The role of geological analysis in the design of interventions for the safety of the road asset. Some examples.

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The Design Management - Geotechnical Unit of ANAS (National Public Road Company) is often involved in study and monitoring activities regarding some instability events affecting the road asset; generally, those events tend to compromise the functionality of the infrastructure.

These circumstances are generally caused by geomorphological, hydrogeological or stratigraphic arrangements, and triggered by specific rainfall conditions that tends to modify the whole stability of the road body and the slope complex as a whole. In particular, as examples of ANAS experiences, two case histories are illustrated. Both situations concern reinforced embankments that, following rainy periods, have shown strong evidence of instability.

In order to size the stabilization measures, necessary for the road restoration, a thorough study of the phenomenon, in both cases, was developed. It was realized by different stages of investigation and monitoring of roadway displacement.

In addition to a thorough geological and geomorphological survey, useful in the identification of particular instability surface forms, specific site-investigation campaigns were prepared and completed by the installation of topographic, geotechnical and interferometric monitoring instruments. At the same time, the geometry of the instability and the evolution mechanisms of the movements were quantified, determining the relationships between the movements and the external conditions, especially the meteorological and hydraulic ones.

This analysis is aimed to obtain all the information useful to define the lines of action that ensure the final safety of the road asset.

Keywords: Road embankment; Instability; Strains; Stabilization.

1. Introduction

Road infrastructures are designed keeping into account the stresses deriving from the modifications of the environmental context that includes them, in order to guarantee their functionality during their whole life. In recent times there have been examples where stretches of road embankments, built in geomorphological contexts and hydrogeological conditions of particular sensitivity, have shown over time, as a result of particular climatic conditions, internal deformations greater with respect of those provided by the project and tolerable from the structure.

The case-histories illustrated as follows relate to earth-reinforced embankments that, following rainy periods, have shown strong evidence of instability, which have partially compromised their functionality, leading to the temporary closure to traffic of the road sections. The Geotechnical Unit of the Design Management of ANAS S.p.A., frequently interested in the study of this kind of events, has been involved in the study, monitoring, site-investigation activities, in order to identify the causes and the mechanisms of instability evolution in act and, finally, to propose and design the stabilization solutions.

Subsequently, in order to acquire all the knowledge necessary to understand the geological and geotechnical reference context, as well as to establish the project interventions of final consolidation of the embankments, specific site investigation campaigns have been prepared, completed by instrumental and monitoring survey. These campaigns consisted of the realization of boreholes pushed deep inside the laying surface of the embankment, with the aim to reconstruct the geological reference model and the thickness of the embankment involved in the movement. The monitoring consisting, however, in the implementation of several independent topographical, instrumental and interferometric systems of reading, as well as instrumented sections such as inclinometers, assestimeter, piezometers, mechanical fessurimeter, optical targets, in order to evaluate the areal extent of the instability phenomenon and to record the different rates and trends of the displacement.

2. Case histories

Two examples of damages occurred inside hearth-reinforced embankments, part of the italian road network, are after described. In that cases it was necessary to analyze the events and, therefore, to design the consolidation works and safety settings, in order to restore the circulation of traffic. Despite the two cases are concerning two different environmental and climate context, in both the events the main factor was represented by the rainfall seepage inside the slope of the road body. In fact, the main instability happened after long rainy periods. The consequent growth of the pore pressure, with the exceeding of the shear resistance of the embankment-slope system, therefore, triggered the strain events.

2.1 Rome hinterland

In December 2010, along an important road, following a prolonged rainy period, there has been a deformation phenomenon with significant proportions, that affected a stretch of the reinforced embankment, causing the partial closure to traffic of the road.

Fig.2.1.1 - Damages and tension cracks along the roadway

In the first emergency phase a provisional safety intervention was prepared by means of a drainage system and installation of metal gabions, in order to lower the pore pressure and, at same time, to create an overload to the foot of the slope, with a stabilizing function. A campaign of site-investigation, instrumental and topographical monitoring was subsequently implemented. It included the execution of 13 boreholes, the use of three piezometers, one inclinometer and one assestimeter, with cadenced readings.

The acquired data have allowed to define a very detailed geological reference model, centred on the instability area. It is represented by geological formations belonging to the prevulcanic sedimentary sequence of the Roman area, consisting, for the most part, by sands and gravels, with clay and silty levels, oxidized horizons and peaty levels, referred to beach and infralittoral and, furthermore, to fluvial and brackish depositional environments. These deposits are followed by pyroclastic materials, belonging to the Sabatini Mounts volcano, with cineritic matrix with pumice. They contains, sometimes, slag and lithic lava and volcaniclastic reworked levels.

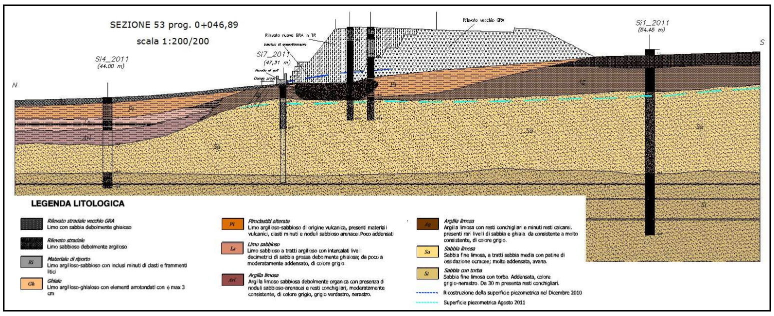

Fig.2.1.2 - Cross geological section in the damaged site

The geological and hydrogeological models, so defined, showed that the sand deposits underlying the road embankment contain an appreciable water circulation that influenced the equilibrium conditions of the roadway. This aquifer is of semiconfined kind, because it’s enclosed between the pliocenic clayey substrate (to the bottom) and a layer of silty clay (to the top). Because of a prolonged infiltration due to the rainfall, the sandy aquifer has developed a growth of the pore pressure and the rising of the piezometric surface. It caused filtration phenomena within the body of the overlying embankment, and the creation of a sliding circular surface, placed immediately behind the reinforced-heart body .

The definitive safety interventions consisted of the realization of a bulkhead of large diameter piles, interventions of consolidation of the soil and, furthermore, of civil works of water gathering.

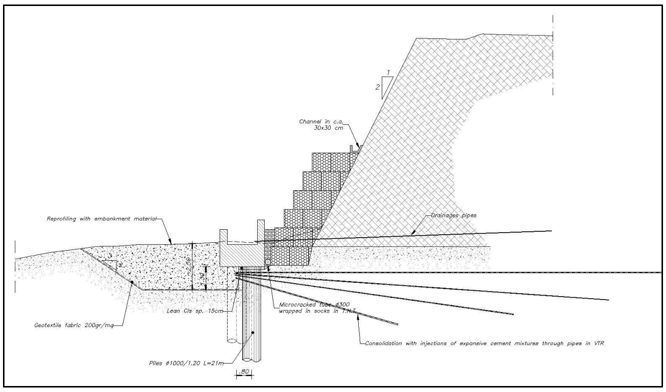

Fig.2.1.3 - Cross section showing the stabilization works

2.2 Liguria – (Northern Italy)

In the Imperia province (Liguria – Northern Italy) a section of road interchange, consisting of a series of ramps located along a slope and supported by reinforced embankments, suffered the first signs of instability in early 2011, as a result of high rainfall intensity events, that have affected the whole Region.

Following the deformational events, preliminary works were made. They were represented by draining trenches above the road and, later, by local consolidation works of the enbamkment.

Between the months of October and November 2012, because of the repeatition of high intensity and long-term rainy events, a recovery of deformation was recorded, causing the appearance of large tension cracks along the road surface, which led ANAS to define a complete consolidation design of the body of the embankment.

Fig.2.2.1 - Overview, from the opposite slope, of the road interchange

At this point, another intervention has been made, represented by the realization of sub-horizontal drains in the body of the embankment. A monitoring plan has also set up, in parallel with a deep geotechnical site-investigations campaign, represented by 69 topographic control points, 10 inclinometers, 4 assestimeters, 10 piezometers, 7 mechanics fessurimeter and the implementation of an interferometrical monitoring, after described.

The complex of the acquired data have allowed to identify a reference geological model, represented by a calcareous-marly substrate, belonging to the “Borghetto d’Arroscia-Alassio” and “Moglio-Testico” Units, which with “S. Remo-M. Saccarello” Units constitutes the "Flysch with Elminthoides" Formation of Ligurian-Piedmont Domain. The substrate is covered, in surface, by a layer of eluvial-colluvial deposits, with significant clay content. The site-investigations have also shown the presence of a main sliding surface inside the cohesive materials that covers the bedrock, immediately below the reinforced embankment affected by the deformation, together with evidence of waterflow inside the fractured part of the rock mass.

So, works of definitive stabilization were realized. They consist of two lines of bulkheads with large diameter piles, with the aim to support the actions of pushing from upstream and to anchor the embankment to the rock substrate. The second bulkhead has been placed on the foot of the embankment and it also reach the bedrock. The works are completed with drainage works along the slope upstream of the embankment.

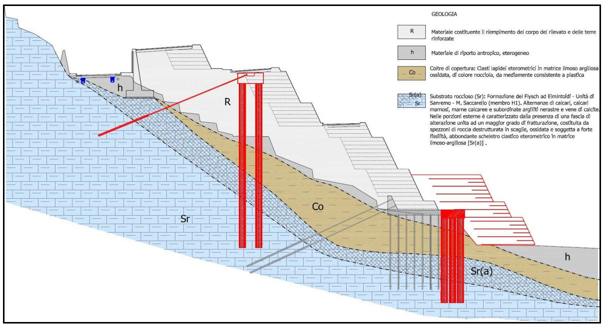

Fig. 2.2.2 - Cross geological section, completed with the designed stabilization works

2.2.1 Interferometric monitoring (Nhazca data): comparison before and after the interventions.

For the evaluation of the areal extension of the instability phenomenon and for a determination of the rates and trends of the displacements, a monitoring station with SAR interferometry Terrestrial (TInSAR) has been installed, by Nhazca (spin-off of La Sapienza University) on the opposite slope. Through this technique, chromatic maps of the survey area were obtained, calculated by comparing the phase value of each pixel of images acquired at different times, that represent the bidirectional movements along the line of sight of the instrument (line of sight).

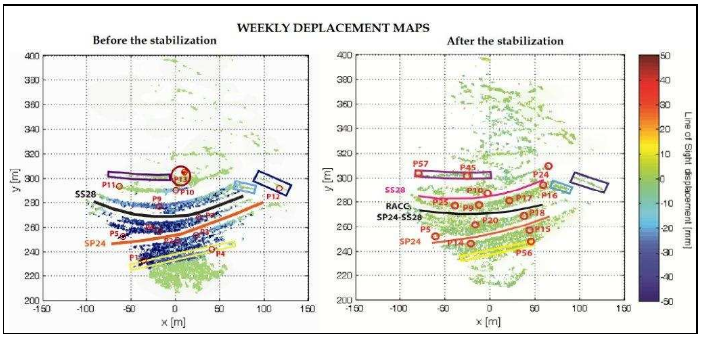

Fig. 2.2.1.1 - Shift TInSAR map before and after the stabilization works

The magnitude of displacement in the following time, from the monitoring network installation, were between -1.5 and -3 mm/day, on approach to the sensor along the line of sight. The embankment has undergone major shifts at the base and in the most western part, while further upstream and eastern portions the movements were more contained. The terrains beyond the foot of the embankment, retaining walls at the entrances of tunnels and the wall on the side of the embankment, however, have undergone no appreciable movement. The rates recorded over the entire displacement have undergone a gradual deceleration in subsequent periods from the initial movement. Just after the completion of the first measures stabilization (anchored bulkheads) the movements were reduced abruptly to zero.

3. Conclusions

In the field of road engineering, as well as the design of new road, the occurrence of damages or slides affecting the road body, causes to acting in the maintenance and safety of existing works that, over time, have been damaged.

In the first emergency, usually, preliminary work are carried out in order to temporary safe the road asset and to assure the traffic along it. In a second phase it is essential to operate with definitivesolutions.

To achieve this, the most information about the soils on which the road will be located and surrounding area are essential. Such information can help to formulate hypotheses about kinematics and mechanism of landslides, in order to propose appropiate design solutions for the last safety.

For this reason it is important to have an adequate campaign of geological site investigations and instrumental and topographic monitoring of the area. So the knowledge of the geological reference model is fundamental in the choice of design solutions to be adopted in the road planning.

The case histories show the fundamental role, as a cause of the damages, played by the response of the road body related to the particular hydrogeological features

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