Works necessary for the protection of the South East UT railway track from hydrogeological instability

Rome-Formia-Naples Railway Line, Italy

DESCRIPTION OF THE SERVICE PROVIDED

This service was performed with regard to the rocky slope above the railway track along the Rome-Formia-Naples line, where rockfalls had occurred. Precise geological and laser scanner surveys, and trajectory plotting analyses, were performed. The project solutions adopted were designed after identification of the possible areas vulnerable to potentially loose portions of rock and after assessment of the forces involved.

Specifically, the following were performed:

- geological characterisation and modelling with the findings of the trajectory analysis modelling;
- laser scanner survey,
- enabling the reconstruction of the DTM (Digital Terrain Model) and identification of the positions of the disintegrating blocks and the volumes which might potentially be mobilised;
- design of the rockfall protection planned.

The service was performed on several different sections of the line. This description will refer to one of them: the section between km 123+500 and km 127+000 approx. of the line in question.

50% Engineering

50% Geology - Geotechnics

Subcontractor: ETS S.r.l.
Contractor: Micos spa
Contracting Authority:
RFI - Rete Ferroviaria Italiana
Works designed:
Protection of the South East UT railway track from hydrgeological instability
Place of realisation of the works designed:
Roma - Formia - Napoli UT Sud Est Railway line
Period of provision of the service:
2015
Value of the works designed:
€ 5.870.000

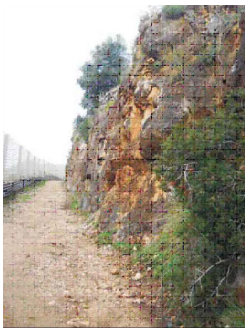
Project area

Western part of the slope, showing the hairpin bend

Continuation of the above to the East The ruined farmhouse is visible

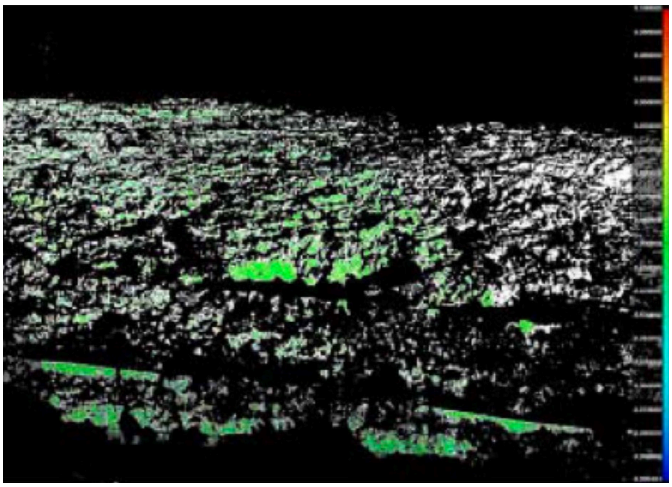
Detail of rocky outcrop

Outcropping rock

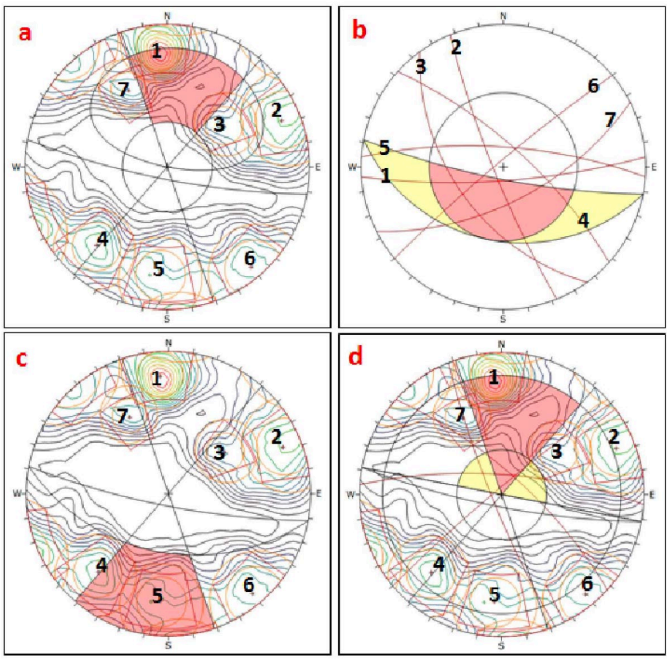


Point Cloud of East Side

Alignment of Scans



Summary of results of the Kinematic Analyses of the type V1 slopes



SURVEY

A terrestrial laser scanner survey was performed of the slopes and of the rock walls above the railway line. The aim of the laser scans was the identification of the potentially unstable masses on the slopes and the structural and geomechanical characterisation of the rocky outcrops.
These were supported by photographic surveys from a helicopter for the production of detailed orthophotos, for the preparation of detailed topographic maps and Digital Surface Models (DSM) to enable study of the trajectories. The surveys were performed from various observation points facing and beside the slopes, to minimise shadow zones.
The survey and subsequent processing of the data enabled the production of a three-dimensional model, both for topography purposes and for the detailed characterisation of the rock walls.
The model consisted of a cloud of over 11.5 million points, with spacing between points varying between 3 and 15 cm; the uncertainty of every single point was of the order of the centimetre (±22 mm) and the mean georeferencing error was about 7 cm for the topographic surveys and about 14 cm for the laser scanner surveys. The surveys were georeferenced by means of GPS measurements and located within the WGS, in relation to the "S.S.7 "APPIA" KM 130" anchor point no. 171705 in the IGM grid. The work was structured in two phases, as follows:

- Terrestrial laser scanner survey of the slopes, focusing above all on the rocky outcrops, starting from 3 different stations.
- Assembly of the partial point clouds to form a three-dimensional model.
- Photographic survey from a helicopter, flying at about 250 m above the ground.
- Preparation of 3D photographic models.
- Georeferencing of the individual models in the chosen system of reference.
- Production of DSMs.
- Characterisation of the mass of rock on the basis of geometric information extracted from the point cloud.
- Kinematic checks to define the types of potential remobilisation of the blocks in relation to the different wall positions and the discontinuities identified.
- CSMR classification and recognition of potentially unstable portions.

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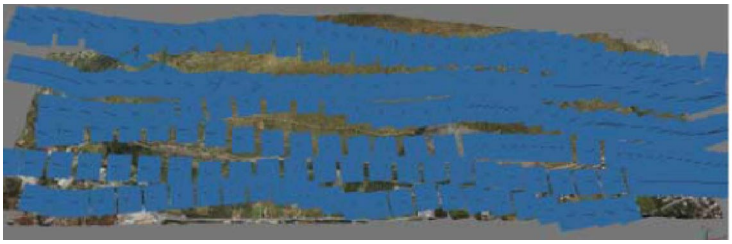
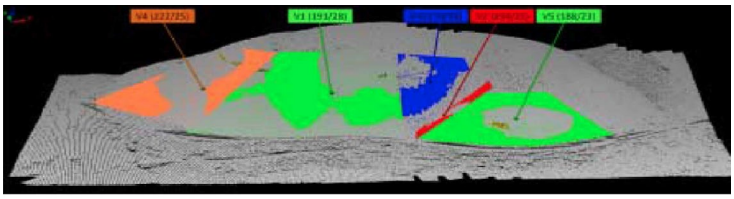


Route followed for the photographic surveys
and relative portions photographed

Layout of DSM extraction area and local system of reference

Processing of the point cloud to define the direction of
the main planes of discontinuity



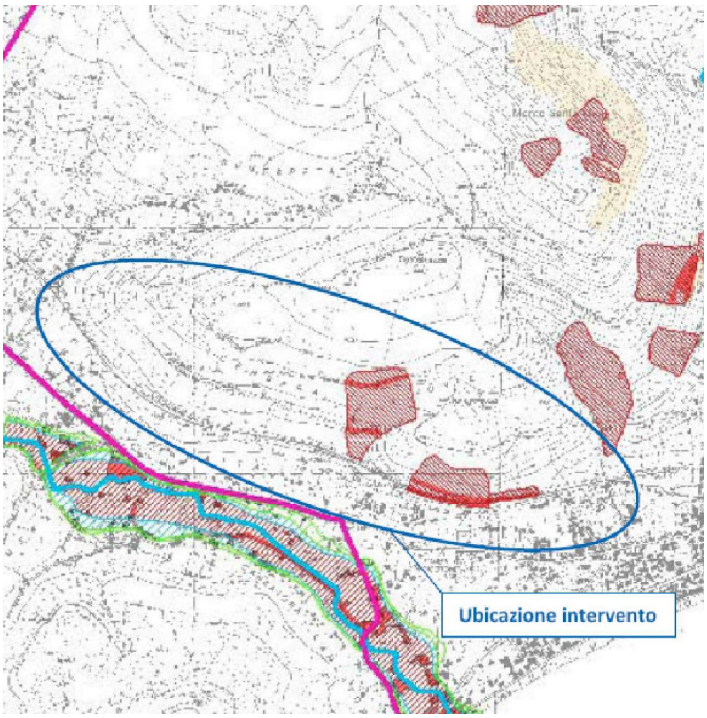
Display of the DEM extracted from the orthophoto of the

Extract from the Geological Map of Italy,
Sheet n. 171 "GAETA"
Scale 1:100,000

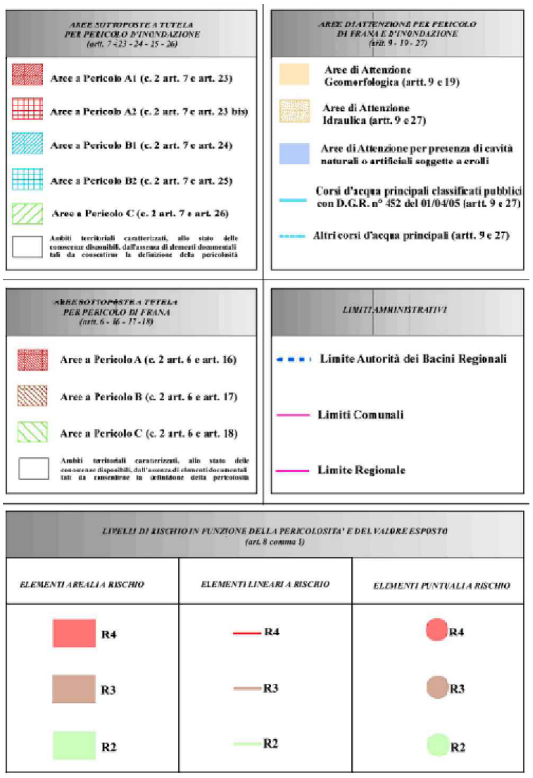
GEOLOGICAL CHARACTERISATION AND MODELLING

From the geological point of view, the outcropping terrains in the area under examination belong to the Lazio-Abruzzo succession.
This term embraces all the structural units deriving from the deformation of the Lazio-Abruzzo Domain.
One of the most noticeable structural elements in this sector is definitely the Lepini-Ausoni-Aurunci Mountain chain, which separates the inner and outer Lazio-Abruzzo units.The Lepini-Ausoni-Aurunci Mountains include monoclines emerging mainly in the NE, consisting of dolomitic limestones, with internal neritic facies dolostones. These sediments can be dated to the Jurassic/ Middle Paleocene.
The sector studied belongs to the south-eastern portion of the Aurunci Mountains. The carbonatic sediments of these mountains are an example of a shelf in which continuous, regular subsidence compensates for the calcareous sedimentation.
This equilibrium, persisting from the Liassic to the middle Miocene, results in the accumulation of very thick layers of shallow water sediments.
The picture is completed by frequent interruptions in the sedimentation, generally local (identified by continental or lake episodes, breccias and bauxites), or brief increases in depth, more noticeable at the edges of the neritic facies, where transitions appear.
The area under consideration contains terrains from the Neocomian - Aptian, including the first levels of bedded diceratides, and the "Orbitolina level" on top, and the Cenomian - Aptian terrains between the "Orbitolina level" and the first beds of Rudiste.
The former, on the eastern edge of the area studied, consist of micritic limestones, calcarenites and whitish and pale brown calcirudites, alternating with dolomitic limestones and dolostones.
The top part contains intercalations of small conglomerate levels, with a reddish and greenish clay matrix.

The latter, in the project area, consist of clearly layered pale brown micritic and detritus limestones, alternating with levels of stromatolitic or sugary dolostones.
Thin interlayers of greenish silty clay sometimes occur.
The Quaternary is represented here by loose or weakly cemented slope debris, with very variable granulometry.



AREAS SUBJECT TO PROTECTION DUE TO HYDROGEOLOGICAL INSTABILITY



KEY

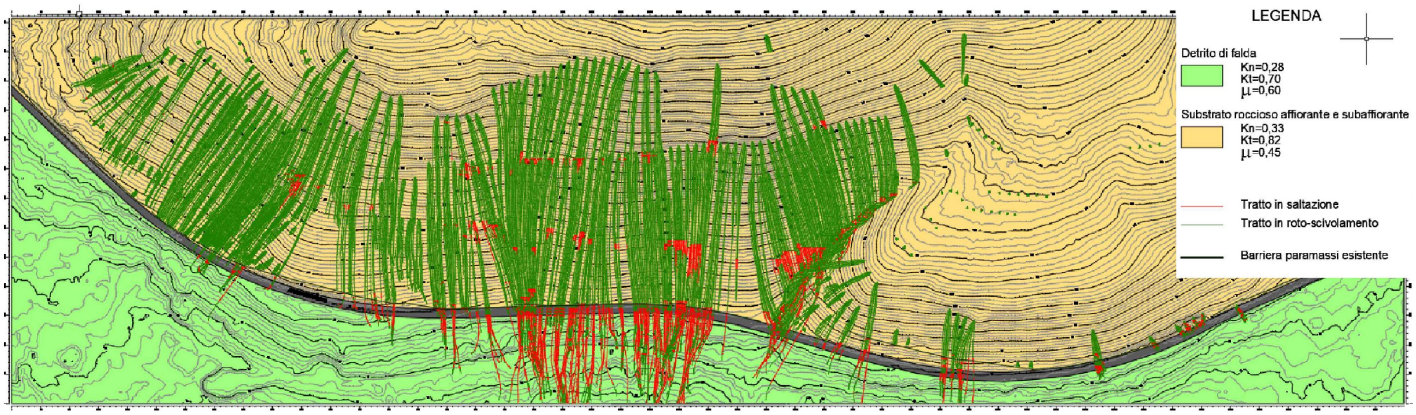
Within the Lepino-Ausono-Aurunca Ridge, the presence of tectonic structures such as the Carpineto-Montelanico line, which shows signs of back thrusting, and the Mount Caccume and Colle Cantocchio structures, described in the literature as remnant portions of nappes (Klippen), appear to indicate an extremely complex structure. In the post-orogenic phase, mainly during the Plio-Pleistocene, intensive distensive tectonic activity occurred, related to the evolution of the Tyrrhenean basin. The current geometry of the sector examined is therefore the outcome of the superimposition of the Plio-Pleistocene post-orogenic distensive tectonics on the compressive tectonics which formed the Apennine chain, during the entire Miocene. This structural evolution led to the formation of two large direct fault systems: the "Apenninic" system, running parallel to the chain, and an "anti-Apenninic" system, running perpendicular to the former.

HYDROGEOLOGICAL RISK

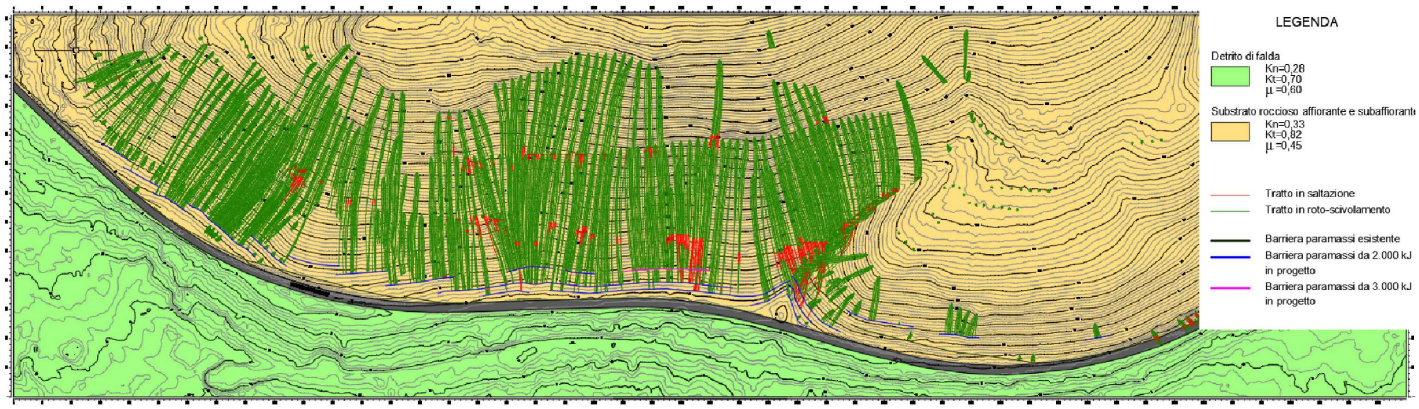
The hydrogeological risk (Hydrological Risk and Geomorphological Risk) was assessed with reference to the Hydrogeological Plan (Piano per l'Assetto Idrogeologico, PAI) issued by the Lazio River Basin Authority. The table used was no. 2.13, Southern Sector: "Areas subject to protection due to hydrogeological instability".

DESCRIPTION OF THE PROJECT OPERATIONS

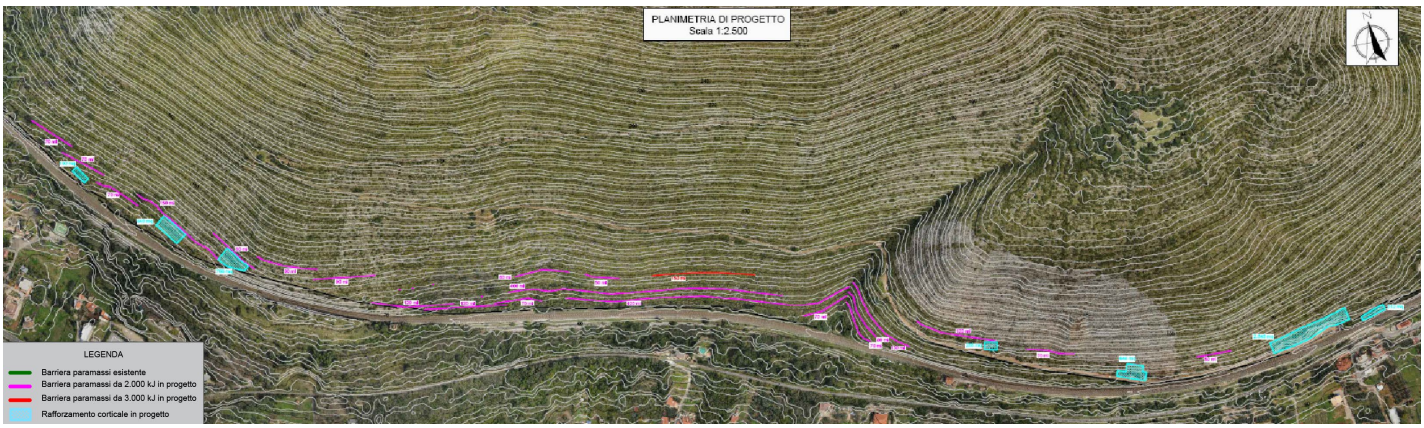
The analyses performed identified blocks of rock of varying size which were potentially unstable due to their specific geology, geomorphology and position. In view of the volumes concerned and the kinetic energy of the unstable masses if mobilised, assessed by trajectory plotting analysis, the works designed involved the construction of rockfall protections of 2,000 and 3,000 kJ, with height of 5 m, installed along sections of varying length, to provide continuous protection of the railway track. Specifically, the project involved lengths of 2,470 metres of 2,000 kJ, and 150 metres of 3,000 kJ, as shown in the project ground plan. In sectors where the detachment of blocks was possible downstream of the rockfall protections planned, surface reinforcement was installed in the form of steel rope panels of 6x4 m with mesh size 25x25 cm, bonded with metal mesh. The rope panels were secured using bars 3 metres long and dia. 24 mm installed at the tops, in the middle of the bottom side, in the middle of the top side and in the middle of each panel, as shown in the enclosed diagram. The anchor points were injected with cement mortar with an acrylic resin additive (with absorption levels verified during execution). The total area covered by the surface reinforcement was 5,088 m2. With regard to the mitigation of the impact of the construction of these works, it should be noted that the height of the rockfall protections was such that they were not particularly visible and they were screened by the vegetation on the slopes below, while due to its type and the relatively small area covered, the surface reinforcement did not require any particular mitigation measures. Moreover, the works did not require the installation of systems to collect the run-off water from the slope since they did not create impermeable surfaces.

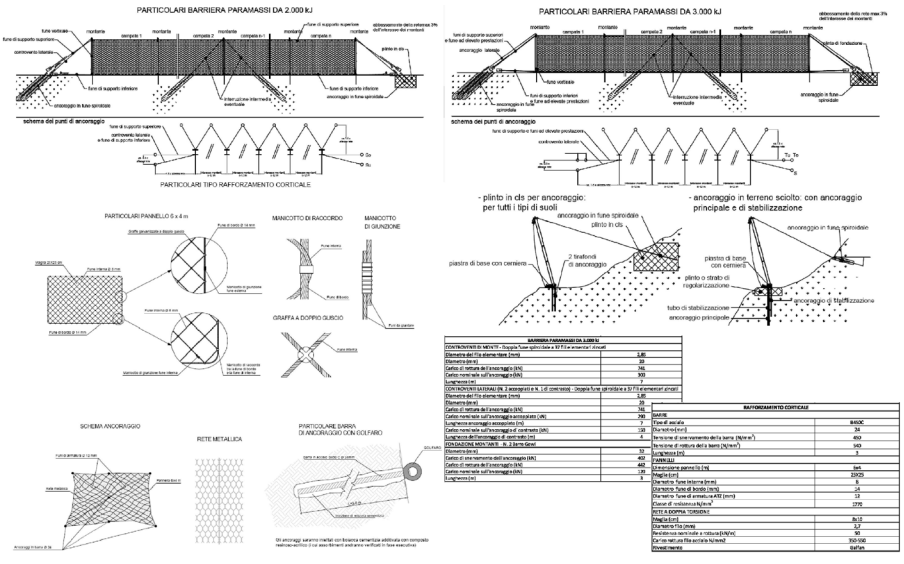


Trajectory analysis ground plan prior to the works



Trajectory analysis ground plan after the works





PROJECT TECHNICAL SPECIFICATIONS

Works necessary for the protection of the South East UT
railway track from hydrogeological instability
Rome-Formia-Naples Railway Line, Italy

PROJECT DATA:

Contractor: Micos S.p.A.
Contracting Authority: RFI – Rete Ferroviaria Italiana
Place:
Roma - Formia - Napoli railway line
UT SE km 123 500 and 127 000
Type of Project:
Transport, Security
Award: Private Treaty
Design: 2015
Status: Completed
Intervention area size: 5.000 mq

PROJECT MANAGEMENT:

Project Manager: Ing. Domenico Chiaino
Design of Structures: Ing. Domenico Chiaino
Geotechnic design: Ing. Domenico Chiaino
Termographic survey, laser scanner: Dott. Geol. Fulvio Epifani
Slope stability analysis - trajectories: Dott. Geol. Fulvio Epifani

PROJECT TEAM:

Ing. Domenico Chiaino
Dott. Geol. Fulvio Epifani

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