The Second Edition of European NO DIG Conference

Segrate (Milan), Italy
25TH May 2023

Paper 7

HDD Horizontal directional drilling used in the construction of the new Metropolitan line in Warsaw, Poland

Lorenzo Pratico[1], Vittorio Manassero[2], Paolo Foppiani[3], Giuseppe Sichel[4]

1 INROCK INTERNATIONAL LTD

ABSTRACT:

The construction of this new metro system in Warsaw city center will obviously affect the equilibrium of the local ground conditions. Of particular concern was the area between Zamoyskiego and Targowa roads, an area comprising historic and preserved listed housing.
In an areas like this one where the soil is inherently unstable and/or composed of loose material works could even cause ground subsidence resulting in significant damage to overlying buildings.
In this section the TBM needed to pass around 10m below the street level.
The consolidation process, which consisted of treating the soil with cement and chemical injections, was utilized to limit the settlement of buildings
The object of the process is to consolidate the ground, providing soil stiffness that allows the formation of a stabilized arch formation in the immediate vicinity of the excavation surface which prevents the spread of tension strain damage in the buildings above.
The soil conditions, which are predominantly loose sands, were deemed favorable for consolidation by cement and chemical injections.
The chemical mixture is required to impregnate even the smallest inter-granular gaps, giving the ground both stronger mechanical features as well as a degree of increased non permeability due to the close proximity of the Vistiola River.
The directional drilling/stabilization process was the most delicate and demanding phase throughout this project.
The design solution proposed consisted of making 48 sub-horizontal drillings, (24 for each tunnel gallery) each of approximately 250m length spread over three rows with a maximum distance of about 1m between each other.

1. INTRODUCTION

Horizontal directional drilling was used in the construction of the new Metropolitan line in Warsaw, Poland
The Metropolitan system of Warsaw is one of the most modern in the world. Presently the system comprises one single line (still being extended) that connects the south and north of the capital city, skirting the Vistiola River for a distance of around 23 kilometres. This line already comprises 21 stations with a track running time of around 30 minutes to travel from start to end station.
A high number of commuters – about 500,000 people every day – and the need to widen the public transport network in this developing city presented authorities with the need to construct a second line linking the west and the east of Warsaw. In this way the metro line should be able to resolve the traffic problems being experienced in the most densely populated inner city areas.

2. Construction phase

On January 24, 2006, Warsaw City Council gave approval for the construction of the second Metro Line which extended for a length of around 31 kilometers extending from the east (Bemowo) to the west (Brodni) of the city.
In late 2009 Italian construction company Astaldi won the contract for the Metro central line together with partners Gülemark (one of the largest Turkish construction design companies) and PBDIM (the largest national construction company of Poland).
The contract signed by AGP (Astaldi Gulemark PBDIM) with the city of Warsaw was for around 3.375 million Zloty (US$1.1 million) and will lead to the completion of the central metro line 2 at 6.3km long with seven stations between the two termini of Rondo Daszynskiego e Dwozec Wilenski.

The subcontractor for the AGP consortium was Icotekne Polska Sp z oo, a polish company established on 09.06.2011 by Icotekne spa.

The section of metro line that extends predominantly underground passes beneath and in between the stations of Powisle and Standion and underneath the Vistiola River.
In order to guarantee greater security the metro line will comprise a pair of tunnels each housing a single track. These tunnels will be bored using a fully automated tunnel boring machine of 6.32 meter diameter.

3. Site installation

The construction of this new metro system will obviously affect the equilibrium of the local ground conditions. In areas where the soil is inherently unstable and/or composed of loose material works could even cause ground subsidence resulting in significant damage to overlying buildings.
For this reason, in the area around the stadium it was necessary to carry out remedial works to prevent subsidence and damage to any surface construction infrastructure.
The subsidence prevention application in focus is located close to the hub near the station, which is an area marked C14, which comprises the stretch of metro linking Stadio station with Treno Vilnius station.
Of particular concern was the area between Zamoyskiego and Targowa roads, an area comprising historic and preserved listed housing.
In this section the TBM needed to pass around 10m below the street level. Moreover the presence of sandy soils ensured that consolidation of the formation was necessary in this area to prevent surface building construction failures.
For the ground consolidation – which needed to be performed under the building foundations without disturbing the surface or cause a worsening of already difficult ground conditions – it was necessary to conduct a detailed technical analysis to assess the potential damage to buildings caused by the construction process.
As a precaution, certain operations were implemented to minimize risk to overland structures.

4. The project

The consolidation process, which consisted of treating the soil with cement and chemical injections, was utilized to limit the settlement of buildings
In particular, what was required was to build a boundary/barrier around the tunnels approximately 3m in thickness using high pressure valve tubing.
The object of the process is to consolidate the ground, providing soil stiffness that allows the formation of a stabilized arch formation in the immediate vicinity of the excavation surface which prevents the spread of tension strain damage in the buildings above.
A cylindrical consolidation zone around the consolidation tubing was designed to be horizontal and extend below the planimetric footprint of surface buildings to avoid the spread of tension-induced deformation at surface due to the advancement of the tunnel excavation below.
The injection mixture and methodology suitable for this type of ground treatment was assessed by careful analysis of the particle distribution curve of the soils and its physical and mechanical characteristics.
The soil conditions, which are predominantly loose sands, were deemed favourable for consolidation by cement and chemical injections.
The chemical mixture is required to impregnate even the smallest inter-granular gaps, giving the ground both stronger mechanical features as well as a degree of increased impermeability due to the close proximity of the Vistiola River.

5 Operations

The directional drilling/stabilisation process was the most delicate and demanding phase throughout this project.
The design solution proposed consisted of making 48 sub-horizontal drillings, (24 for each tunnel gallery) each of approximately 250m length spread over three rows with a maximum distance of about 1m between each other.
The geometric pattern of the stabilisation boreholes made is divided into three sections:
1) A combined curved section from entry to approximately 40m away with a radius of curvature of 100m;
2) A central straight section from approximately 40m to approximately 70m away from entry;
3) A combined curved section from approximately 70m to 250m with a radius of curvature of approximately 330m.
The difficulty of this project resided primarily in boring holes with a combined radius of curvature with high accuracy (around 50cm) in a highly built up area, as illustrated in the following graphical presentations.
This project was unique in completing blind holes of 250m, installing injection tubing that served two purposes:

- Stabilise the hole during the drill pipe extraction phase;
- Inject the stabilisation mixture to ensure ground integrity, thereby permitting the improvement works necessary for the successful completion of the new metro tunnel system.

The stabilisation phase was successfully completed in June 2012 and the TBM passed successfully through these zones with minimal ground disturbance by the end of June 2013.

This article was written by Lorenzo Pratico from HDD drilling tools, equipment, products and services supplier Inrock