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Road Subway under the Railway Line in Mestre

Passage souterrain sous la ligne ferroviaire à Mestre

Unterführung der Eisenbahnlinie in Mestre

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SUMMARY

This paper describes a prefabricated road subway for the Venice-Trieste railway line, constructed using a technology whereby it was "driven into place" to avoid interrupting the railway traffic, and overcoming waterproofing problems due to the existence of the groundwater.

RÉSUMÉ

L'article décrit le passage souterrain préfabriqué de la ligne ferroviaire Venise-Trieste réalisée à partir de la technologie de mise en place "par poussée" afin d'éviter l'interruption du trafic sur les voies, et de surmonter les problèmes d'impérméabilisation liés à la présence de nappes phréatiques.

ZUSAMMENFASSUNG

Der Artikel beschreibt die vorgefertigte Unterführung der Eisenbahnlinie Venedig-Triest, die ohne Unterbrechung des Bahnverkehrs mit der "Schub"-Technologie verwirklicht wurde, und zwar im Grundwasser mit den dadurch bedingten Abdichtungsproblemen zur Erreichung eines dauerhaften Bauwerks.

1. INTRODUCTION

The road tunnel under the via Terraglio, at km No. 2 - 773 of the Venice-Trieste railway line, comes within the scope of a much larger project for eliminating the level crossings in the rennovation and improvement of the Mestre road communications network.

The choice of the subway solution was dictated by techincal considerations as well as concern for the environment and the appearance of the structure: an overpass would have proved difficult to connect to the existing ground-level road network, though the nature of the soil and existence of a water bed very close to the surface involved difficulties in the subway project's execution and extra problems of maintenance and durability.

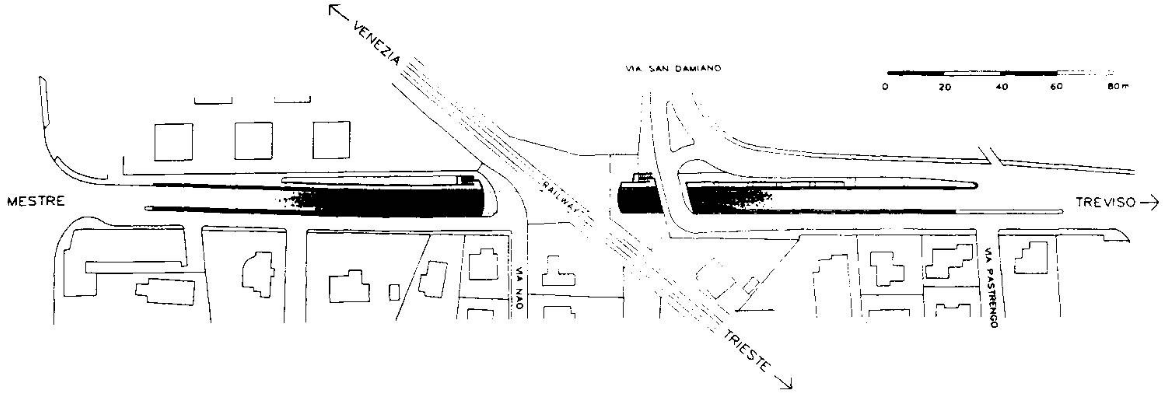


Fig. 1 - General planimetry

The subway comprises an underground section 47.50 m long under the railway tracks with open-air ramps on either side for a total overall length of about 300 m with maximum longitudinal gradients of 1 in 12.5.

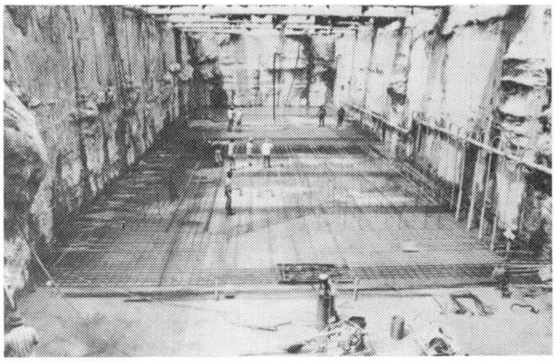
The road carriageway is 7.50 m wide with side lanes and has a minimum height of 5.00 m inside the tunnel: there is a footpath running parallel to the road, with the same gradients but raised with respect to the road surface both for safety reasons and to enable the passage under the railway of the technological utilities contained in an underlying trench duct, the footpath is also linked to the ground level by flights of steps just outside each end of the tunnel (fig. 8).

2. NATURE OF THE LAND

The stratigraphic nature of the land may be summarized as follows: beneath a couple of meters of top soil, there is a poorly-compacted layer of sand and silt with a lenticular trend; from 4 to 10 meters in depth, there is sand and salty silt alternating in thin moderately-consistent cohesive strata, from 10 to 24 meters, there is a moderately-compacted sand and silt layer, generally involved with a thin clay and silt stratum, followed by clayish silt and slimy sand. The depth of the water bed is about 1.50 m underground.

3. TECHNICAL SOLUTION USED AND PROJECT STAGES

The technique adopted for passing the existing important railway line without



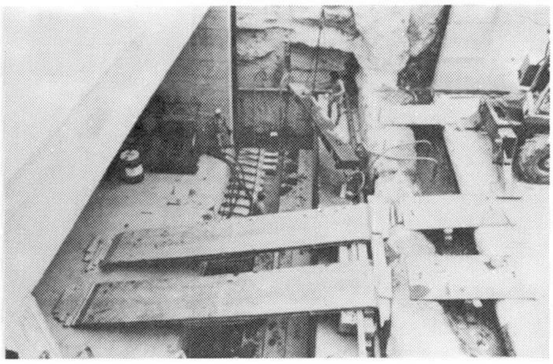


Fig. 2 - Construction of launching bed   Fig. 3 - Hydraulic jacks

interrupting normal railway traffic is based on the construction of a pre-fabricated reinforced concrete element (monolith) and its subsequent pushing into place under the railway line by means of hydraulic jacks.

The project stages included the initial construction of continuous walls of reinforced concrete diaphragm plates cast in the presence of bentonite mud, partly strutted against each other at the tops and partly left free, withe a maximum length of 24 m sunk to a depth sufficient to counter water infiltration and arranged with a closed-perimeter tank layout to allow for excavations inside them for the construction of the concrete monolith and ramps for access to the subway.

This method was chosen because of the geotechnical features of the soil and more particularly because of the subway's location in the vicinity of buildings and the existence of the water bed very close to the surface for which artificial lowering was unacceptable. A reinforced concrete floor slab 1.0 m thick (fig. 2) was then cast in the first tank, near the railway bed, at a depth of 9.60 m from the plane of site, to provide the support for the construction of the monolith and the surface for sliding and guiding said monolith; it was completed with a thrust-bearing wall for countering the jacks during shifting operations.

The monolith was then constructed, forming a boxed structure made of reinforced concrete with an overall size of 12.60 m wide by 7.60 m high by 43.50 m long and a constant thickness of 1.05 m; the driving side sloped away at a 45 angle and its perimeter was shaped for sharpness.

In the next stage, after demolition of the diaphragm wall standing in

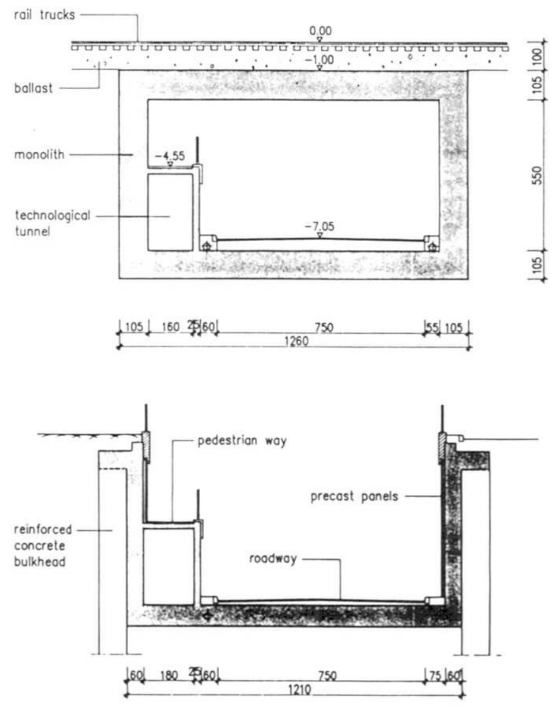


Fig. 4 - Sections

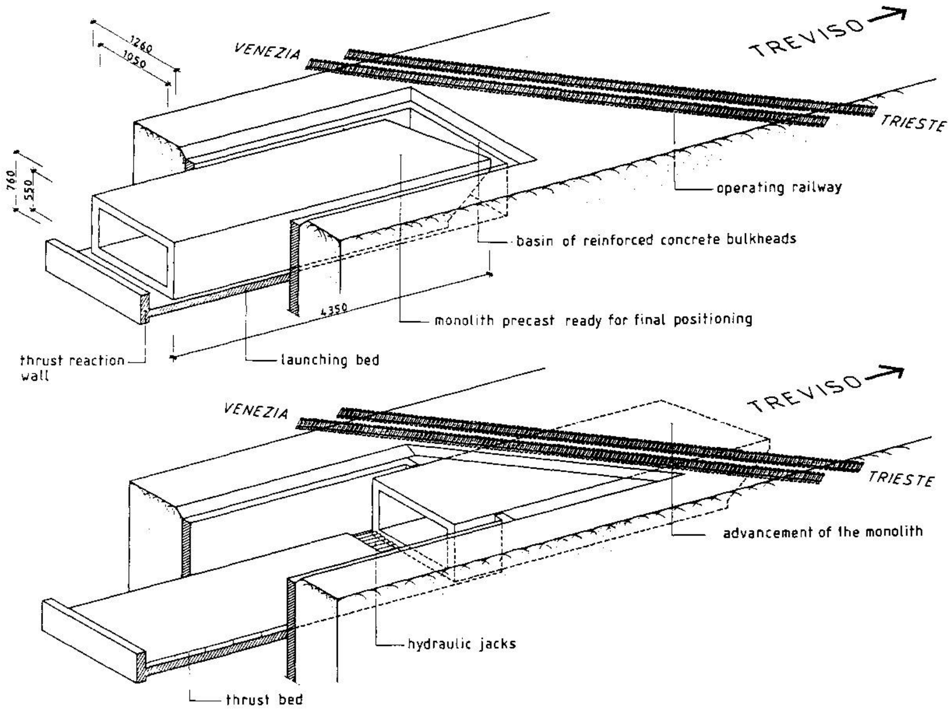


Fig. 5 - Scheme of the positioning operations

front of the railway line, this monolith (weighing about 4.000 metric tons in all) was driven into place by 30 hydraulic jacks, divided into three groups and operating simultaneously but indipendently in order to correct any rotation of the structure (fig. 3).

A number of coupled IPE 600 metal girders, arranged under the sleepers so that they rested on a layer of sliding rollers on the top slab of the monolith and on the ground on the other side, enabled the tracks to be supported during the monolith-driving operations without interrupting railway traffic.

In the area under the tracks, hydraulic protection of the advancing face during the shifting stage was provided by two continuous longitudinal walls of high-pressure jet-grouted concrete piles 16 m long, placed side-by-side.

After the monolith had been driven into place, the access ramps were constructed of "U"-shaped structures composed of slabs and walls cast against diaphragm plates.

Sealing of the casting joints between the wall and the slab was done by inserting an expanding water-stop beading made with sodium bentonite and butyl rubber.

The risk of floating due to hydrostatic pressure from below was overcome by connecting the walls of the "U"-shaped structures with the tops of the reinforced concrete diaphragm plates, thus increasing the load brought to bear.

The faces of the ramp walls were lined with self-supporting reinforced concrete square-corrugated panels, placed in such a way as to leave a cavity of a few centimeters to enable air circulation and the collection of any infiltrated water in the bottom for channelling into the main drainage system.

4. RAINWATER POUR-OFF SYSTEM

The rainwater pouring down the road and footpath ramps is intercepted by several crosswise grid-covered ducts and, together with any infiltrated water, is poured off by pipelines embedded in the concrete slabs to two pumping units situated at the foot of the ramps on each side of the subway.
The overall flow rated for the maximum intensity of rainfall has been calculated at 117 lt/sec and each of the pumping units has been fitted with two electric pumpes for a delivery of 60 lt/sec each and for a head of 13 m as the water has to be raised to the level of the town's sewage system. In the case of breakdown of either pumping unit, the two pumps in the other unit are sufficient to raise the full flow of water: to cater for this possibility, the pits housing the two units are connected by a pipeline undor the road through the subway.
Each pump has an absorption of 11.2 KW and is supplied normally from the mains electricity but also has a stand-by generator on ground level for emergency use.

5. STEPS TAKEN TO ENSURE DURABILITY FOR THE MONOLITH

As the structure is entirely underground and in the presence of water, durability had to be ensured with regard to the environmental conditions (which are moderately aggressive), to the kind of forces coming to bear and to the type of reinforcment (which is not very susceptible to corrosion) so a test calculation for the structure's cross-section was done in cracking limit conditions according to the CEB FIP model code using a nominal value of $W2 = 0.2$ mm.
After calculating the mean opening of the cracks (Wm) for the mean vield (εsm) generated on the mean distance between cracks (Srm), it was decided that the value specified by the characteristic value $Wk = 1.7 \times Wm$ was not to be exceeded.
The reinforcement was arranged in two layers with a concrete cover of 4.5 and 10 cm respectively, using class $Rbk = 30$ MPa concrete on the assumption of a resistance to simple tensile stress of $fctm = 2.6$ MPa.
To reduce cracking due to hydraulic shrinkage, the concrete was made using the combination of a superfluidifying additive with an expanding agent.

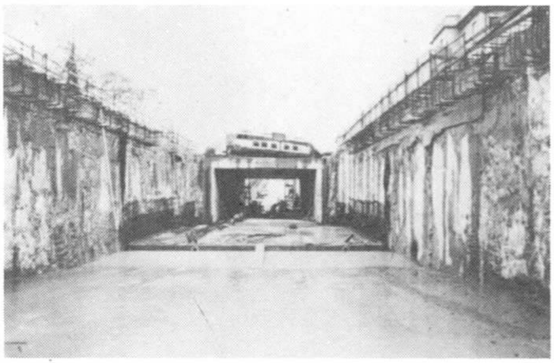


Fig. 6 - Launched monolith

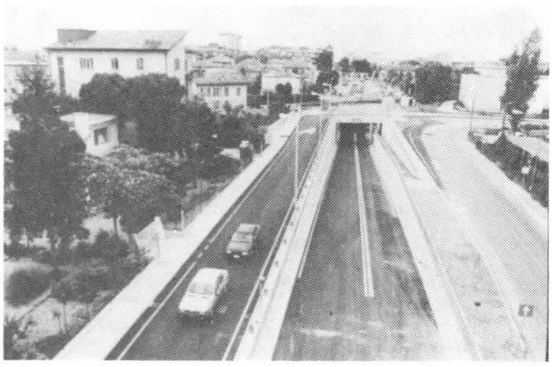


Fig. 7 - View of the completed subway

The superfluidifying additive not only gave the mix the necessary workability (22 cm slump), resulting in a concrete with a lower permeability (due to lowering of the water/cement ratio) and a higher initial mechanical compressive strength, it also enabled a controlled-shrinkage concrete to be produced with smaller quantities of expanding agent.

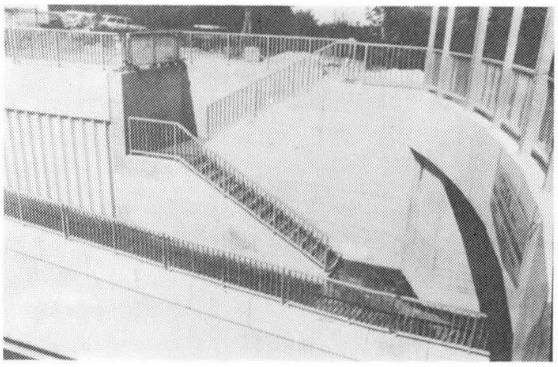


Fig. 8 - View of a flight of steps

The mean shrinkage of the concrete in place after 6 months was calculated in 380 μ / m and the expansive agent was proportioned on this value.

The castings were cured by keeping the concrete wet and protected from evaporation with tarpauline for four days, though the expanding process was over in one day.

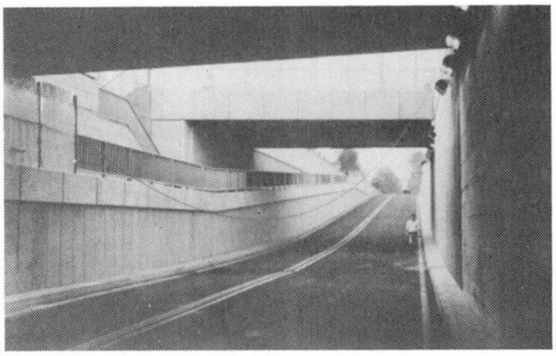


Fig. 9 - View of a ramp

About one month after completion of the castings, the walls of the monolith were waterproofed by brush-application of an impregnating solvent-based primer on the outside; as the roofing slab was susceptible to greater mechanical stress during shifting of the monolith because of the sliding of the metal girders supporting the railway tracks, this was waterproofed with a two-component epoxy resin, which was touched up in any damaged areas after the monolith was in place.

The bottom slab was treated on the inside with elastomerized bitumen before laying the road surface.

6. MONOLITH CONCRETE COMPOSITION AND FEATURES

- Slump : 22 cm
- Cement : 325 Portland - 340 kg
- Dry aggregate max diameter 25-27 mm - 1900 kg
- Water : 170 lt
- Water/Cement ratio : 0.50
- Aggregate/Cement ratio : 5.60
- Compressive strength after 1 day : Rmb = 9 MPa
- Compressive strength after 28 days : Rmb = 36 MPa
- Shrinkage after 6 months : 380 μ / m
- Naphthalene sulphonate polymer superfluidifier (NSP) : 3.4 lt
- Expanding agent with special clinker rich in free lime : 25 kg

7. ACKNOWLEDGEMENTS

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