SmartMeasures
Tough projects call for smart measures.

AmbergSeismics

Consorcio Antioquia al Mar S.A.S.
Guillermo Gaviria Echeverri Tunnel and its access roads Megaproject

Project

- Guillermo Gaviria Echeverri Tunnel and its access roads project Megaproject
- Two lanes road tunnel as part of the corridor aiming at linking the Center of Antioquia and the Country to the Antioquian Urabá Sea
- Seven tunnels: Guillermo Gaviria Echeverri (9,730 m) and 6 shorter tunnels varying from 136 m and 1,073 m.
- Section varying from 20 m^2 to 120 m^2 (predominantly 100 m^2)
- Excavation mechanized and drill & blast method

Contractor

- Consorcio Antioquia al Mar (CAM)

Duration

- 2016 - 2023

Safely building the longest road tunnel in Latin America

The Guillermo Gaviria Echeverri Tunnel and its access roads Megaproject is a road project located nearby Cañasgordas and Giraldo Municipalities in the Antioquia Department, Colombia. Along with several other structures, it comprises the construction of the 9.7 km Toyo tunnel. The project belongs to the Proyecto Autopistas de la Prosperidad which is part of the National Government Program Fourth Generation Roads 4G and it is executed as a public work led by the national government of Antioquia.

The Toyo and its access roads project will connect the concessions Mar 1 (Medellin - Santa Fe de Antioquia) and Mar 2 (Cañas gordas - El Tigre). Together with these projects, it aims at connecting production centres located within the Antioquia Department, the country middle region and the Pacific and Atlantic coasts. The tunnel is being built by the Consorcio Antioquia al Mar (CAM) according to a public contract. It comprises the excavation of a main tunnel and an escape gallery being excavated with two opposite drifts (Giraldo and Cañasgordas Portals)

Figure 1: Project location. Foto Source: FCC Construcción.

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"Infrastructure projects of the magnitude of the longest Tunnel in Latin America, drives us to look for state-of-the-art technology that allows mitigating the negative impacts generated by the geological diversity commonly found in the rock formations of Colombia.

This is particularly true for this project, since the tunnel crosses a part of the Western Cordillera taking us from soft sedimentary to hard igneous rock masses, resulting in important uncertainties for each heading. By using the TSP 303 Plus such uncertainties can be mitigated. The system has become a key tool for the project, because through its implementation, it is possible to better address the upcoming headings and to be able to make assertive planning of the tunnel execution time.

Additionally, it allows to have a more proper estimation of the primary support materials and components (concrete, arches, metallic fibres, bolts, etc), which significantly improves site planning while at the same time minimize the uncertainties related to the geological risk."

Carlos Andrés Giraldo
Technical and Engineering Office Director
Consorcio Antioquia al Mar

Task

- Systematic use of TSP along the entire tunnel excavation
- Geological prediction of at least 130 m ahead of the tunnel face
- Correlation with other construction relevant parameters

Challenges

- Highly varying rock mass condition along the almost 10 km transept
- Evidence of shear and highly fracture rock mass in different type of lithology
- Identify zones with high risk of collapse, squeezing, etc.

Products Used

- One Amberg TSP 303 Plus System

Local geology along the tunnel alignment comprises sedimentary and igneous rocks of two formations: Penderisco and Barroso. The first formation includes thin layers of shales, siltstone, mudstone and lydite occasionally interbedded by volcanic rock packages (basalt and diabase) while the second comprises basalts, gabbro, diabase, andesites and volcanic tuff. According to the geological forecast, a number of fault zones and intrusions are expected along the transect. Likewise, predicted RMR values range between 20 and 80 indicating a high variability of the rock mass condition along the almost 10 km transept to be crossed. The overburden varies from a few meters around portal area up to about 900 m in the middle of the tunnel.

TSP campaigns and geological documentation

Until June 2022, about 40 TSP campaigns were performed in the project from which about 20 campaigns were carried out in the main tunnel and its twin gallery. In the following table, specifications about the currently available data as reported by the operator is shown:

Portal	No. TSP campaign	Investigated length (m)	Average range (m)
Entrada[1] (Giraldo)	10	1.083	155
Salida[1] (Cañasgordas)	7	1.504	167
Total	17	2.587	-

[1]Surveys done in main tunnel or escape gallery

Since its implementation beginning of 2021, the TSP has been used systematically in both drifts. The favorable rock condition along the Barroso formation has allowed reaching larger average prediction range compared to the surveys done at the Penderisco formation. However, 155 m represents a very good prediction range considering the rather weaker rock prevailing along this formation

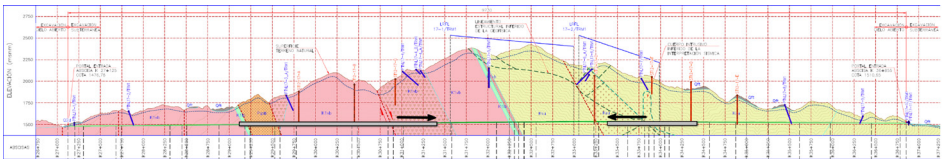

Figure 2: Total predicted length of the 17 available datasets upon the geological forecast. The two main rock formations, Barroso formation (left-hand side, orange, pink and green) and Penderisco formation (right-hand side, yellow) are easily differentiated. The arrows indicate the direction of the headings (left: Entrada, right: Salida).

Seismic results validation and generation of support graphs

Seismic forecasts have been continuously validated using the geological documentation after excavation. Figure 2 and 3 show the dynamic Young's modulus (Edyn) estimated from the seismic results, the RMR as reported by site geologists and the type of rock support applied in each heading, Portal Salida and Portal Entrada, respectively.

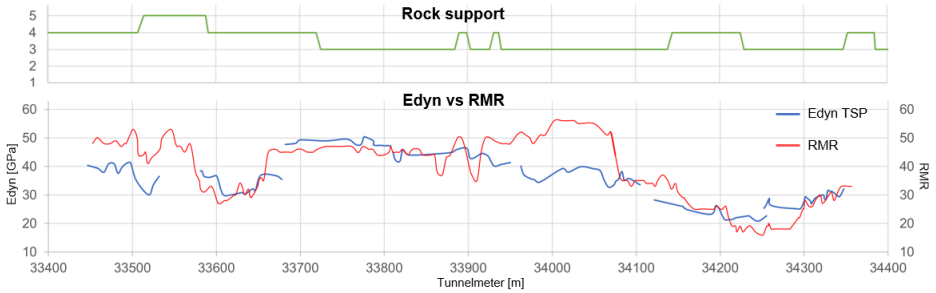

Figure 3: Edyn vs RMR values for the Portal Salida. The top figure shows the type of rock support employed (1: light rock support for favorable rock mass, 5: heavy rock support for very poor rock mass).

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"The implementation of the TSP 303 Plus system during the construction stage of the Guillermo Gaviria Echeverri Tunnel and its Escape Gallery, has allowed to considerably increase the knowledge of the geological and geotechnical condition of the rock mass to be excavated.

It has allowed timely identification of complex geological zones associated to faults, rocks with unfavourable geomechanical conditions and, sections with possible water bearing zones, that could have compromised the stability of the underground cavity.

These early detections allowed an improvement in decision-making and in the construction planning when crossing those sectors. Moreover, they significantly reduced the associated geological risk, allowing in a direct way, a better approximation of more realistic execution times and an better estimation of the required resources by site personnel."

Carlos Andrés Castro Muñoz
Geologist
Consorcio Antioquia al Mar

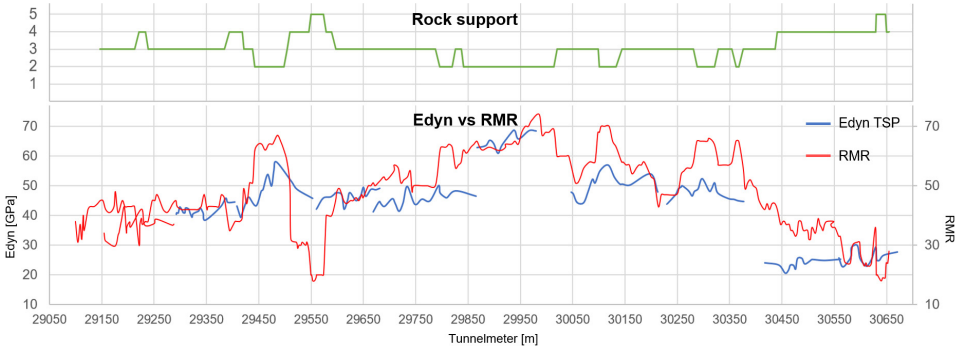

Figure 4: Edyn vs RMR values for the Portal Entrada. The top figure shows the type of rock support employed (1: light rock support for favorable rock mass, 5: heavy rock support for very poor rock mass).

The correlation between the rock mass classification system (RMR) and Edyn are evidenced along most of the investigated area. Also, the type of rock support employed correlates very well with the elastic modulus. Indeed, after collection of large number of seismic results, inferences about the most likely type of rock support to be used was given together with the rock mass condition prediction.

Additionally, Edyn values are plotted against maximum accumulated deformation as measured along the tunnel transept using tape extensometers. The figures allow a simple verification of the Edyn areas for which a certain deformation is to be expected. By adding the type of support, additional conclusions can be drawn about the relationship between Edyn, the accumulated deformation and the selected support.

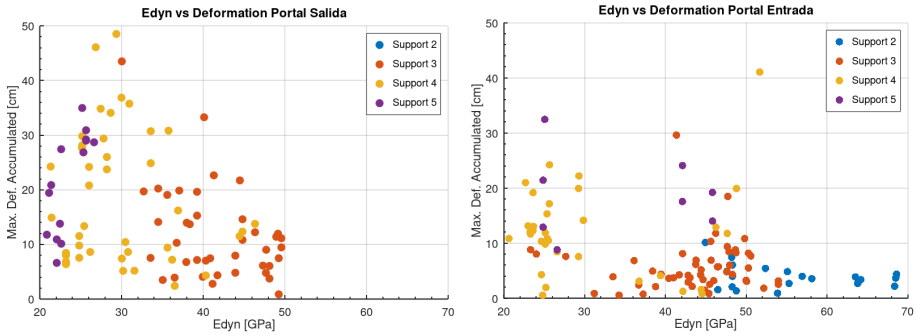

Figure 5: Plots of Edyn versus maximum accumulated deformation including primary rock support as built. Left: Portal Salida, right: Portal Entrada.

Based on the correlations, the following main conclusions can be drawn per portal:

Portal Salida

- Edyn range: 20 – 30. Highest deformation possible, up to around 50 cm.
  For Edyn < 26, rock support 5 is used predominantly, otherwise support type 4.
- Edyn range: 30 – 40. Still high deformation possible, up to around 40 cm.
  For Edyn < 35, rock support 4 is used predominantly, otherwise support type 3.
- Edyn range: 40 – 50. Moderate deformations, up to around 20 cm.
  Rock support 3 is used predominantly. Support type 4 only in punctual cases to control deformations > 10 cm.

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"In recent years, Colombian engineering has been carrying out unprecedented tunnel construction in the mountain ranges of our country. With the presence of Colombian and foreign professionals, in particular Spanish engineers, who contribute with their experience and monitoring and control tools to this type of works. We have managed to combine skills and knowledge transfer. This is the right team to take on the execution of a mega project like this one.

The consortium assumed the project in 2015 (pre-construction) and from January 2018, with the ongoing construction phase, working 24 hours a day, seven days a week. Only 5 percent of the almost 22,300 linear metres of underground excavations have yet to be completed (March 2023). Which is a very good timing since the route of the road is located in an area with a complex and ethereal geography. There are many reasons for this progress. One of these is the implementation of the TSP at the end of 2020, which provided the personnel in charge of the excavation processes with the state-of-the-art technology required for a major project."

Edwin Díaz Pinzón
Project director at Carlos Alberto Solarte Solarte
Member of Consorcio Antioquía al Mar

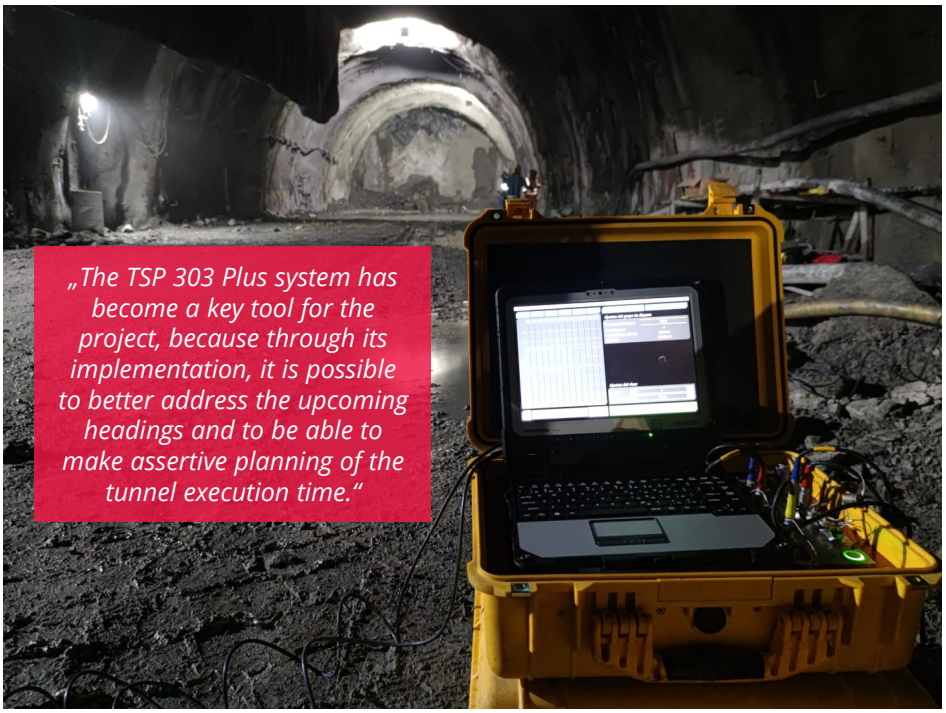
Portal Entrada

- Edyn range: 20 – 30. Highest deformation possible, up to around 30 cm. Rock support 4 is used predominantly. Support type 5 in punctual cases to control deformations > 10 cm.
- Edyn range: 30 – 40. Low deformations, < 10 cm. Rock support 4 is used predominantly.
- Edyn range: 40 – 50. Low to high deformations, up to around 30 cm. Rock support 3 is used predominantly. Support type 4 and 5 used in punctual cases to control deformations > 10 cm.
- Edyn range: 50 – 70. Very low deformations, < 6 cm. Rock support 2 is used predominantly.

Such reference works can be used as tools for the interpretation of seismic data. They contribute to a more detailed prediction that includes information about the expected deformation and the rock support to be used. In addition, the reliability of the information obtained from these figures is likely to increase considerably with the integration of further data to be collected.

Conclusion

The TSP results and their comparison with the excavated geology and the estimated RMR values have shown that TSP 303 is an efficient and reliable tool to obtain geological information up to 150 m or more ahead of the face. Furthermore, by analysing data from different sources, such as geological information, rock classification and convergence measurements, additional useful information can be obtained, which greatly supports the decision-making process for the appropriate support class during tunnelling.



„The TSP 303 Plus system has become a key tool for the project, because through its implementation, it is possible to better address the upcoming headings and to be able to make assertive planning of the tunnel execution time."

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