Milan M5 metro extension – the construction of Lotto station

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Summary

This paper describes the construction of a deep station during the work on the extension of Metro Line 5 in Milan, Italy. Operating in an urban context that included the presence of an existing line (Milan Metro Line 1), the work had to grapple with some very particular problems so as not to interfere with the area's normal city life. Several construction choices and technical solutions were adopted to reduce impacts as much as possible and to suit local needs. The contribution points out the attention to the issues that make this activity so particular for excavation, ground support and structural solutions, and also for the split between civil and tunnel works carried out simultaneously on the same site.

Keywords: *Underground, metro, top-down, precasting*

1. Introduction

Lotto M5 station, situated in the northwest zone of the city of Milan, is part of the extension of the Bignami-Garibaldi Line 5 towards San Siro and stands adjacent to the existing Lotto M1 station, which belongs to Line 1.
The project location is a highly urbanized environment of a residential and tertiary nature. The intervention area is also characterized by intense pedestrian and vehicle traffic, as well as multiple public transport lines.

2. Characteristics of the work

Lotto M5 station is the deepest on the entire Metro Line 5 (approximately 30 metres from ground level to the excavation bottom) and constitutes an interchange with Line 1.

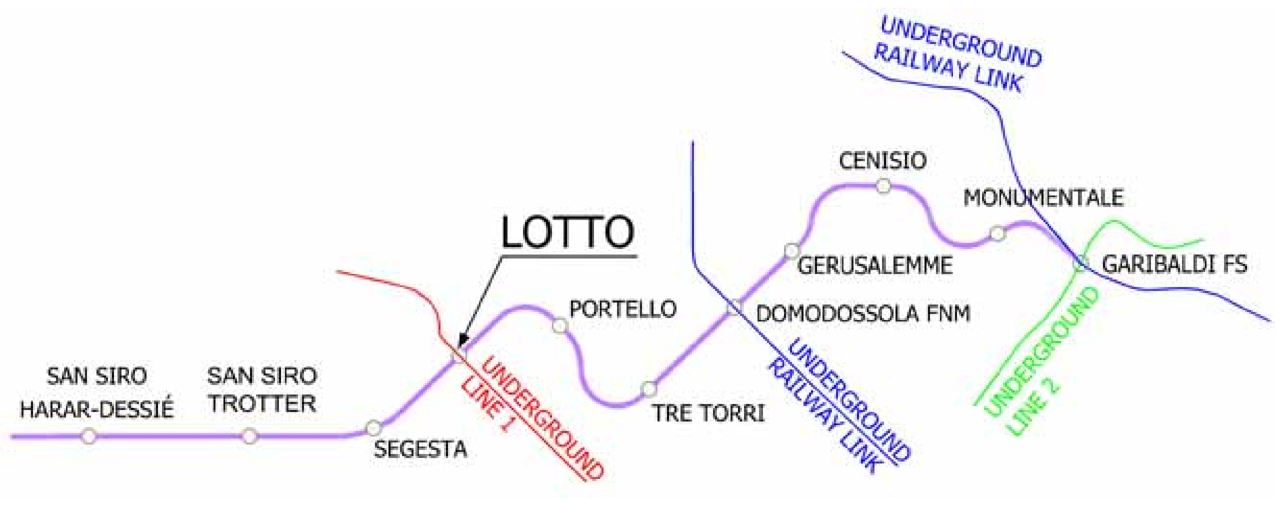

Fig. 1 *Overview of Lotto station on Line 5 extension*

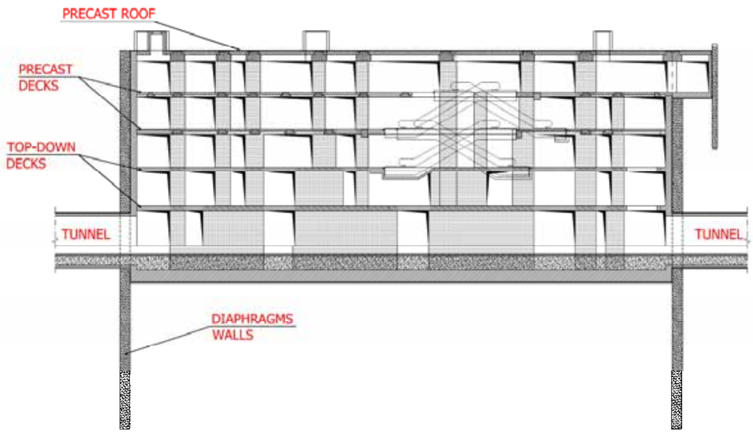

Fig. 2 *Longitudinal section*

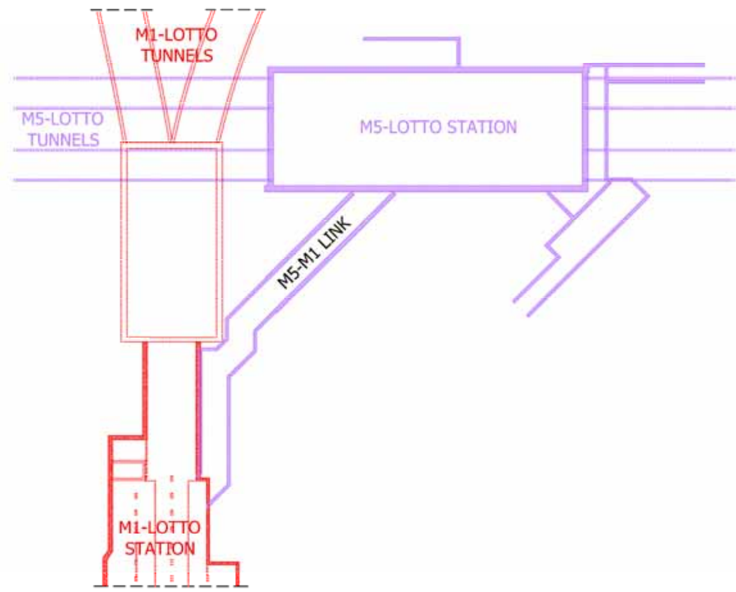

Fig. 3 *Schematic layout Lotto stations and tunnels*

From the realization standpoint, the excavations were supported by reinforced concrete diaphragms with both short and long term uses. The presence of an important hydraulic head (over 15 metres) and the notable excavation depth required the use of a hydromill, a machine able to limit verticality errors and, thanks to interpenetration between primary and secondary diaphragms, ensure good water tightness. During the excavation phases the diaphragms were supported by several rows of steel anchors and struts and by two decks realized with top-down technique. In the long term the diaphragms are supported on the totality of the definitive decks.

Base waterproofing was ensured by means of a series of injections, while adding to the ground a mix of water, concrete, silicate and bentonite. The base slab of the station is connected by means of shear keys to the diaphragms, which, in addition to the weight of the station's internal structures, have a stabilizing function in relation to any long-term floating phenomena.

3. Geotechnical conditions

The context in which the work will take place consists basically of sands and gravels in the presence of the water table. The characterization of the materials in the zone is fairly well known because the city of Milan already has three metropolitan railway lines, an urban link railway line and a large variety of underground structures for different uses. The underground context is also fairly homogenous.

4. Particular design aspects linked to the urban context

As mentioned in the introductory section, some design choices resulted from the insertion of the work in a densely urbanized context characterized by important pre-existing underground structures, constituted for example by the existing Lotto M1 station.

4.1 Two-level struts

The presence of the M1 section adjacent to the new station did not allow the realization of anchors for at least a third of the perimeter. As shown in Figure 4, in this area the anchors were replaced with metal struts. These struts have spans of up to 23 meters and diameters of up to 90 cm (slenderness 70-110).

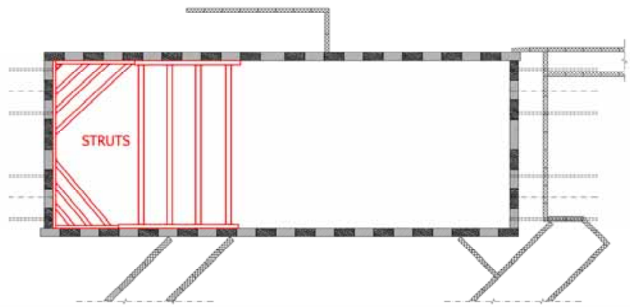

Fig. 4 Struts plan

Fig. 5 Excavation phase

In addition to the usual operational difficulties connected with the realization of the bottom-up casting of the internal structures (e.g., interruption and resumption of reinforcement and pouring of the cavity walls beneath every row of struts) it was a contractual requirement to contain the realization times. This aspect led to the use of prefabrication technology for the three foreseen bottom-up decks.

4.2 False tunnels inside the station

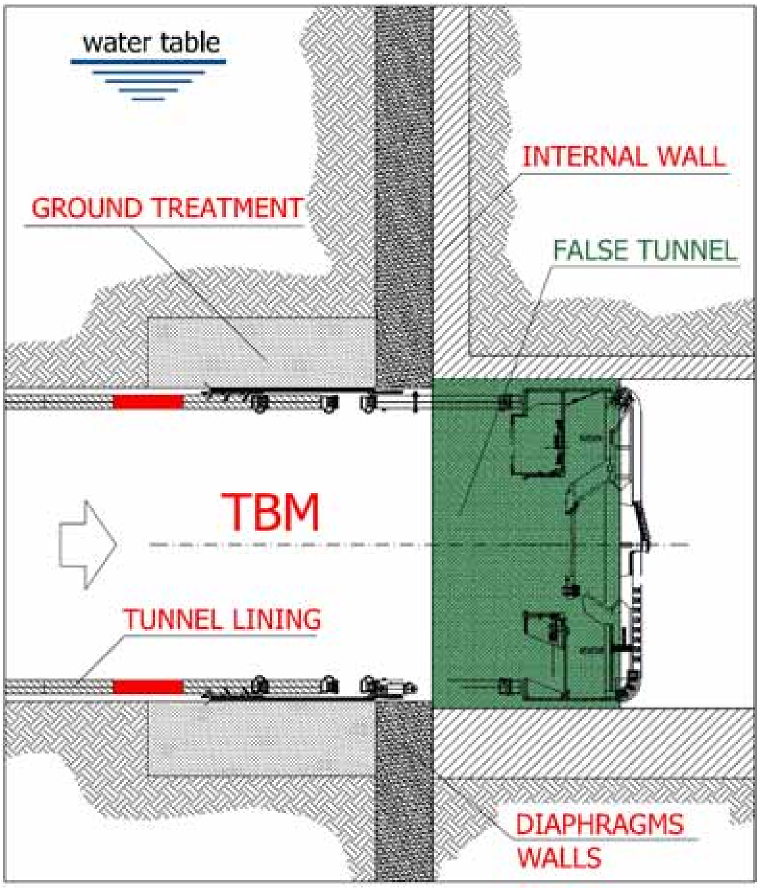

Fig. 6 TBM Break-in

At the entrances and break-outs below the water table of the TBMs from the stations, soil treatments were carried out behind the pilings aimed at reducing the permeability. In order to avoid water inflows in the entrance/break-out phase, the plugs must be sufficiently broad, in the longitudinal sense of the station, to enable assembly of at least one segment ring before the cutter head goes beyond the grouted face. In many cases of excavation in urban environments it is not possible to execute a complete treatment because of interferences with existing buildings or roads. To get around this problem, in the Lotto station worksite it was decided to make false tunnels, thus shifting the entry/exit phase of the cutters laterally within the station.
The dimensions of the concrete blocks that constitute the false tunnels were derived as a function of those of the TBM, and the circumferential framing support for containing the radial pressures of the machine in the thrust phase is disposed externally with respect to the footprint of the shield. To avoid slippage and raising, the false tunnels are connected to the base slab by means of ribbed bars.
For waterproofing in the break-in and break-out phases of the cutters in the station, the advantage that the presence of the false tunnels offers inside the station is that of being usable in the presence of a partial treatment of the soil behind the pilings.
On the other hand, this temporary protection work presents the disadvantage of having to be

demolished in any case since it interferes with the architectural layout of the station.

Fig. 7 *Lotto station TBM Break-in*

4.3 Separation worksite shaft / M1 connection

A further aspect linked to the surface traffic regards the separation, also at the level of preparatory works, between the construction phases of the station shaft with respect to the exits and to the connection with the M1, which in other situations presenting less interference has not been necessary.
In the case at hand, the internal structures of the station shaft, up to the pouring and the backfilling of the roof, were planned so as to divert the traffic on the station. This will make it possible to open the worksite in the adjacent area and to excavate the connecting corridor to Lotto M1 between pilings. Placed between the two structures, the station and the connecting corridor, is a piling of reinforced concrete diaphragms that will have to be cut and demolished to open the connection. The choice of separating the work made it necessary to reinforce the piling, even if subject to future demolition.

5. Particular design aspects linked to worksite requirements

The economic/organizational requirements of the worksite often affect the construction design of an infrastructure work. This section describes some design choices adopted as valid solutions to these problems.

5.1 Steel anchors head above the water table

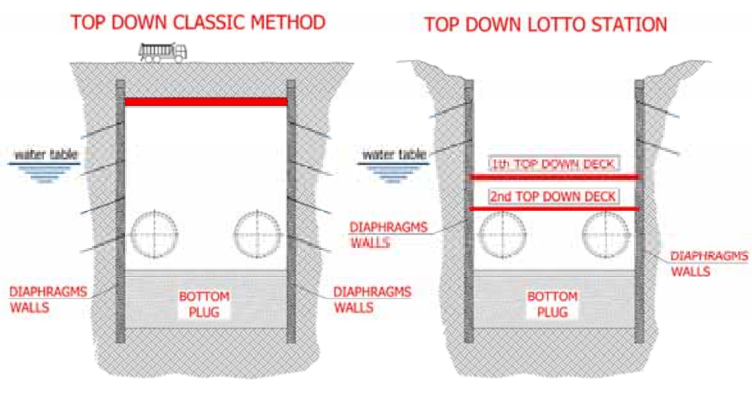

Fig. 8 *Top-down classic method vs. top-down Lotto M5 station*

The level of the water table in relation to the depth of the excavation often requires anchors with submerged head. In these cases it is necessary to use a more sophisticated drilling technology than that which makes it possible to realize anchors above the water table. For this reason the implementing enterprise requested that an alternative solution to the anchors be studied, which led to the use of a mixed top-down method. By this we mean that the decks realized in the first phase, together with anchors above the water table and struts, are part of the horizontal contrast system of the pilings. In addition, in this context, the top-down method was not used in the classic sense which calls for covered excavation. Indeed, intermediate floored retaining walls subject to an important state of membrane and bending stress are realized.

5.2 Top-down decks: opening sizes and pouring phases

Fig. 9 *Top-down decks: opening sizes*

The top-down decks of the Lotto M5 station have a short-term function as horizontal contrast for the pilings, and a long term one in which the slabs are subject to heavy gravitational and horizontal loads. This dual function determines a different load condition and a different geometry of the holes in the short and long term.

In this case the enterprise requested larger opening sizes for lowering materials and machinery for service into the station worksite and the TMB worksite. The construction system used gave the possibility of a separation of the TMB and station worksites. In this way the activities were conducted simultaneously without interfering with each other.

To make the opening sizes conform to the architectural layout, pourings in the subsequent phase were necessary, connected to those of the first phase by means of mechanical joints (threaded/sleeved bars).

Temporary metal struts were placed in critical zones of the slab for more effective redistribution of the membrane stresses generated by the thrusts of the earth and water on the diaphragms.

5.3 Precasted decks

Fig. 12 *Assembly phases of beams and slabs*

In order to speed up the delivery times of the work, the executing enterprise chose the prefabrication solution to realize three floors of the Lotto M5 station, including the roof. The floors are constituted of prefabricated concrete beams reinforced with non-prestressed reinforcement and of slabs, lightened or solid according to the structural needs. The beams rest on the pilasters, dividing walls and supporting walls realized in the work. Structural requirements linked to the geometric complexity of the floor in the area of the side escalators made it necessary to realize some portions of floor during the work.

5.4 Metal columns encased in concrete pilasters

Fig. 10 *Metal support columns, top-down decks*

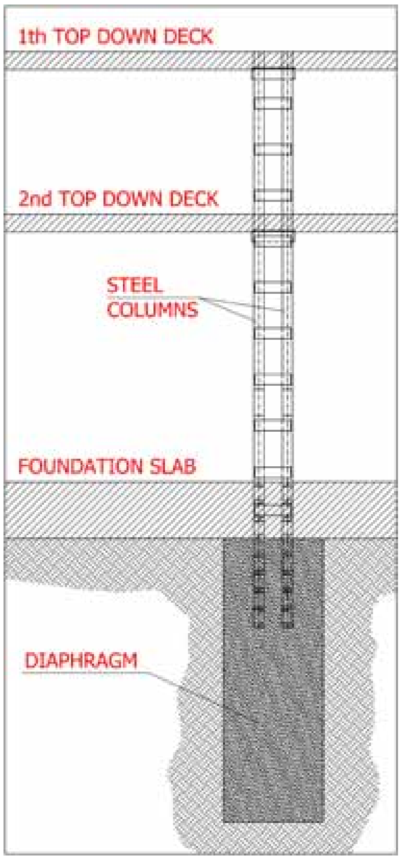

Fig. 11 *Metal support columns - scheme*

The top-down decks were supported in the short term by metal struts founded on reinforced concrete diaphragms (fig.11) realized at the same time as the perimeter pilings. The beams are encased in lean concrete, removed in the excavation phase.
All the metal elements were calibrated so as to be kept inside the reinforced concrete pilasters definitively, although not being considered long term for resistance.

6. References

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