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Geotechnical Characteristics in Road Tunnels of Sierra Valle Fertil. San Juan. Argentina

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ABSTRACT:
The Sierra de Valle Fertil is located in the west of Argentina (San Juan province). It is being crossed by the National Road 150 that has 40 km in length including six bidirectional road tunnels with a total length of 2000 meters. All tunnels have the same horseshoe shape cross section with a area of 70 m^2. They were designed following criteria given by Highway Tunnels of PIARC "Cross Section Design for Bi -Directional Road Tunnels" of 2004.
The first three tunnels are developed through soft sandstones with siltstones and shales (middle Triassic). The next two in slightly cemented sandstones and conglomerates (Lower Triassic) and the last is in rigid greywackes (upper Carbonic). The support provided by the design was estimated by using RMR and Q method.

1 INTRODUCTION

The Sierra de Valle Fertil is located in the west of Argentina (San Juan province). It is being crossed by the National Road 150. This road is a part of a bi-oceanic corridor that runs from Porto Alegre (Brazil) to La Serena (Chile) (figure 1).

Figure 1.Location of Valle Fertil tunnels (circle), within bi-oceanic corridor.

This road sector has 40 km in length including six bidirectional road tunnels with a total length of 2000 meters (figure 2).

All tunnels have the same horseshoe shape cross section. They were designed following criteria given by Highway Tunnels of PIARC "Cross Section Design for Bi -Directional Road Tunnels" of 2004.

The circular portion has an inner radius of 5.68 m. The area itself is about 70 m2, which includes the area between the roadway, sidewalks side gables and the inner perimeter. The minimum free structure gauge, vertically, is 5.25 m., a value that complies with current regulations and provides a rematch to accommodate any resurfacing (figure 3).

It was considered desirable to reduce the longitudinal slope gradient as much as was possible. They vary between 1.7% (Tunnel 7) to a maximum of 2.9% (Tunnel 1). Figure 4 shows longitudinal and transverse sections.

2 GEOLOGICAL SETTING

The geological formations are various Carbonic-Permian (Paganzo Basin) and Triassic (Ischigualasto-Villa Union Basin) sedimentary rocks, close to a National Reserve (Azcuy, 1979, Bossi, 1971, Curri, 2009, Gioia, 2006, Miall, 1977, Roger, 1993, Rosello, 1996,

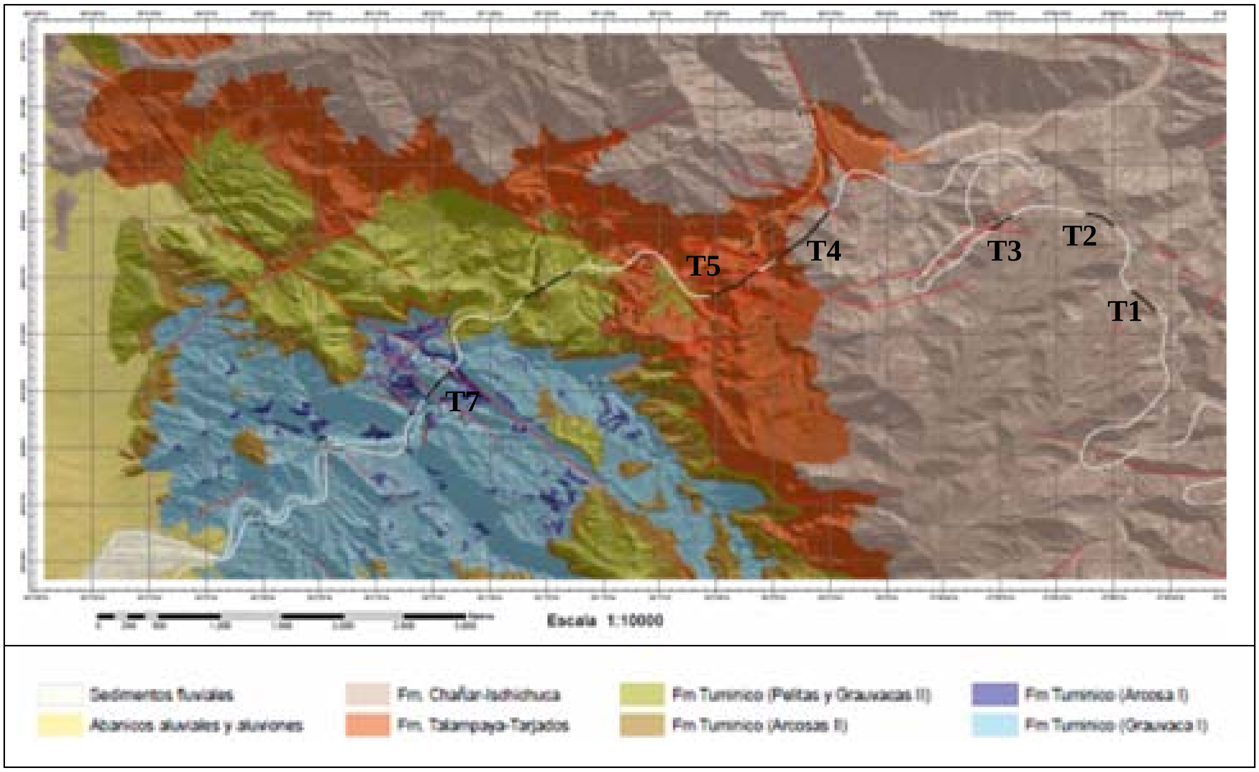


Figure 2. Location of tunnels T1 to T7, in a regional geology environment.

Romer, 1966, Sill, 1969, Stipanicic, 2002). The Sierra has been formed by the reactivation of the basin during the formation of the Andes (10by bp) with a thick-skinned tectonics. GPS measurements show that Valle Fertil fault, that is the west limit of the range, is a feature that separates two tectonic regions, with high seismogenetic potential. The trace of the route follows a creek that cuts anticlinal folds.

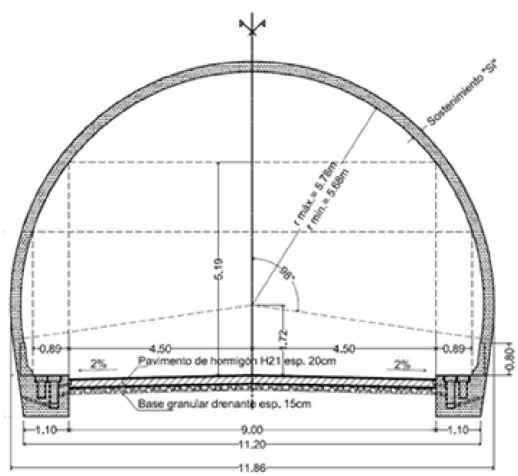
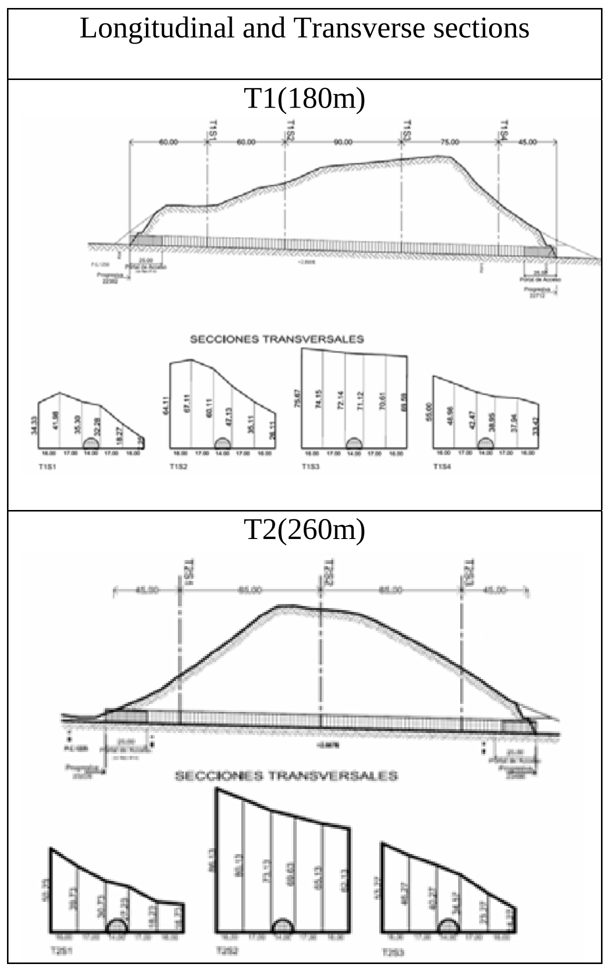


Figure 3.Cross section of all tunnels.



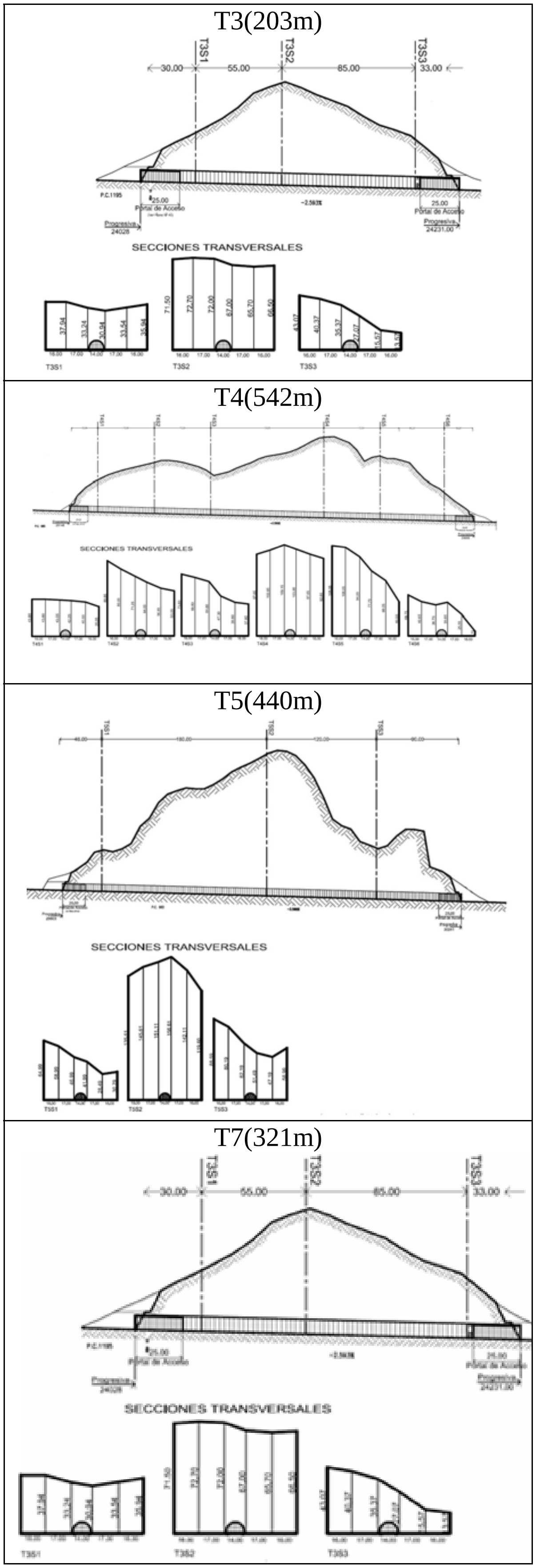


Figure 4.Section of all tunnels.

The first three tunnels are developed through soft sandstones with siltstones and shales (middle Triassic). The two following slightly cemented sandstones and conglomerates (Lower Triassic) and the last is in rigid greywackes (upper Carbonic) (figure 2).

Tunnels T1, T2 and T3 has similar structural geology features, but as the tunnel alignments changed, their influences were different (figure 5).

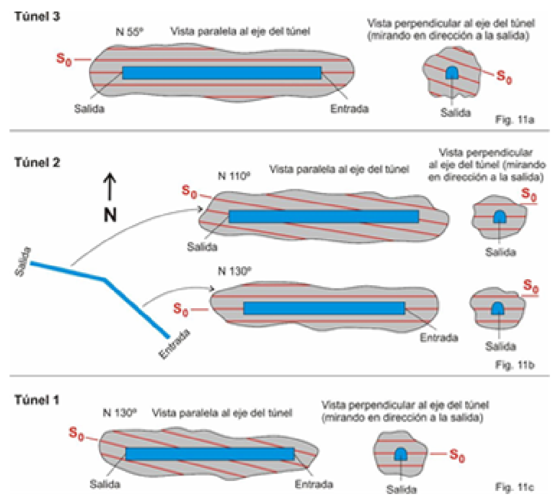


Figure 5. Influence of geological features on T1, T2 and T3.

T1, T2 and T3 were excavated in a sequence of fine silty and tuffaceous sandstones with interbedded siltstones and triassic dark shales. They are grading up into fine sandstone facies sediments consist mostly of fine sandstones and mudstones interbedded with laminated dark shale banks. In T3 predominates sandy layers (figure6), while the T1 and T2 predominate shaly facies (figure 7).

Figure 6. Sandy layers inT3

Figure 7.Shaly layers in T1.

Tunnels T4 and T5 share the same geology and structural features (figure 8).

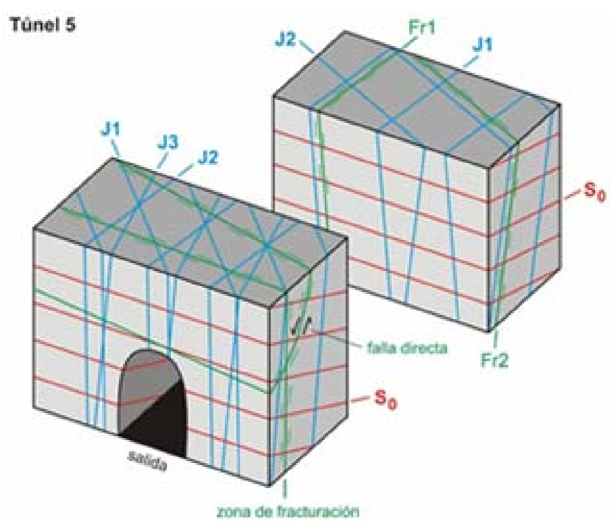


Figure 8.Structural features of T4 and T5

In this case, predominate red cross-stratified sandstone, with red clay levels and layers and lenses of coarse matrix. The thickness of the layers varies between a metric to decimeter size (Figure 9).

Tunnel T7 shows reddish-brown sandstone formed by greywacke with gray fresh cut formed in Carboniferous age. They have well stratified planar layers of variable thickness (from 0.5 to 0.10 m to 1 m). There are thin layers of white sandstone lens shaped, of centimeter thickness, interspersed in the gray greywackes. (figure 10)

Figure 9. Red sandstone in portal entrance of T5

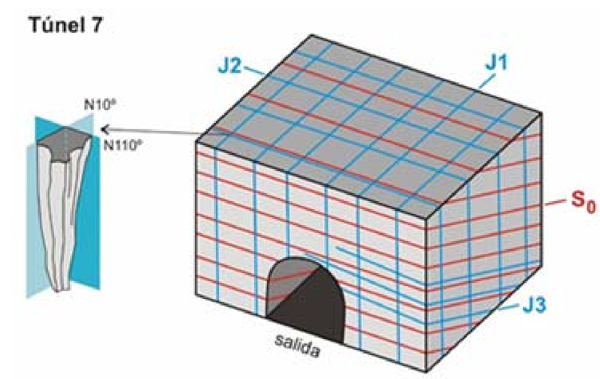


Figure 10. Geoestructural features of T7

3 GEOTECNICAL ASPECTS

3.1 *Rock mass characterization*

Rock mass characterization was done following the Hoek Brown model.

Tables 1 and 2 summarize the results of compression tests and uniaxial compression diametrical (Brazilian test) samples of sandstone and mudstone.

It is observed that intact rocks samples present are of medium to high resistance.

The support provided by the design was estimated by using RMR (Bieniawski, 1989) and Q (Barton el al, 1974, 1993 method. During construction geological surveys were conducted on the front as it was excavated, and expected support was adjusted according to them.

Table 1. Uniaxial Compressive Strength

ID	Location	Lithology	UCS (Mpa)
CP1	PS T2	Yellow sandst.	108.3
CP2	PS T5	Red sandstone	81.3
CP3	PS T5	Red sandstone	75.9
CP4	PE T7	Black Sandst.	220.6
CP5	PE T7	Black Sandst.	182.8
CP6	PS T5	Mudstone	128.6
177-06	PORTAL	Mudstone	87.2

Table 2. Indirect Tensile Strength (Brazilian Test)

ID	Location	Lithology	Brasilean test (Mpa)
CP1	PS T2	Yellow sandst.	4.3
CP2	PS T5	Red sandstone	3.0
CP3	PS T5	Red sandstone	4.3
CP4	PE T7	Black Sandst.	10.6
CP5	PE T7	Black Sandst.	2.4
CP6	Ps T5	Mudstone	9.9

3.2 *Support types used in tunnels*

The solutions were raised in five kinds of support, modifying the provisions of the RMR method.

Support Type S1 (Q> l0 - RMR> 55) was not found in the excavation front and was not used.

Support Type S2 (5 <Q <l0 - 48 <RMR <55) considered sealed with shotcrete 4cm Type H25 minimum thickness. Also, 25mm diameter dowels and 4.0 m long in the vault, spaced 1.5 m x 1.5 m, and 1st layer of shotcrete support fiber 7cm H25 minimum thickness. Final lining consists of Projected H25 7cm minimum thickness.

Support Type S3 (l <Q <5-35 <RMR <48) considered sealed with shotcrete fiber type 5cm H25 minimum thickness. Also, 25mm diameter dowels and 4.0 m in length, in walls and ceiling, spaced 1.5 m x 1.5 m, and a first layer of shotcrete support with fiber type H25 minimum 10cm thick. Final lining consists of type H25 shotcrete 10cm depth.

Support Type S4 (0.05 <Q <l - 10 <RMR <35) considered a sealed with shotcrete fiber type 5cm H25 minimum thickness, and 25mm diameter dowels and 4.0 m in length, walls and ceiling, spaced 1,25 m x 1,25 m. Also, 1st layer of shotcrete support with fiber type 7cm H25 minimum thickness profile and steel sets spaced HEA or HEB 1.25 m between them, 2nd layer of shotcrete support fiber type H25 minimum thickness of 13cm. Final lining was 10cm thick H25.

Support Type S5 (Q <0.05 - RMR <10) was not used in the tunnels

In all cases fiber shotcrete has 40 kg/m3 of steel fibers. In some places, it was replaced with wire mesh l00mm x 100mm x 6 mm in diameter.

The summary of the support types found in tunnels is shown in Table 3.

Table 3. Summary of support types for tunnels

	SUPPORT (m)						
	S1	S2	S3	S3M	S4	S4M	S5
1	-	-	155	-	30	-	-
2	-	-	170	20	40	-	-
3	-	-	-	-	142	51	-
4	-	120	394	-	12	-	-
5	-	50	354	-	34	-	-
7	-	-	271	-	50	-	-

3.3 *Portals*

The portals were designed considering the minimum of the rock mass, using the type 5.

To ensure the stability of the excavation area of the tunnels portals, it was executed a micropile umbrella of 3" in diameter and 9mm in length spaced 0.4 m as shown in Figure 11. The piles were vinculated with a concrete beam to the entrance structure (Figure 12).

Figure 11. Micropile umbrella

Figure 12. Umbrella vinculation beam

3.4 *Excavation sequence*

The excavated section was divided in an upper crown and a lower bank. The excavation was carried forward by a crown central pilot tunnel 4.5 m x 4.5 m and afterwards, it was dug the sides (Figure 13).

Figure 13. Excavation partition of crown

The length of the excavation cycle depended on the quality of the rock mass, varying from 3.5 m to 4m for solid type 1m for S2 to S4 type.

After the excavation of the crown, communicating both portals, we proceeded to the excavation of the bank. Corresponding roof supports to stabilize the excavation were installed as the excavation progressed.

The effectiveness of the support was verified with the realization of convergence measurements at stations located at specific positions of the tunnels. The measurements were performed with tape extensometer

4 CONCLUSIONS

The excavation of the tunnels crossing the Sierra del Valle Fertil was controlled by sedimentary rock types present. In hard rocks, drill and blasting methods were used and in soft rock, it was possible to use mechanical excavation procedures.

The tunnels excavated in stiff rocks (T4, T5, and T7) were less demanding than those provided for in the design. Instead, the tunnels in soft rocks (T1, T2 and T3) required more supports than those stipulated in the design.

Convergence was monitored by measurements with extensometer tape sections. Its measurement showed stabilization within a few weeks after the excavation.

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