Geological design for complex geological-structural contest: the example of SS 125 "Nuova Orientale Sarda"

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The following work is an example of road design in geologically complex environments, which requires a particular accuracy in the definition of the Geological Reference Model. In the studied area the rock masses involved in the plan are strongly deformed by tectonic activity that occurred over time. For this reason, the analysis of geological formations has been addressed, above all, to the study of geomechanical features, such as strength resistance and elastic properties of the rock mass. The integrated analysis of the data coming from geo-structural and geomechanical surveys carried out on rocky outcrops in the area, and of the data obtained from site investigation and laboratory test on rock samples, has allowed to improve the characterization of rock masses and the definition of Rock Quality Indexes. The study provided the values of GSI for both formations, used to obtain the geotechnical parameters, adopted for the design of project interventions. The project included the study on the reuse of soil and rocks coming from the excavations, ahead of the ascertainment of their environmental characteristics by means of chemical analysis. Abnormalities in the chemistry of some samples are interpreted as due to the nature and evolution of the geological formations, and not to environmental pollution.

Keywords: Rock masses, Geological Reference Model, Geostructural relief, Reuse of soil, Chemical analysis.

1. Introduction

A fundamental role in order to define the geotechnical characterization of soils and the geomechanical characterization of rock mass, is played by the identification of the geostructural and geomechanical features, and the Geological Reference Model, of the geological units outcropping in the area where the road plan is located. All this factors affects the resulting choice of design solutions.

An example is rapresented by the design of the new SS 125 “Nuova Orientale Sarda” Tronco Tertenia – San Priamo 1° Lotto - 1° e 2° Stralcio.

The track of the whole parcel, developed in the south-east part of the island, 100 km far from Cagliari, along the Torrente Quirra Valley, is long more or less 13 km and is composed by 11 viaducts for a whole length of 750 m, and 3 tunnels (1 artificial and 2 natural).

2. Geological and Structural Framework

The road plan is located along the lower part of the right slope of the Rio Quirra Valley, in a complex geological contest, that outcrops along it. This valley follows the development of a a transtensive tectonic element with regional importance, of which the path follows the development. The valley is bordered by mountains composed by the Paleozoic basement units, represented by an alternations of metasandstones, metapelites, metavulcanites, metaepiclastites, metaconglomerates and greenish-gray shales, affected by polyphasic deformation, schistosity and by a medium-low degree of metamorphism. The terrains interested by the construction of the road belong to the Meana Sardo tectonic Unit, overlapped on Gerrei Unit; the Meana Sardo Unit is overlapped by the Genn'Argiolas unit.

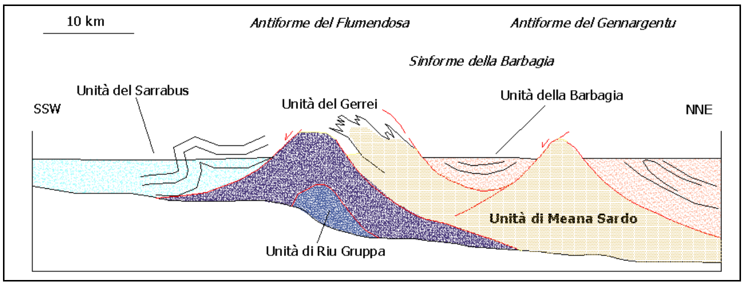

Fig.2.1 - Schematic geostructural diagram of the Paleozoic basement in the south-eastern Sardinia.

2.1 Local Stratigraphic Succession

The units, that are directly involved by the project, have been identified in the literature, in the formational stratigraphic nomenclature, with the terms of S. Vito Sandstones and Monte Santa Vittoria Formation.

S. Vito Sandstones

This formation is placed at the base of the Meana Sardo Unit and is composed by an association of metarenites and quartz-mica metapelites, with shiny appearance, and, rarely, by metasandstones and thin levels of gray and greenish-gray metaquarzoarenites, with intercalations of gray or black metapelites and metasiltstones. In the middle part of the formation there are often metaconglomerates with elements of metasiltstones and metasandstones. In the section covered by the plan of the new SS 125, the outcrop formation is affected by schistosity, levels and lists of quartz, reflecting phenomena of *boudinage* or elongation in the stresses direction.

The basis of this lithostratigraphic unit does not outcrop; it rests with tectonic contact on the Gerrei Unit and is covered, in unconformity, by metaconglomerates of Muravera or, directly, from the Monte Santa Vittoria Formation.

The unit is referred to the Cambrian - middle/lower Ordovician.

Monte Santa Vittoria Formation

This formation is composed by two different lithofacies, represented by: metaepiclastites (cfr. Manixeddu and Monte Corte Cerbos Formations of Bosellini and Ogniben, 1968) to prevailing volcanic matrix, of various granulometry, with intercalations of metagraywackes, metasandstones and metaconglomerates with quartz pebbles, identified with the acronym MSVa; metagraywakes and metandesites (cfr. Serra Tonnai Formation of Bosellini and Ogniben, 1968), known as MSVb and represented by volcanic greenish metagraywakes, with intercalation of greenish-gray metavulcanites with composition from basaltic to andesitic. The Formation is related to an effusive activity from intermediate to basic composition and deposition of graywakes resulting from the rearrangement of the volcanic deposits. The unit is referred to the Middle Ordovician.

These two formations have been involved in a series of plicative structures, which lead the San Vito sandstones to outcrop into the antiform cores, and the Monte Santa Vittoria Formation in the sinform cores.

In addition to these two formations, the tectonic unit includes the Muravera Metaconglomerates Formation, made up polygenic, heterometric, often coarse metaconglomerates, in quarzoarenitics matrix, not outcropping in the study area.

The bedrock just described is, at times, covered by ancient conoid deposits, including blocks and heterometric pebbles of metamorphic substrate, mixed with sandy-silty matrix reddened and well thickened; eluvio-colluvial blankets, consisting of angular blocks in silty matrix, without sorting; recent alluvional deposits, stabilized and thickened, and current alluvional deposits, formed by blocks and pebbles with poor matrix.

Fig. 2.1.1 - S. Vito Sandstones. Small fold deformations in the micaceous metapelites.

Fig. 2.1.2 - Monte Santa Vittoria Formation. Metagraywakes and compact metandesites.

3. Geostructural and Geomechanical Characterization

The road design in such rock masses has required a study of the geomechanic quality features, that lead to the definition of their strength and of the elastic parameters of the rock masses.

The site investigation data come from different campaigns, subsequently held in trust by ANAS, and include 71 boreholes, 10 geomechanical survey points, 38 geognostic trenches and 11 rifraction seismic bases.

Therefore, the classification of rock masses has been made starting by data obtained during the geostructural and geomechanical survey of the rock outcrops (according to standard ISRM), obtaining the GSI index. Then a comparison between the results coming from survey and those obtained from site-investigation and laboratory tests (RQD, Point Load Test, uniaxial compression of rock samples) was made.

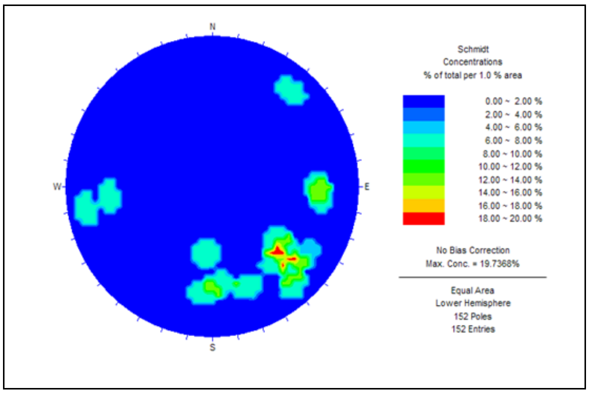

Fig. 3.1 - Diagrams Schmidt Examples.

This comparison led to the attribution of geotechnical parameters on the basis of which the project interventions have been designed.

Based on the obtained values of the index GSI, the two studied formations have been included in the "Geological Strength Index for Jointed Rocks" (Hoek & Marinos, 2000) (Fig.3.2) diagram. In this diagram the GSI values, obtained from survey data (oval empty areas) are drawn together with the ones obtained from site investigation and laboratory tests (oval hatched areas).

In general, it shows a good correspondence between the two sets of data, with an appreciable overlap between the areolas, which represents the index variability fields for the two units.

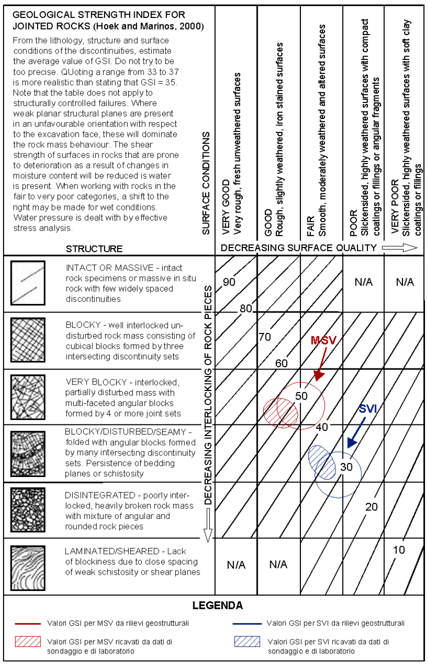

Fig. 3.2 - Diagram for the estimate of the GSI index from geological observations.

4. Environmental Study

The project, in addition to the precise definition of MGR, with a high degree of reliability, includes the study on the reuse of soil and rocks coming from the excavation, preceded by their environmental characterization works.

Through chemical analysis of environmental characters, in fact, anomalies in the soil samples chemical parameters coming from the layers of surface alteration of the substrate, and from alluvial deposits, found along the path, have been found.

In some samples, the values of arsenic, zinc, mercury and cobalt are higher than Contamination Threshold Concentration. This situation, in an area characterized by the presence of a mining site (Baccu Locci), at the foot of Mount Cardiga, can be refers, however, to the so-called "natural background". In fact, during the mining activity, metal sulfides (zinc and lead overall) and arsenopyrite were exctracted, so it confirms the presence of those chemical elements inside the minerals founded into the rock mass.

The lithologies forming the bedrock, by which dismantling/alteration alluvial deposits and eluvio-colluvial accumulations originated, contain mineralization. Thus, there is a correlation between the mineralogical and petrographic composition of the sediments accumulated and the nature of the geological formations outcropping in the area of immediate concern, in which widespread circulation of hydrothermal fluids led, locally, to the formation of appreciable concentrations of metal-bearing metal sulphides.

5. Conclusions

The road design, especially in presence of infrastructure of considerable extent, presupposes a thorough knowledge of the geological and geotechnical characteristics of the soils outcropping in the area of roadway location and interacting with the planning civil works.

This is possible to obtain through direct studies of the area, through surface surveys, integrated with the data coming from geological site investigations planned on the basis of the design elements.

In the present case, in particular, the geological units belong to the ancient metamorphic substrate, whose behavior is difficult to achieve only following the laboratory characterization. Therefore we proceeded through the geostructural and geomechanical characterization of rock masses, by which we have obtained the geotechnical design parameters. In particular, the work involved the evaluation of geomechanical characters from both the examination of the direct geological analysis of the outcrops present, and the systematic analysis of data obtained by site investigations (boreholes), integrated with laboratory testing on rocks. The results, obtained through two different ways, indicate a significant convergence.

Another aspect that is often necessary to consider, is the environmental one, mainly if the design choices allow the recycling of materials resulting from excavations. The environmental characteristics of these soils are determined by chemical analysis regulated by national legislation.

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