A comprehensive monitoring system of mechanized tunnelling in urban area – Automated control of geotechnical measures, topographic surveys, rail tracks geometry and TBM data

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ABSTRACT

This paper aims at presenting some of the technical solutions implemented for carrying out geotechnical monitoring activities at the under construction high speed railway entering the city of Bologna (Italy), on the Milan-Naples railway line.

Construction of the Bologna section foresees construction of two tunnels (6 km in length, 9.4 meters diameter). The tunnels are driven by two Earth Pressure Balance Tunnel Boring Machines (EPB TBM), with 15 m axis distance, underneath the existing and active railway embankment. Soil cover ranges between 10 and 21 meters, with geology varying from a sea clay and loose sandy deposit to a deposit of gravel and sand strata with high percentage of fines both above and below water table. The tunnels run close to major buildings and beneath bridges and other infrastructures.

Tunnels construction requires a comprehensive monitoring system to analyse ground conditions, underground movements and stress-strain change in pre-cast lining segments; as well as surface displacements. Golder Associates – Italy, has designed the monitoring system providing a real time data visualization of all acquired units coming from geotechnical and structural sensors, robotic total station, TBM machines, and electrolevels with the goal of monitoring the existing railway tracks. The whole system provides data to Golder Instrumentation Data Interpretation and Evaluation system (GIDIE) that is a dedicated web application for multiple-party access at different user levels, to gather, manage and store monitoring data.

Keywords: monitoring, database, tunnelling, topographic survey, electrolevels, total stations, data management, GIS web service

1 INTRODUCTION

In common practice structural engineers use a Section interested by construction intervention stretches within the urban area covering a total length of 6,700 meters; majority of the tack (5,700 meters) is located underground, where two parallel tunnels are drilled with a relative displacement of about 400 meters of a EPBM with respect to the other. Drilling activities started in June 2003.

Geology of the area interested by the project is initially characterized by the presence of clay, whereas farther portions of the tunnels and going to be drilled in sand and gravel layers; the average soil thickness covering the tunnels vary from 20 to 26 meters.

The complexity of the project requires the capability of the monitoring system to take care of different interconnected elements. Classic issues related to tunnelling operations have to be considered, along with others related to the fact that tunnels are driven beneath the existing railway embankment having the highest traffic density within Italy and within a urban area highly populated.

Complexity of the project reflects in the complexity of the monitoring plan, which encompasses different technologies and data gathering systems supplying data to a centrally managed database and a web application allowing users accessing data in a controlled and traceable way.

The following monitoring activities have been implemented within the system:

- structural and geotechnical monitoring
- automatic topographic survey monitoring by means of total stations
- monitoring or rail tracks geometry by means of electrolevels
- EPBM parameters monitoring.

All the monitored data are collected through a dedicated Web server which allows users to get accessibility to the monitoring data, querying the

database and displaying results by means of a WebGIS dedicated application named GIDIE.

2 STRUCTURAL AND GEOTECHNICAL MONITORING

The geotechnical section of the monitoring plan is done by means of 16 automatic topographic survey sections located at varying distances along the tunnels' path at significant locations for the drilling parameters to be gathered.

The following devices have been installed:

- in-hole multi-base extensometers
- electrical piezometers capable of monitoring interstitial pressures through a multi-level groundwater table
- removable in place inclinometers with the aim of monitoring displacements related to the tunnelling activities
- strain gauges in some tunnels' concrete rings
- electrical crack-meters with the aim of detecting fissures which might occur in existing buildings and infrastructures
- pressure transducers.

The devices listed above supply data to in-the-field automatic dataloggers located next to the monitored sections; from dataloggers data are sent through the GMS connection to a central server which collects data and stores them in a centrally managed database, and make them available for users on the Web.

3 AUTOMATED TOPOGRAPHIC SURVEY SYSTEM

The surface movement are controlled by monitoring of about 230 cross topographic sections with a span of 25 meters. Each section is made up of 8 prisms. Sections are installed and removed along the tunnels' path with the proceeding of their driving, ensuring control of the amount of subsidence 50 m ahead of the first EPBM and 130 m back of the second one. In this way only a reduced number of Total Stations, varying from 4 to 7, is needed for covering the area of the subsidence basin.

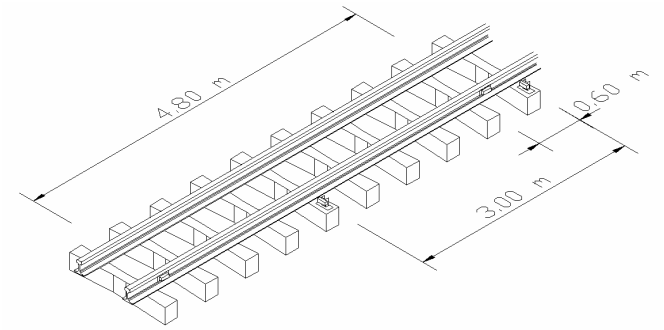
With a time span of 3 hours, displacement data are collected by measuring the position of the whole set of prisms in place (about 150-200 prisms are measured at each time).

Similarly to the geotechnical sections, the total station's data are collected by means of GSM on a web server and made available to the web application.

4 RAIL TRACK MONITORING

The railway displacement are controlled with a series of a Electrolitic Tilt Sensors. These sensor are installed onto the rail track in two different orientation:

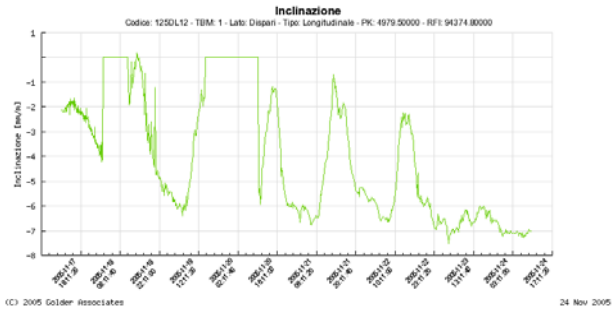
- on the long axis of the rail track (Longitudinal Tilt)
- on the long axis of the ties (Transversal Tilt).

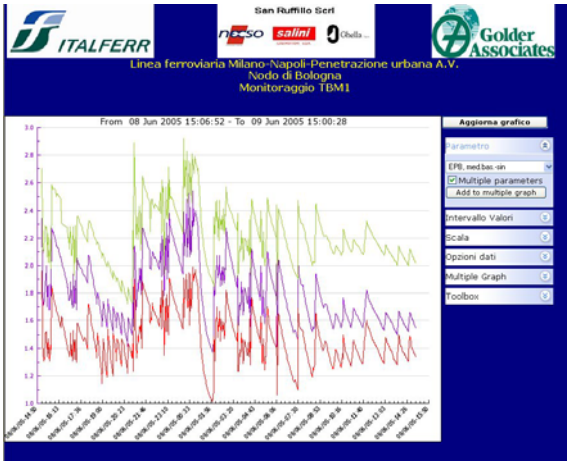


Longitudinal Tilt measures the variation of inclination of the rail track while Transversal Tilt measures twist of the rail track that is defined as difference of transversal inclination on a 3 meters stretch base. Tilt sensors are installed and removed along the tunnels' path with proceeding of their driving: longitudinal tilt are installed with a span of 4,8 meters, transveral tilt with a span of 3 meters.

Data from Electrolitic Tilt Sensor are acquired with a time interval of 5 minutes and data are col-

lected through GSM connection, processed and uploaded to the Web Server for real time data interpretation.

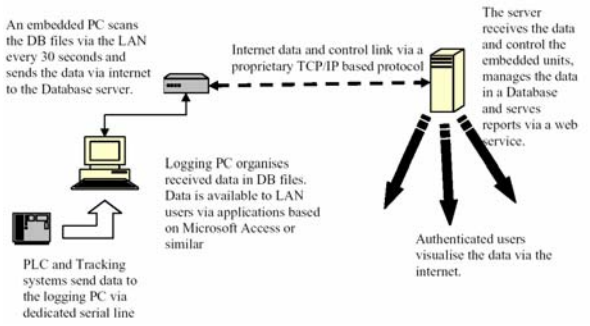




5 TBM WEB MODULE

Golder Associates was also asked to develop a dedicated web application with the goal of managing operational parameters of the two EPBMs, requiring real-time data to be available on the Web.

This application is based on a client-server configuration. A small embedded PC unit is located on-site, and is connected via the Local Area Network (LAN) to the contractor's PC which logs data coming from the two EPBMs. The embedded unit accesses the logging PC to look for new data every 30 seconds and sends the data via the internet to the Main server located in the Golder office. The server receives the data from the embedded units and stores them in the database to be shared to authenticated users in the form of graphs and reports via internet.

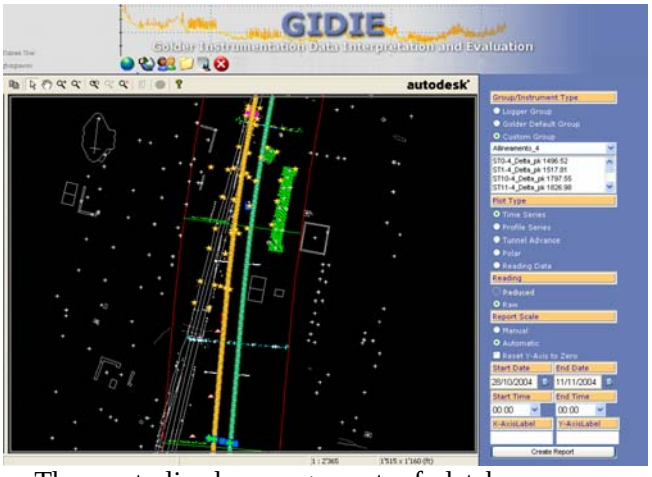


The typical output web page is presented in the following screen. Parameters can be shown with reference to date of advance as well as to the concrete ring installation.

Two hundred parameters are collected for each TBM and immediately published on the web

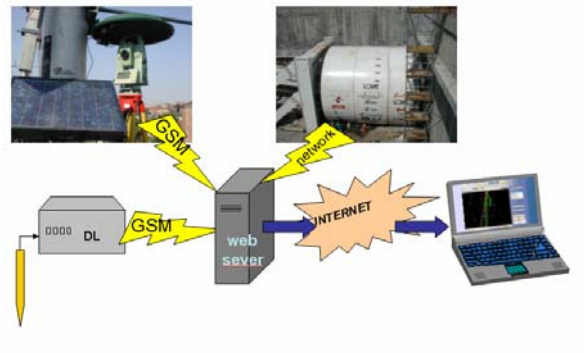
6 GIDIE WEB DATABASE

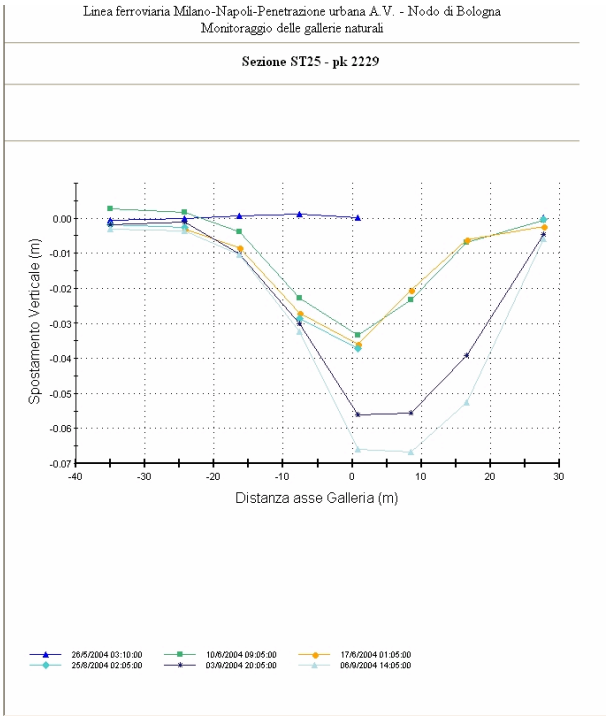
GIDIE is a web-based application specifically developed by Golder for a comprehensive monitoring system of mechanized tunnelling. The application is based on a relational database which stores monitoring data and which can be interrogated by users via a dedicated web interface. Users are given the capability of querying the database and display results both by means of tables as well as graphs; data can be exported by users in different formats suitable to be fatherly analyzed or inserted in reports. The database has been provided with a WebGIS interface, providing users with an dedicated interface for interrogating and displaying data having a spatial component.



The centralized management of database ensures consistency of data while avoiding redundancy of data which need to be shared among users; the possibility for users to get access to real-time data represents also the key element in highlighting anomalous conditions which may arise during the tunnelling process.

The power of having the whole data available in real time on the web allow the client, the construction management and the designer to control real time information on the progress of the tunnelling, on the settlement induced by the excavation and on the EPBM parameters. This enable an enhanced safety of the system providing a key for addressing corrective actions on the tunnel driving as function of soil condition changes and EPBM parameters adjustment.





7 CONCLUSIONS

Golder Associates designed, developed and deployed a monitoring system for a major infrastructure as the construction of two tunnels entering in the urban area of Bologna. The system allows the real time data interpretation trough the web, of all the data coming from total stations, from geotechnical sensors, strain gauges embedded in precast liners, EPBM unit, and rail track electrolevels.

This enable both owner, contractor and construction management to get accessibility to real time information on the progress of the tunnelling, on the settlement induced by the excavation and on the EPBM parameters. This provides enhanced safety of the system and a key for addressing corrective actions on the tunnel driving as function of soil condition changes and EPBM parameters adjustment.

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