Construction of portals in difficult conditions in the Andes, Peru

M. Boisán, M. de Cabo & C. Quiroga
Subterra Ingeniería, Spain

ABSTRACT: Yanango Tunnel is located in Junín, Peru; enhancing the connectivity between Lima and the Central jungle between Tarma and La Merced. The construction was awarded to a JV (MPM and Balzola) in a 25 MUSD contract, and took place from 2015 to 2016, and its inauguration was last September 2017. The tunnel has a length of 1,062m with three traffic lanes, in a section of the 96m^2. The geology is composed by fair to good geomechanical quality granodiorites. The main challenge was the construction of both portals, requiring changes in their initial designs, constructing two false tunnels structures before starting the excavation. The Western Portal was excavated in colluvial soils, with only 15º between the hill side orientation and the tunnel axis. To ensure the stability of the lateral slope, a soil nailing was necessary as well as a heavy micropile umbrella.

1 EXIT PORTAL

The construction of the tunnel started by Exit Portal on February 2016. It was located in an almost vertical hill side, with good quality rock mass with RMR between 59 and 68 points.

Initial solution proposed the excavation of slopes 1H/10V reaching 80 meters height (Fig. 1).

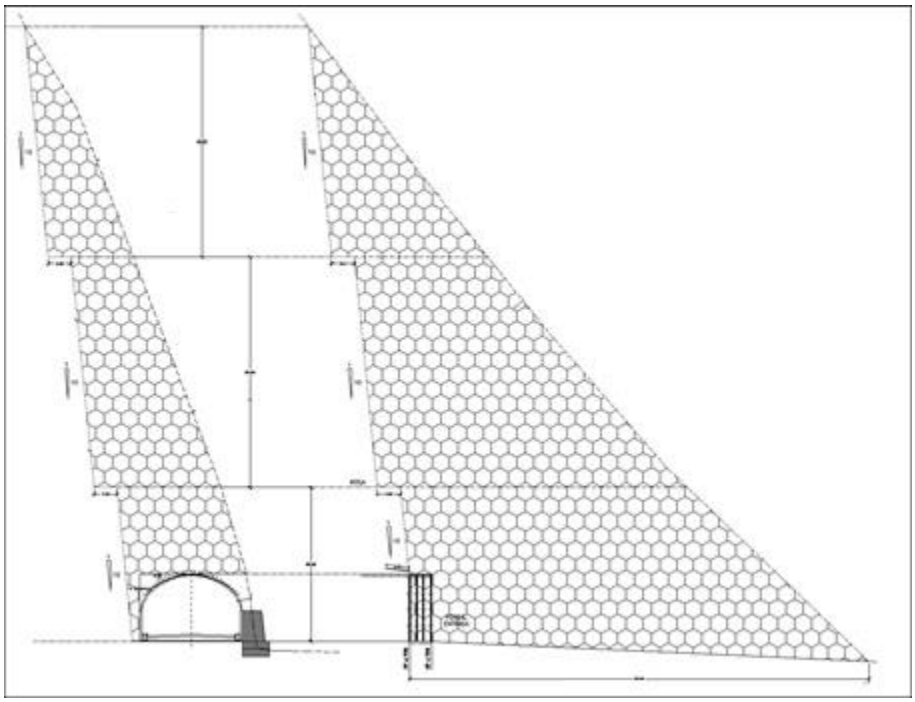


Figure 1. Inicial design of exit portal.

In order to avoid this complex excavation and to save time and costs, the solution adopted was to reinforce with bolts the natural slope without any excavation, and to construct sequentially the tunnel: false tunnel, a transition section, and afterwards starting the tunnel excavation (Fig.2).

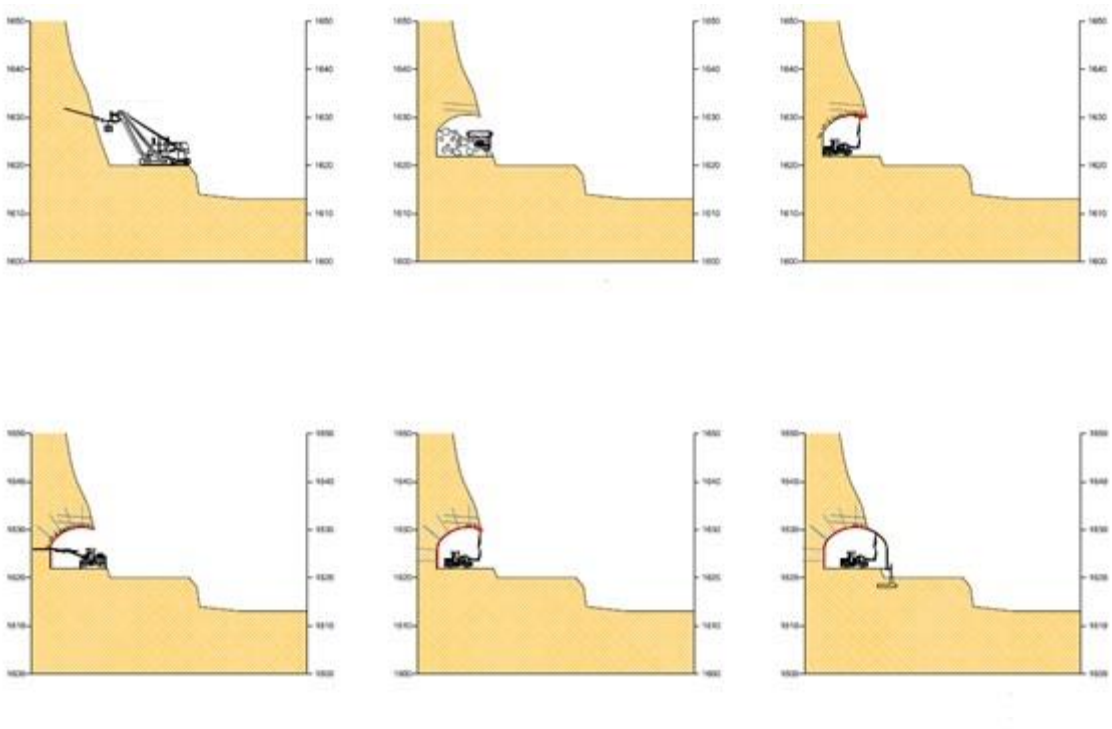
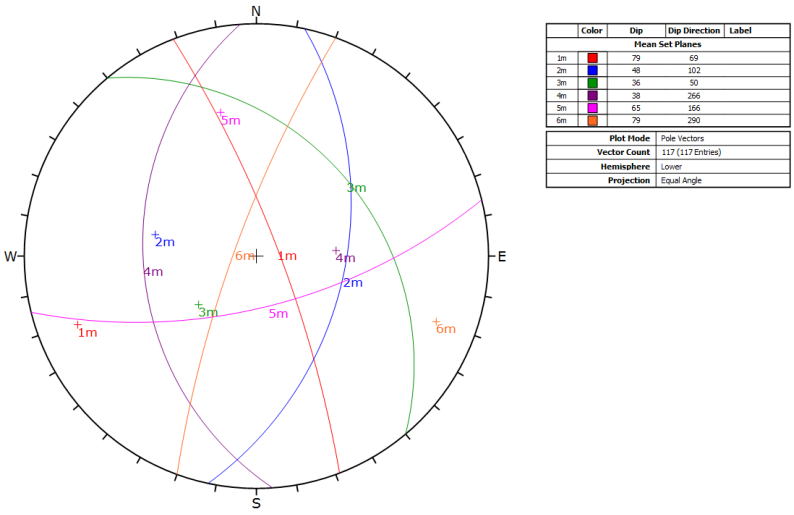


Figure 2. Excavation sequence in exit portal.

Based on geologic mapping, six families of joints were defined (Fig. 3); and were used to analyse and define the proper reinforcement of the natural slope and the support of the part-tunnel.



	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		79	69	
2m		48	102	
3m		36	50	
4m		38	266	
5m		65	166	
6m		79	290	

Plot Mode	Pole Vectors
Vector Count	117 (117 Entries)
Hemisphere	Lower
Projection	Equal Angle

Figure 3. Joints in exit portal.

As result, a pre- reinforcement, the execution of a lateral forepole executed perpendicular to the natural slope with ϕ32 mm bolts of 10 m length was proposed. This pre-reinforcement consisted of two rows of bolts spaced 90 cm horizontally and 1 m vertically. These bolts, in addition to providing a protection to the vault at the time of execution of the partial tunnel, served to stabilize possible wedges and planar breaks that might appear. (Fig. 4)

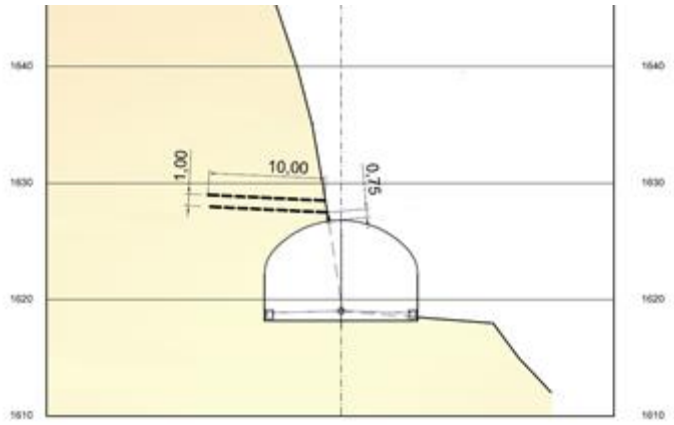


Figure 4. Pre-reinformcement in natural slope of exit portal.

In the part-tunnel, the support consisted on:

- Fiber reinformcement shotcrete: 5+5 cm
- Φ25 mm and 4.5 m length bolts spacing 2.3 m (T) x 1.23 m (L)

The construction of the 37 meters long of this part-tunnel was in steps of 1.23 m and last one month.

As finished, a false tunnel structure was built. This structure, composed by steel arches and shotcrete, was calculated to support the fall of a block of 5 tons weigth. (Fig. 5).

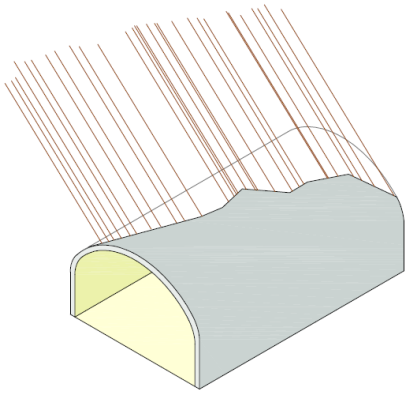


Figure 5.- Finished structure scheme.

Photography 1. Slope pre-reinforcement.

Photography 2. Part-tunnel and structure construction.

2 ENTRANCE PORTAL

The Entrance Portal (West portal) was located entirely in colluvial soils. The original design defined a lateral slope of 45m high in three banks with a slope 1H/3V. (Fig. 6). In order to try to decrease the high of the slope, based on the low quality of the soil, a new geometric design was carried out.

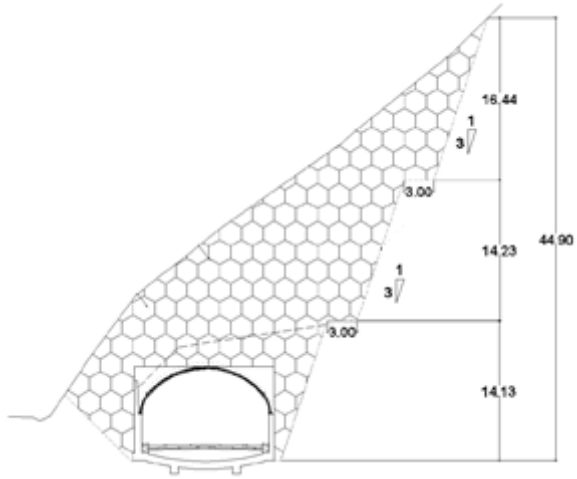


Figure 6. Inicial design of entrance portal.

The new design consisted on a soil nailing for a lateral slope 35 m height, composed by four banks 4m high with a slope 1H/4V. In order to get the less height possible, frontal slope was define with only 15º between the strike of the hill side and the tunnel axis.

In order to define soil properties and the rock contact, three pits and a 40 m length borehole was carried out. In addition, and based on the complex of the portal, an inclinometer was installed in the borehole in order to control the stability during the portal excavation.

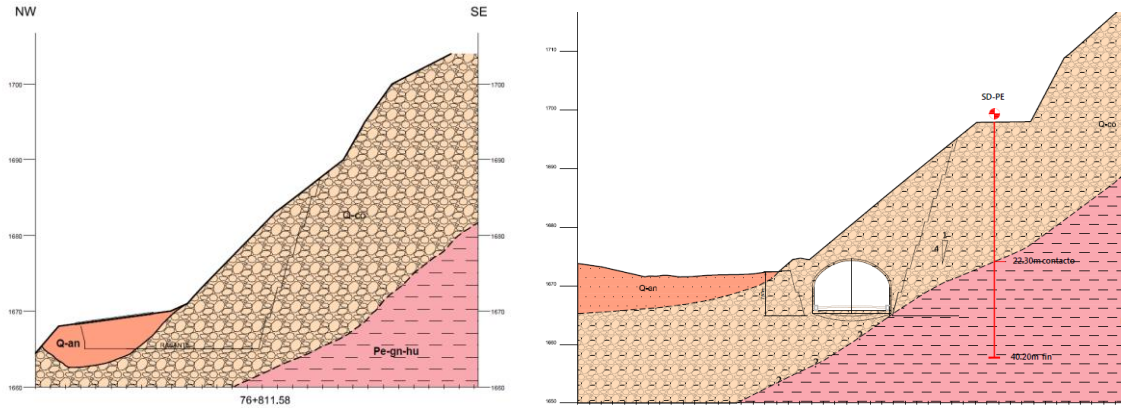


Figure 7. Geological sections in entrance portal.

Based on the stability analysis carried out, the soil-nailing was composed by (Fig. 8):

- Self-drilling bolts of 40ton, spacing 2.0m (H) x 1.5m (V) with lengths between 6 and 9 meters
- 20 cm of shotcrete
- Double steel mesh
- Drains

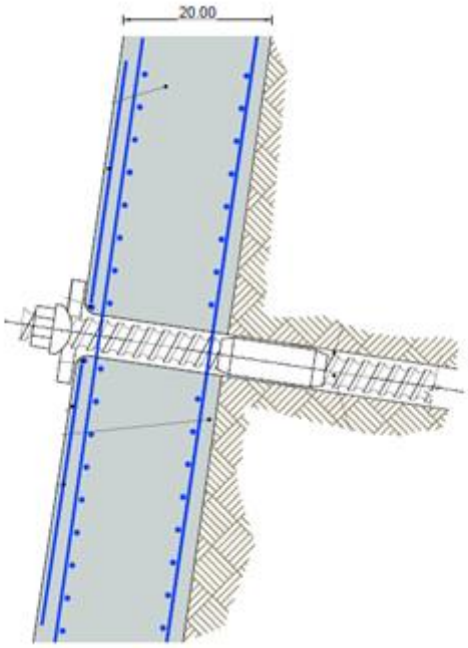


Figure 8. Slope reinforcemente detalis in entrance portal.

After this soil nailing, the false tunnel structure was built and the landfill above completed, before starting the construction of a double canopy tube forepole and the excavation of the tunnel. Figure 9.

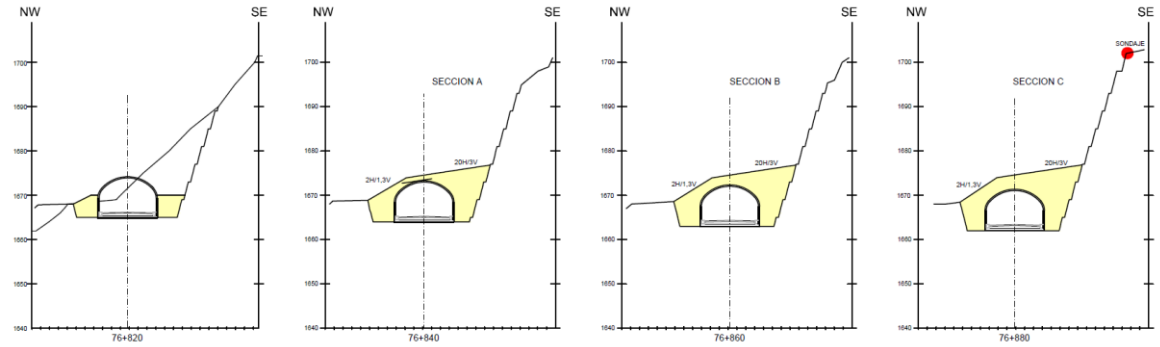


Figure 9. Land fill of false structure.

During the construction, the inclinometer was measured frequently in order to control deep movements. The results showed some movements that was possible controlled modifying slightly the construction process (Figure 10). In addition, topographical landmarks was controlled in the slope to detect superficial movements.

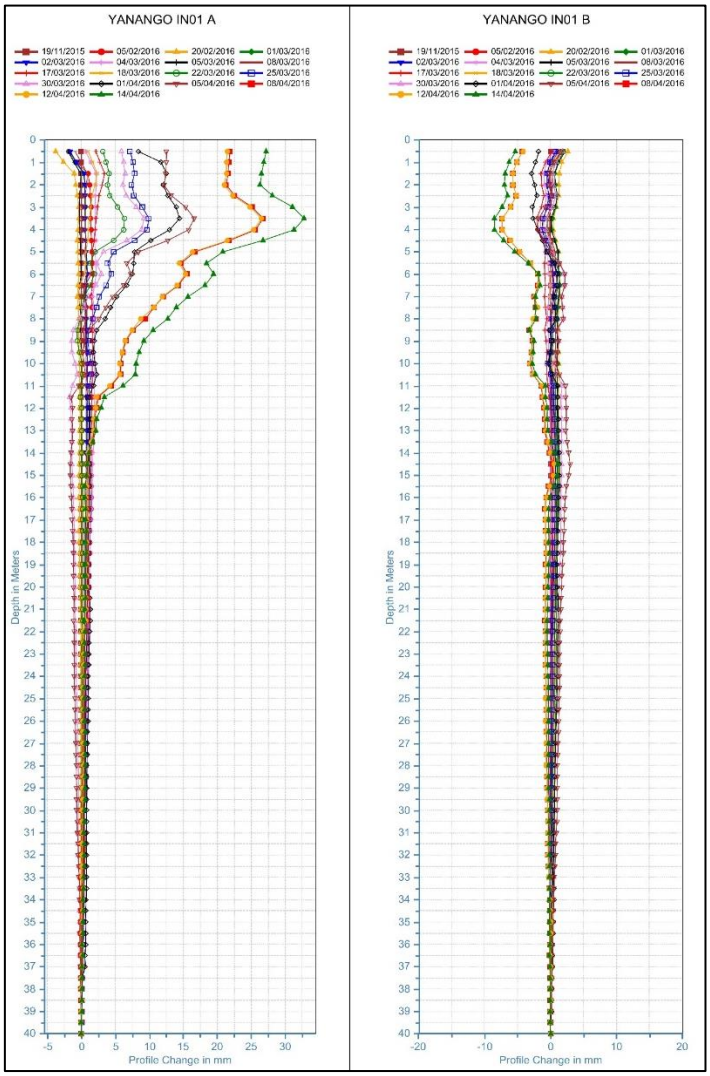


Figure 10. Inclinometer measurement.

The main excavation and reinforcement of entrance portal started on February 2016 and ended on June 2016, having placed 808 self-drilling bolts and 135 drains.

Photography 3. View of the excavations.

3 CONCLUSIONS

The complex Andean orography sometimes requires unconventional solutions to achieve an adequate design of the portals of the tunnels in order to get viable designs.