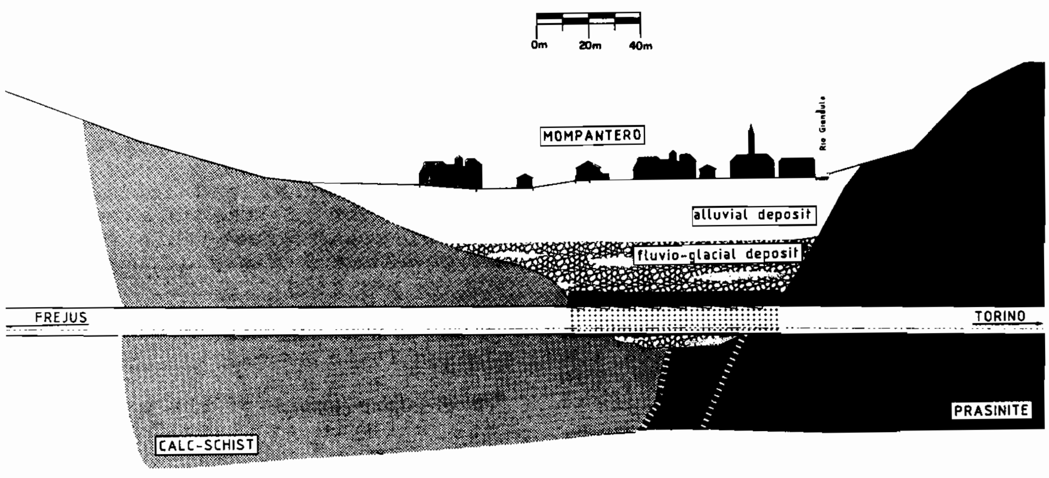


Fig. 2. Longitudinal section along Mompantero tunnel

surface, namely, reduced flow in the Giandula stream (Fig. 3) and near drying-up of the spring called "Fontana Maria", which is the main source of water supply to all the surrounding villages.

## 2 METHODOLOGY FOR CONSOLIDATION AND WATER PROOFING

Faced with the situation described above and also taking into account the delicate conditions while


Fig. 3. Plan view of the project showing the tunnel intersection with Giandula river

driving the tunnel under the built-up area of Urbiano with less than 50 meters coverage, it was obviously necessary first to stabilize the excavation and then to recover the tunnel profile with an appropriate filling of the fall-out cavities and, finally, to proceed with water proofing the area of the tunnel involved in the intense water inflow, to guarantee not only its complete sealing but also to gradually recover the original hydrogeological conditions.

This was achieved with chemical injections into the soil carried out by CONSONDA (a firm specialized in grouting) in two steps to form a waterproof ring beyond the excavation profile.

Two-component polyurethane resins were used, capable of expanding freely up to 30 times their original volume and with a 25 to 125 second setting time.

Considering the altitude of the tunnel and the local hydrogeological network, non toxic mixtures were used in the waterproofing treatment following the guidelines of the local Health Authorities.

For executing the work, an operational program was investigated to include the necessary control of the excavation profile to avoid material falls in the tunnel and surface collapses. Therefore, the following 3-phase operating sequence was established:

Phase I: Stabilization of the excavation and filling of the fall-out cavities, using this procedure:

1 - Filling the main shute hole with light concrete.
2 - Side bolting of the ribs with 4.5m long steel bars, spaced radially at 1.5 meters.
3 - Local reinforcement with stiff ribs placed between those already installed.
4 - Consolidation and stuffing of the area involved in the falls with injections of cement grout and subsequent treatment with a self-expanding polyurethane mixture.

The consolidation was performed through a radial pattern of three, valved, pvc injection pipes. The 15m long pipes were spaced at 2m across the tunnel and inclined in the direction of the advance, into the collapsed area. This pattern was repeated 5 times (roughly one pattern per rib).

Phase II: Operations to drive through loose material

1 - Improvement of the excavation face with injections of cement grout through valved fiber-glass tubes, spaced at 1.5 meters and 15 meters long.
2 - Reinforcement of the tunnel profile with the conventional umbrella arch technique: truncated cone surface of consolidated terrain reinforced with steel tubes against falls during excavation and to partially redistribute the loads on the reinforcement, largely eliminating the eventual load

asymmetry. Based on the results of tests, from 27 to 50, 12 meter long, 114mm external diameter, 7.1mm thick valved steel pipes were used. Work under the umbrella progressed for 9 meters, leaving a 3 meter safety area beyond the face that would be overlapped by the subsequent umbrella. After the operations of drilling and tube installation, a primary series of grout cement injections was performed at low pressure, followed by a secondary series only in the valves where greater absorption had been observed (15 bar).

3 - Advance drainage along the excavation profile for a length of at least 20m:

* 8 to 10, 3" drainage steel pipes, gradually inclined upwards, distributed from the middle to top of the excavation profile;

* 4 to 6 bottom level drains 2" with microfissured PVC tubes protected by unwoven fabric sheaths.

Phase III: Waterproofing of the ground around the tunnel

1 - Installation of a Casagrande-type piezometers on the valley-side bore for continuous monitoring of hydraulic equilibrium.

2 - Injections (first step) of polyurethane resins conveyed by radial grids of valved metal tubes, totalling 8 over a circumference of about 240° (3x2m grid). During this step 3" (75mm dia), 4.5m long metal tubes were used.

3 - Injections (second step) of polyurethanes resins conveyed by radial grids of 7 valved steel tubes (3x2m grid). During this step, which had the purpose of sealing off water inflow and supporting the ground, the highest injection pressures were used, using 1 1/2" (40mm) diameter, 3m long metal tubes.

The treatment described (Fig. 4) was only applied to the bore

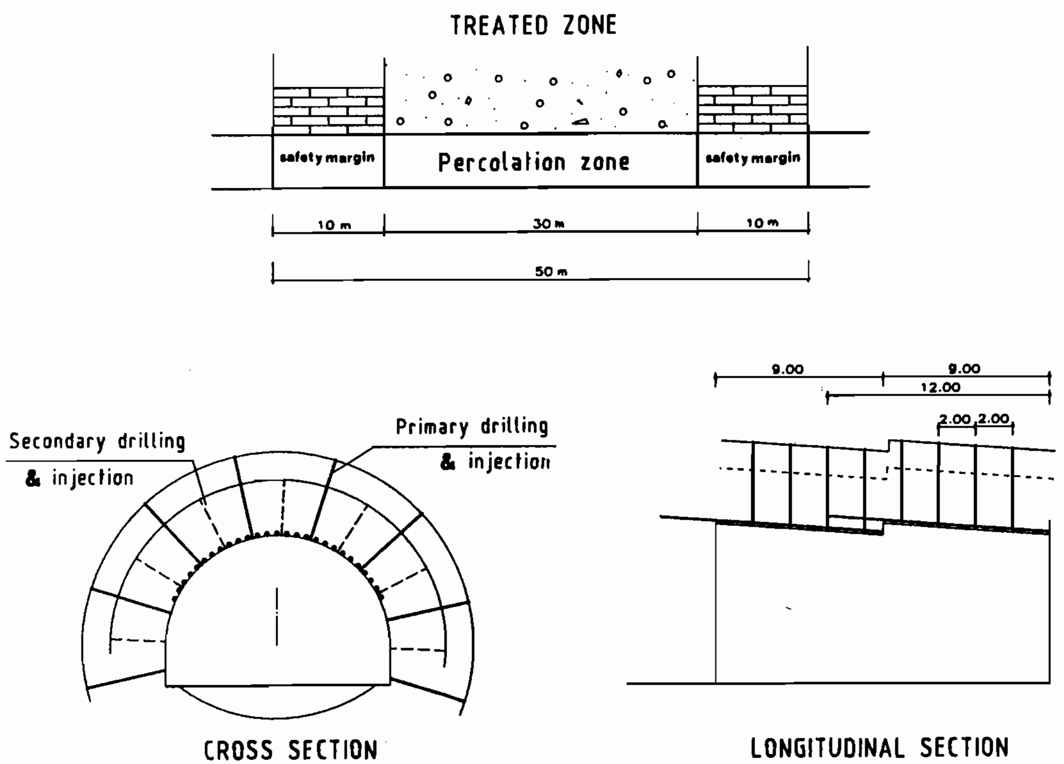


Fig. 4. Water-proofing scheme

adjacent to the valley, in the area where the highest water inflow had been measured. Operations were performed in the tunnel supported only by the primary lining (ribs and shotcrete), continuing to drain water through 3 bottom drainholes to avoid increasing the hydraulic pressure on the supports. On completion of the 50cm thick concrete lining, the 3 drainage holes were injection-filled to restore the hydraulic situation.

On the Turin side, the stabilizing operations were extended from 310 to 360 meters to guarantee a 'safety length' of about 10 meters on both ends.

## 3 FINAL REMARKS

The operations which were performed achieved the objectives set to stabilize and water-proof the Mompantero tunnel and safeguard the built-up area above.

With particular reference to water-proofing, 61745 kg of two-component polyurethane resin were used, through 1596 meters of drill holes, equal to 38 kg/m per hole, or 1122 kg per meter of tunnel.

In the treated area, initial water inflow was 18 l/s, which decreased to 13 l/s after the first injection step and to 7 l/s at the end of the second step.

The last water inflow (concentrated in 3 emergency points) was not stopped until completion of the final lining to avoid excess load on the waterproof ring and the primary lining, but temporarily captured and conveyed outside the excavation with adequate tubing.

Parallel to the sequence of waterproofing operations, piezometric readings indicated gradual increase of the water head, from an initial value of 1m to 2.5m at the end of the first injection step and 11m at completion of waterproofing (Fig. 5).

Subsequent piezometric readings confirmed gradual recovery of the hydrogeological balance towards the original conditions before the excavation began.

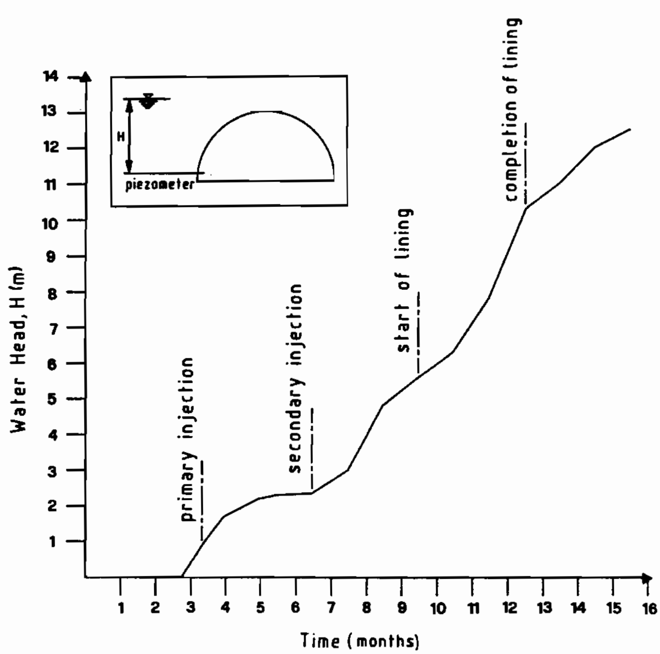


Fig. 5. Results of water proofing measured by piezometer