Geotechnical and structural monitoring during doubling of a transportation corridor: first insights and lessons learned from a dense monitoring network

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Abstract

Transportation corridors are nowadays more and more crucial for the social and economic systems of the place where they are located. The huge impact of failures on these assets can lead to severe consequences, both from the economic and the safety point of view. In this context, Geotechnical and Structural Monitoring (GSM) can be a powerful tool for an effective maintenance of transportation assets and for safety purposes during new construction works. Thanks to the technological evolution that has occurred during recent years, several monitoring technologies are now available to perform monitoring with such a purpose.

This work focuses on the role of GSM within a doubling of a State Road stretch over a distance of 3.1 kilometres in the municipality of Valfabbrica (Perugia, Italy). This stretch of road includes 2 tunnels, with lengths of 874 metres and 1,545 metres, as well as 2 viaducts.

In addition to the standard instrumentation (e.g., load cells, strain gauges, total stations; inclinometers and piezometers, etc.), the monitoring project was integrated with improved and innovative solutions (e.g., Terrestrial and Satellite SAR Interferometry, distributed fiber optics, PhotoMonitoring™, etc.). This, in order to increase the level of control and safety through a knowledge, control and emergency monitoring, able to provide information on the evolution of slopes and structures affected by the works.

Keywords: Geotechnical and Structural Monitoring, Transportation asset, Monitoring

1. Introduction

The present work is focused on the role of geotechnical and structural monitoring during the construction of new linear infrastructures (tunnels and bridges) near Perugia in the Central Italy called SS 318 "di Valfabbrica". The construction works, which started in November 2020, have been entrusted by ANAS S.p.a. to Valfabbrica 2020 S.c.ar.l., a consortium formed by Donati S.p.A. and NV Besix SA. The geotechnical and structural monitoring has been committed to NHAZCA S.r.l., a Startup of Sapienza University of Rome.

The intervention, which will make it possible to completely standardize the Umbrian route of Perugia-Ancona to four lanes, consists in the construction of the second carriageway of the S.S. 318, alongside the existing one opened to traffic in 2016 as a variant to the old route of the state road. The duration of the works is expected to be about 3 and a half years.

The portion of roadway to be doubled, in particular, is about 3 km long (between the progressive 16+224 and 19+354), including the "Casacastalda" tunnel (1,545 m) and the "Picchiarella" tunnel (874 m). Two viaducts for a total of 190 meters are also included: the "Tre Vescovi" and the "Calvario" (Fig.1). Because the adjacent section has already been constructed with 2 lanes, only the left carriageway will be built.

Figure 1: View of an area of the construction site with one of the main viaducts under construction in the foreground (Picture from ANAS S.p.a.).

2. The monitoring network

Within this project, in addition to the construction works, a particular emphasis was placed on the monitoring plan. As a matter of fact, the planned road layout is inserted in a complex geological-geomorphological context, mainly involving the lithoid units of the marly-arenaceous and the eluvial-colluvial units and their alteration. In some limited sectors, the road stretch works will intercept landslides and eluvial-colluvial deposits of variable thickness, even relevant. The tectonic context is linked to the Apennine and post-Apennine deformation phases, documented with significant seismic events in the area of interest. Also, during the construction of the original road, now open to traffic since 2016, a collapse occurred during the excavation of a tunnel. For such a reasons, the geotechnical and structural monitoring activity performed on the whole area affected by the works is of particular interest. The planned instrumentation consists of numerous and mixed monitoring sensors, selected according to the parameters to be measured and the structures to be monitored (Fig.2). Most of the sensors are configured for automatic and continuous data acquisition and transmission, through the installation of data loggers and data transfer units.

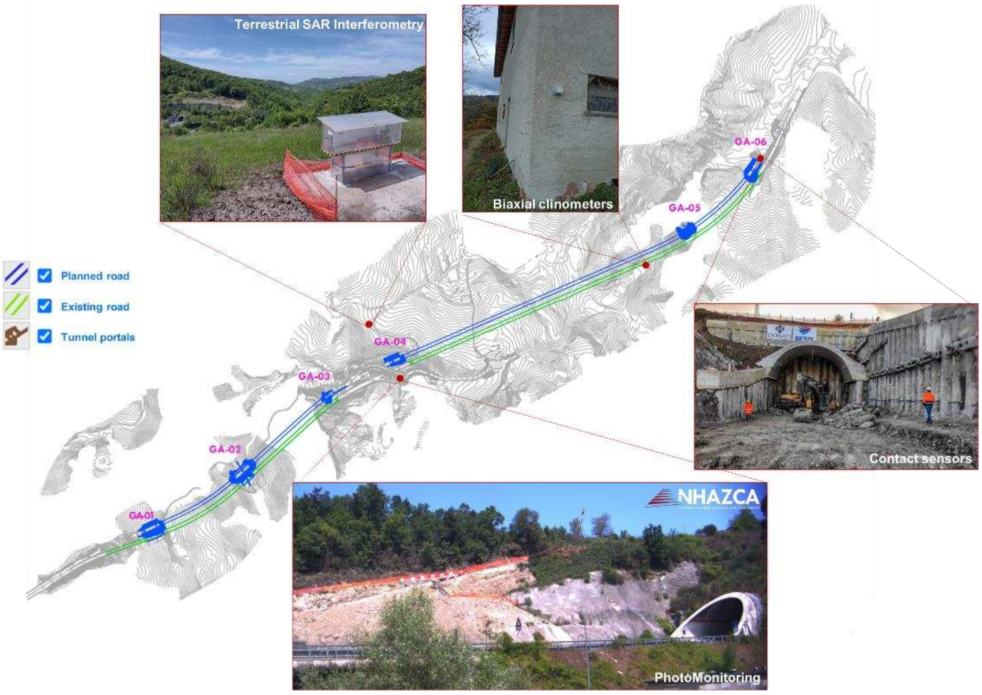

Figure 2: Project layout with evidence of the existing road, the project road, tunnel portals, and some monitoring sensors installed.

In this context, NHAZCA has been dealing, starting from November 2020, with geotechnical and structural monitoring of the road section being worked on by the company Valfabbrica 2020 S.c.ar.l. The monitoring activities consist of the supply, installation, and management of all the instrumentation required by the project. In detail, the activities can be summarized as follows:

- Design of the monitoring plan, in close collaboration with the design team of the construction company.
- Supply of sensors and accessories on time during the various phases of the work progress.
- Installation by specialized technicians.
- Regular maintenance of the installed instrumentation and data transfer.
- Preparation of installation and monitoring reports.
- Management of the acquired data.
- Management of the web platform for data distribution.
- Control and interpretation of data (Fig.3).

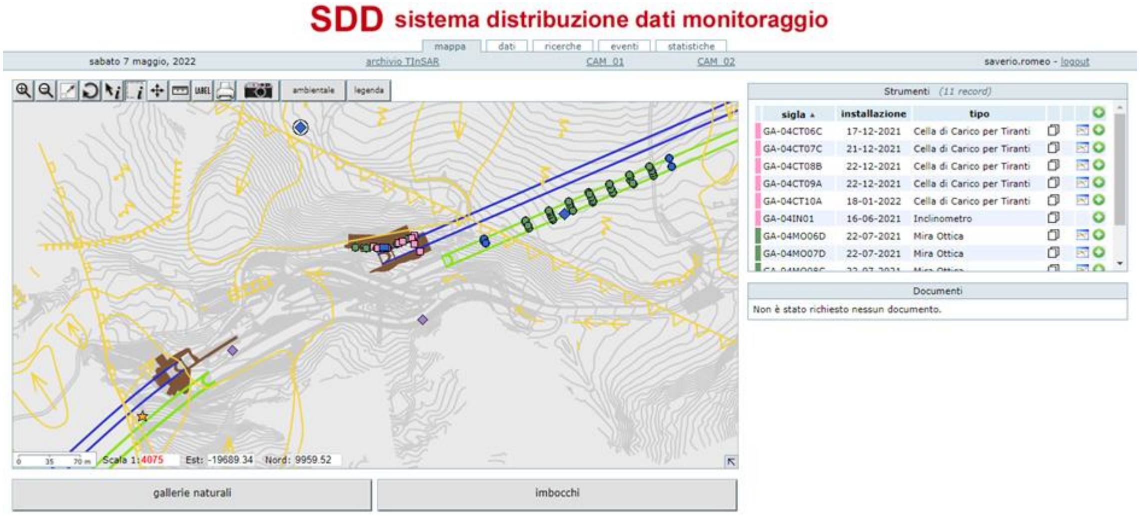

Figure 3: View of the web platform for monitoring data distribution.

Below is a summary list of the instrumentation used and the services provided:

- Load cells for use in tunnels, stabilization struts and reinforcement bulkheads.
- Strain gauges for use in tunnels and for the monitoring of deformations in concrete.
- Automated Motorized Total Stations and prisms for topographic measurements.
- Extrudemeter for excavation face detection.
- Inclinometric readings to monitor subsurface deformations of the ground.
- Piezometric readings to measure groundwater levels.

The activities already planned in the project phase have been integrated, on request of the construction company, with a series of innovative and improving solutions to increase the level of control and safety. This through a knowledge, control and emergency monitoring able to provide information on the evolution of the slopes affected by the works in progress and on possible interferences with the surrounding landscape and existing works. The integrations and the related updates have been designed for a faster management of the information flows, also providing an automatic and continuous monitoring. The main technologies used concern:

- Automatic inclinometers to monitor continuously subsurface deformations of the ground.
- Biaxial tilt sensors to monitor structures affected by rotations and inclinations.
- Weather station to monitor real-time environmental changes and make corresponding warnings.
- Terrestrial SAR interferometry (TInSAR) for high-accuracy measurements of slopes and structures.
- Satellite SAR interferometry (A-DInSAR) for the estimation of surface deformation processes.
- PhotoMonitoring^{TM} to map and monitor the displacement pattern of unstable slopes.
- Distributed optical fibers for strain measurement on the walls of the existing tunnel.

Below (Fig. 4) are shown some elaborating results of the ongoing monitoring at one of the inlet bulkheads of the new tunnel. Specifically, the results, in terms of time series, of i) load cell for use in reinforcement bulkhead (yellow dot), ii) inclinometric readings to monitor subsurface deformations (red dot), iii) prisms for topographic measurements in the existing tunnel (green dot), iv) strain gauges in construction tunnel (blue dot) are shown.

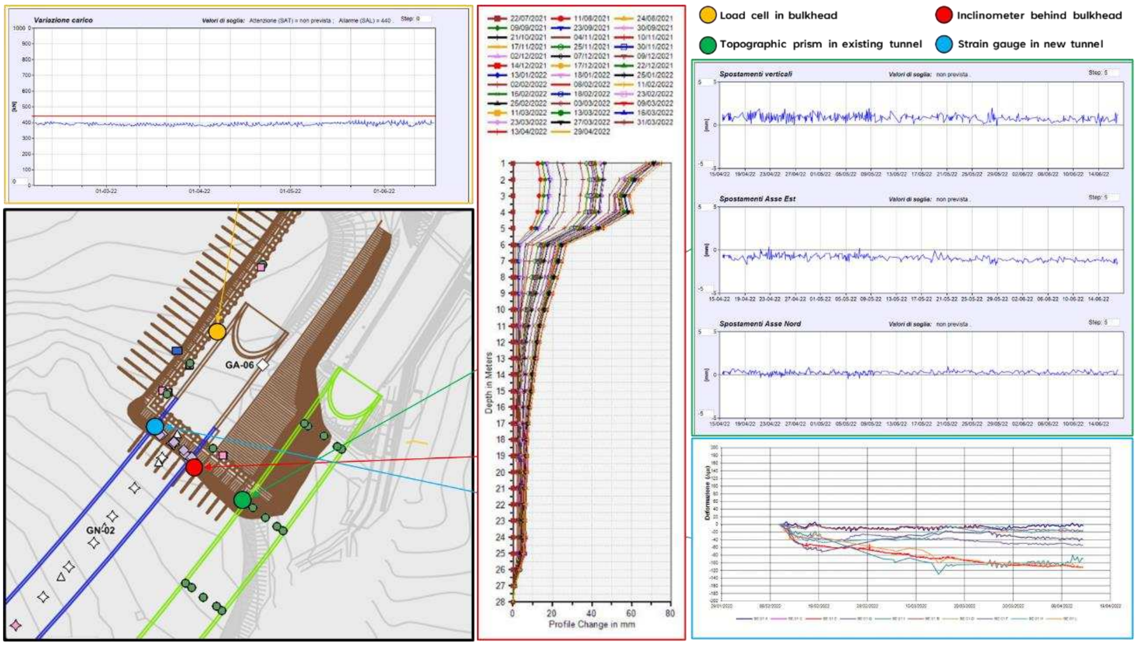

Figure 4: View of the elaborating monitoring results displayed in the web platform for data distribution.

3. Discussion and Conclusions

This work describes the monitoring activities carried out in the context of a road stretch doubling of about 3.1 kilometres in the municipality of Valfabbrica (Perugia, Italy). This road stretch includes 2 tunnels, with lengths of 874 metres and 1,545 metres, as well as 2 viaducts.

Particular attention was paid to the role of Geotechnical and Structural Monitoring (GSM) as powerful tool for safety purposes during new construction works. In addition to the standard instrumentation (e.g., load cells, strain gauges, total stations; inclinometers and piezometers, etc.), the monitoring project was integrated with improved and innovative solutions (e.g., Terrestrial and Satellite SAR Interferometry, distributed fiber optics, PhotoMonitoring™, etc.). This, in order to increase the level of control and safety through a knowledge, control and emergency monitoring.

The added value in using a combination of remote sensing techniques and contact measurements can be extremely beneficial in GSM, especially during infrastructure constructions in critical areas. As an example, Remote Sensing monitoring techniques (e.g., Satellite InSAR) can be used over widespread areas to identify discrete locations, where to focus in-situ monitoring activities, and or survey to better characterize the observed phenomena. In fact, to monitor a specific parameter, the most suitable technique, or a combination of techniques, should be properly assessed according to the general purpose and the site-specific conditions.

In consideration of all these aspects, the design of monitoring activities is becoming more and more crucial, and which serve to provide for more efficient and cost-effective monitoring for the safety of construction works.

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