

BRESCIA AUTOMATIC CONTROL LIGHT METRO

BRESCIA, LOMBARDY, ITALY

TUNNELLING - GROUND IMPROVEMENT

Products: Groutmaster SR10S; ETAM 38/27 3v Valved Pipes; EPM 27300 Flex 2C Pol Packer

Project

The Brescia Metro, is an automatically controlled light rail system, which will link the neighbourhoods in north of the City of Brescia to those of the south-east along the historic centre.

The entire line is being developed at different depths: in the Northern area the route will be built in trenches; the historic centre will be crossed in a tunnel, formed by EPBM; the remainder of the track will be built at grade and with viaduct.

Work started in 2004 reached substantial completion in 2012.

Problem

Beneath the "Punto & Virgola" buildings in the business district, it was necessary to perform ground improvement to enable the mechanized excavation of the tunnel by a full section EPBM (Earth Pressure Balance Machine), to minimise the risk of subsidence on the structures above.

The tight project program meant that the improvement intervention had to be completed within 20 calendar days.

Solution

Groutmaster SR10S was selected as the most appropriate ground improvement medium. It was to be injected over a thickness of 3m around the profile of the intended excavation to approximately level of the rail line.

The mixtures were injected in several passes by a volume-controlled system, limited by a pre-set pressure based on wastage minimisation.

The ground influenced by the consolidation can be divided into three zones, according to the schemes proposed in Figures 3,4 and 5.

The difference between zone 1 and 2 is:

- Zone 1 received two passes of treatment
- Zone 2 received a single pass.

Client:

Metro BS

Main contractor:

ASTALDI

Consultant:

BALOSI RESTELLI ENGINEERING

Products used:

Groutmaster SR10S, ETAM 38/27 3v - Valved pipe, EPM 27300 Flex-2C Pol - Packer

Date of construction:

March – May 2009

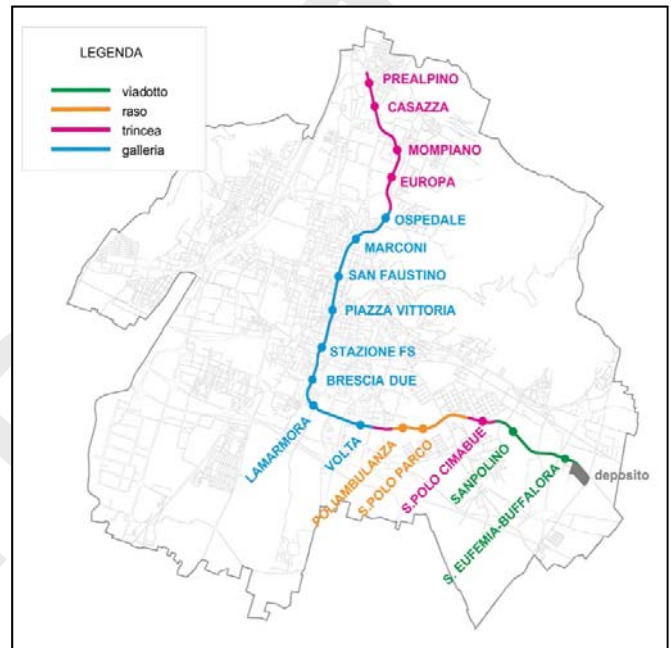


Fig. 1 - Brescia Metro Line

Date: 2004



Fig.2 - Scheduled EPB exit place

Date: March 2009

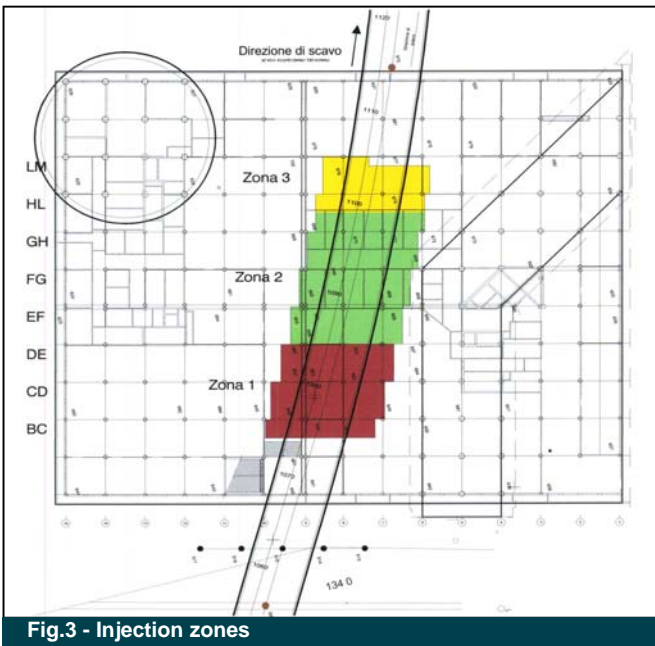


Fig.3 - Injection zones

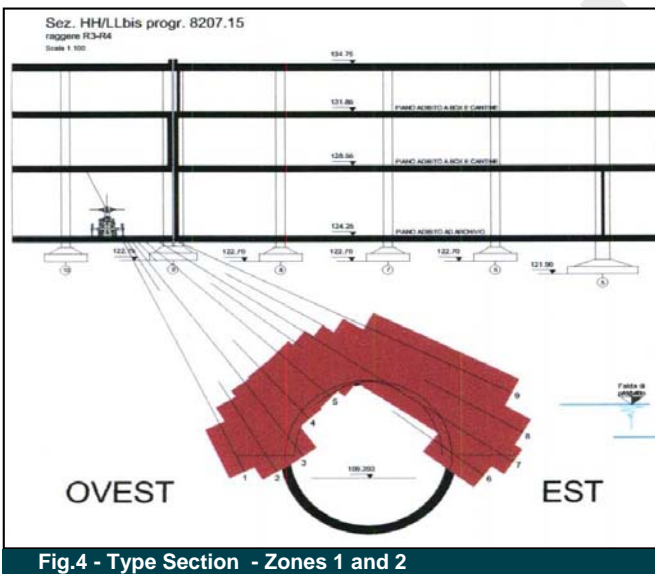


Fig.4 - Type Section - Zones 1 and 2

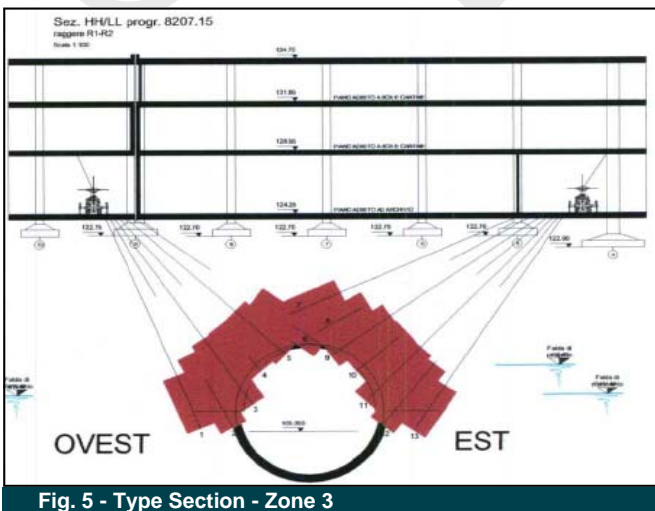


Fig.5 - Type Section - Zone 3

Injection mixture

During the preliminary phases of the project, laboratory tests were performed to develop mixtures and component selection. Specifically, the material had to have a gellification time of around 50-60 minutes, provide enhanced mechanical strength and penetrate the soil with an effective distribution.

Initial laboratory tests enabled the selection of the most appropriate product: Groutmaster SR10. Groutmaster SR10 is a silicate single phase product with an anhydrous dry component, combined with water in a preset proportion.

This result ensures a high degree of mechanical strength to the treated soil, with an appropriate distribution, in addition to the permeability even if the treatment sought was not required.

Tests conducted on sand samples treated with Groutmaster proved the desired results. The treated sand samples, taken from three different positions at different distances from the injection site were cohesive and strong. Groutmaster SR10 offers:

- Consolidation effect: Stable crystalline structure after gellification with an effective cubic strength of up to 4Mpa.
- Low initial viscosity for effective penetration
- Waterproofing effect; Permeability of 10^{-9} m/s after 28 days.

Chemical Mixture detail

- GROUTMASTER SR10 (for 1 litre mixture) 0.57-0.64 kg
- Density (20°C) 1.30-1.37 kg/l
- Initial Viscosity 5-12 cP



Fig.6 - Groutmaster

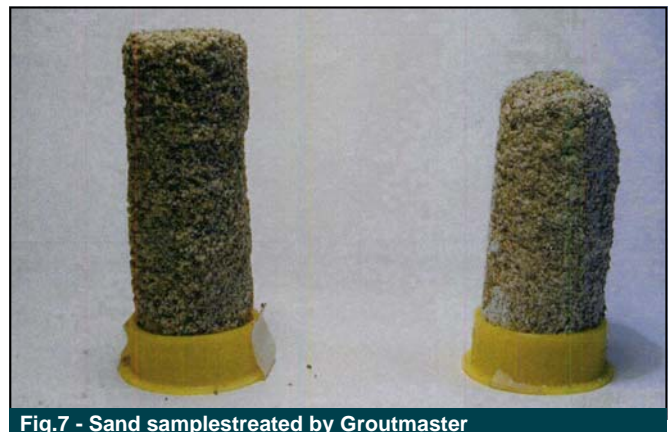


Fig.7 - Sand sample treated by Groutmaster



Figs. 8 and 9 - Mixing and injection system



Date: May 2009

Settlement analysis

Based on experience gained during previous surveys in other sites, Fig. 10, shows a hypothesis of subsidence induced by excavation only.

The green areas were expected to settle around 4.5 mm (areas to be treated). In red areas (which are untreated) were expected to subside between 4.5 and 8 mm, twice the previous average value. The blue area indicates areas where the greatest settlement, is expected; between 8 and 11 mm.

Figure 11 shows the settlement experienced at monitoring points between the beginning of the shift in the drilling and milling.

Analysis of the monitoring data suggests the following:

- In the untreated areas, settlements of around a 10mm originating from the excavation were experienced and taken into account during the project phase; as shown Fig.10.
- In the treated areas, very low settlements of 3 - 5mm were experienced, particularly in areas of entry and exit of the EPBM.
- Toward the centre of the tunnelling pass, an increase in level was experienced of up to 8mm, induced by injection treatment.
- The settlements of the tall buildings "Punto & Virgola" were insignificant and not noteworthy. Differential settlements were also insignificant

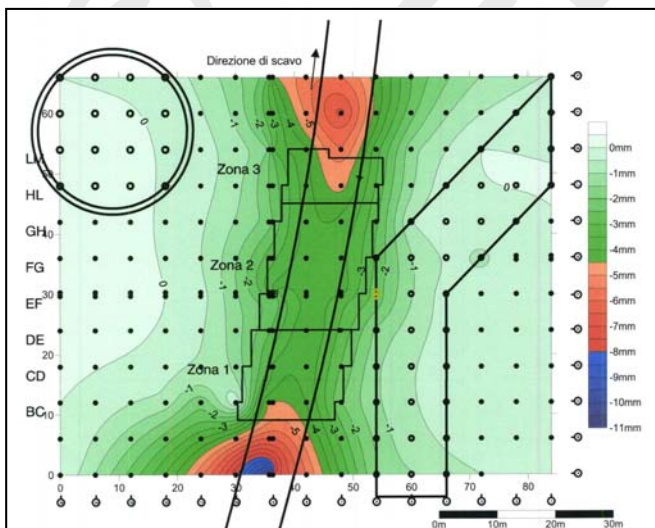


Fig.10 - Hypothesized settlement by the passage of the EPBM

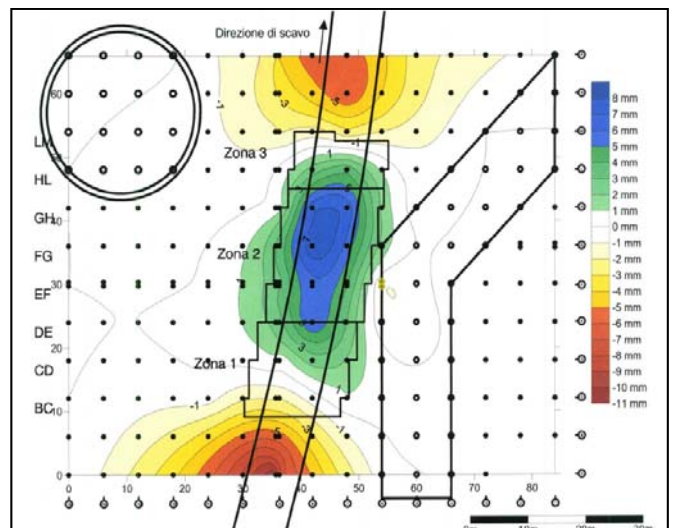


Fig.11 - Recorded settlement between the start of treatment and the passage of the EPBM

Result

The treatment carried out achieved the objectives: the settlement of the structures above were contained and were far lower than was expected without ground improvement. This is despite the tight programme for the works of only 20 days which required that in a single injection pass, around two-thirds of the radial had to be treated. This forcing resulted in the ground swelling/upheaval that was not fully counterbalanced by subsidence induced by the excavation.

The mechanized excavation was conducted without any problems around the EPBM or with the structures above. The Groutmaster SR10S, produced excellent consolidation results from the efficient and effective injection works.



TBM



Injection equipment

The ground improvement featuring injection of the chemical mixture were carried out using specific equipment:

- **EMP 27300 Flex-2C Pol:** Twin mechanical packer for grouting with two leather and plastic sealing caps and a flexible central pipe (which accommodates deformations of the ETAM series pipe better) fitted with valves, during the grouting phases. It is a special packer with different cap diameters available (For details see the appropriate Technical Data Sheet).
- **E-T.A.M 38/27 3V:** Valved rigid PVC grouting pipe, with three valves per meter and produced with a quick-coupling sleeve (For details see the appropriate Technical Data Sheet).



Packer - EMP 27300 Flex-2C Pol



E-T.A.M 38/27 3V

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