TIMPA DELLE VIGNE TUNNEL
FALRENA, SA-RC MOTORWAY, ITALY

GROUND REINFORCEMENT AND PORE WATER PRESSURE REDUCTION
Products: P.E.R. Ground, P.E.R. Ground Drain

Problem
During the excavation of the Timpa delle Vigne north tunnel from Reggio Calabria, a very high rate of tunnel convergence was recorded of 15 mm/day. A huge face collapse occurred, due to the unexpected condition of the low-quality rock mass. Generally, phyllitic schists affected by the presence of clay, resulted in a highly weathered rock mass. The low permeability of the clayey ground in a high water content condition formed local aquitards which gave rise to pore pressures which could induce instability.

A solution was required to reduce and control the ongoing tunnel convergence post-collapse. Firstly, increased use of fibreglass pipe umbrella support systems and longitudinal drainage were installed. However these counter measures were found not to be effective as there was insufficient bond strength between the ground and fibreglass pipes. In addition, the pore water pressure was not sufficiently reduced due to there being insufficient drainage installed at the face and boundary of the tunnel.

Solution
Any intervention selected had to achieve a twofold goal:

1. To introduce effective reinforcement with adequate bond-strength between element and ground
2. To substantially reduce pore water pressure.

These objectives were achieved through the application of two ELAS P.E.R.Ground systems;
- P.E.R. Ground and
- P.E.R. Ground Drain, featuring integrated coaxial drainage.

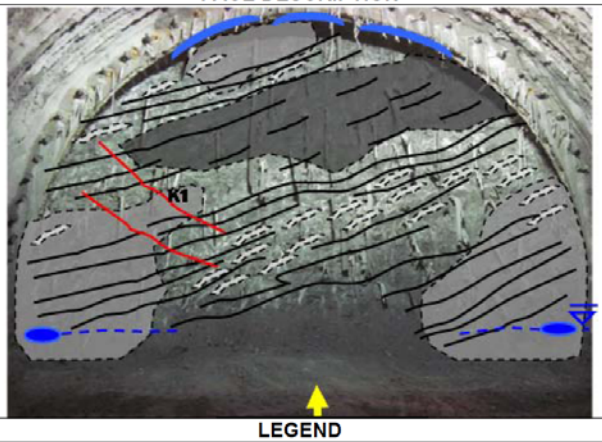
The P.E.R.Ground system used consists of a fibreglass reinforcing bar surrounded by an expandable textile sheath, which is injected with a low-shrinkage cement mortar.

Client:
ANAS
Main contractor:
Pizzarotti S.p.A.
Consultant:
Geodata S.p.A.
Products used:
P.E.R.Ground and P.E.R.Ground Drain
Date of construction:
July 2010 - December 2011

P.E.R. Ground is also available with additional drainage or with a TAM permeation grouting function.

In Timpa delle Vigne, 20m long P.E.R. Ground fibreglass reinforcement bars were used for the basic system. For the multifunction drainage and reinforcement product, P.E.R. Ground Drain, a 10 m long reinforcement element was combined to a drain of equal length, consisting of a micro-slotted PVC pipe protected by geotextile.

FACE DESCRIPTION



LEGEND

Litology	
	Schists or phyllites phyllitic
	Phyllitic shale of massive structure
	Phylklitic altered phyllites or schists
	Quartz veins
	Schistosity
	Discontinuty
Water inflow	
	Presence of water table

Geolithological features
Phyllitic schist or dark phyllitice. These quartz veins in size from centimeters to decimeters.

Major structural
The rock mass is foliated and techtonized. The scistositydips at face with 350/15. A series of joint system characterized by 120/40 was surveyed. The quartz veins are fall within the schistosity and they are concentrated at the center part of the face.

Notes
The face seems wet. At the footing of the tunnel walls, the water inflow was detected as noted the presence of groundwater. In the tunnel crow, the dripping of water from consolidating elements is observed. A part composed of weathered phyllitic schist having lower strength than remaining portion of the face is surveyed (dark grey hatched). The part of crown and that of walls are characterized by phyllitic shist with concisvency (use of percussive ripper)

Extract from the geo-structural survey at the face

Project Description

This innovative technique for improvement in soft ground tunnelling was applied in the Timpa delle Vigne tunnel, a recent infrastructure project in Italy, along the Salerno-Reggio Calabria motorway between km 294 +600 and km 304 +200.

The twin-tube tunnel features:

- Total length of 780m, of which 650m is conventional excavation and 130m 'artificial' excavation;
- Maximum overburden is about 65m;
- Maximum longitudinal inclination (downward in the Reggio Calabria direction) is equal to 3.8% for both tubes;
- Planimetric alignment of the curve has a minimum radius of 1205m for the North tube and 995m for the South tube;
- The total useful span for each tube is 11.2m to meet the traffic requirements, with two 3.75m running lanes for the main carriageways, supplemented with a 3.0m emergency lane and a 0.7m wide lateral platform for traffic signage;
- Seven niches, provided for the safety equipment and required accessories, are placed every 150m;
- Two cross-passages are placed every 300m, connecting the two tubes for emergency purposes.

The excavated area of the tunnel varies between 150 m2 and 170 m2. The conventional excavation was carried out by mechanical hammer over the full face excavation. A total of 4 advancing faces were planned in order to meet the project scheduling.

A heavy primary support system was designed to maintain the tunnel cavity and control the global stability of the surrounding rock mass. This primary support consisted of soil improvement measures using P.E.R.Ground, forepoling, steel arch umbrella, steel ribs, reinforced shotcrete and lateral bolts. Cast in-situ reinforced concrete forms the final lining for the long term stability of the tunnel.

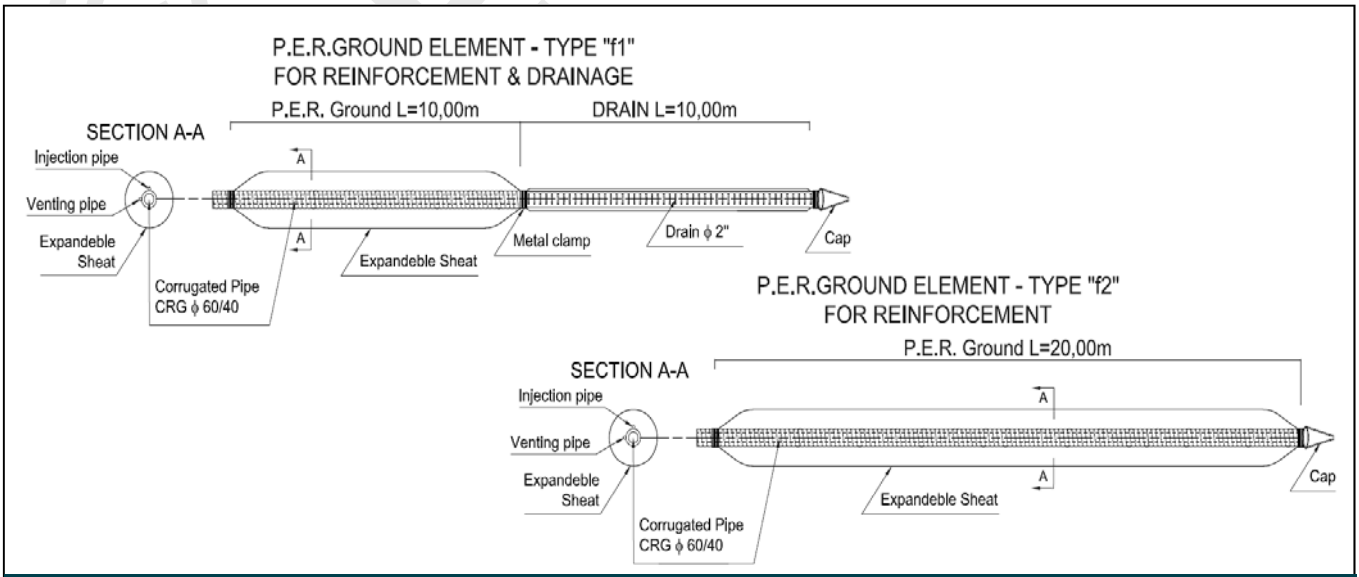
Following the face collapse and ongoing convergence problems, increased traditional counter-measures proved unsuccessful. Insufficient bond strength between reinforcement and surrounding ground and excess pore water pressure remained.

The two P.E.R.Ground systems overcame these problems.

The P.E.R.Ground system is characterized by an excellent anchorage between the reinforcing element and surrounding ground, due to the mortar confined within the sheath, pre-mounted on the reinforcement element. This provides an area of adherence , greater than that offered by traditional fibreglass elements.
This wide area leads to increased skin friction which can be more effectively transmitted to the ground. Furthermore, the expansion of the pressurized sheath compacts the ground surrounding the drill-hole and the associated increase of radial pressure can be accounted for as an increase of apparent cohesion .

The P.E.R.Ground DRAIN system has the same reinforcing functionality, but with an additional drain and the simultaneous benefit of soil reinforcement and the reduction of pore water pressures prior to the excavation. The drains are evenly distributed at the tunnel boundary and face, to direct the water seepage to the drill-holes (where it can be controlled) and not to the excavated surfaces. This reduces the water pressures at-depth, consequently increasing the overall stability of the tunnel. The draining action can also be improved through the use of pumps. The combination of reinforcement and drainage reduces installation time and cost.

By containing the injected grout within a fabric sheath, P.E.R.Ground also reduces grout loss and washout, leading to more efficient and effective grouting operations.

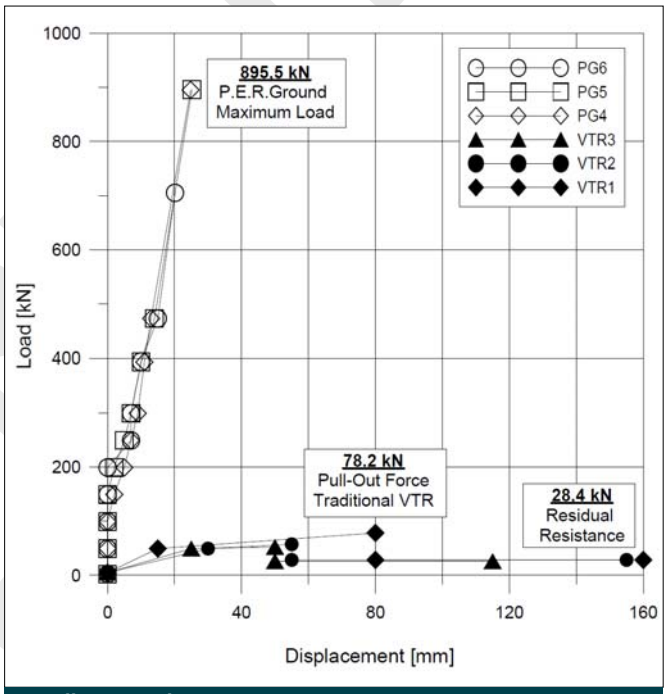


Two different types of P.E.R.Ground: Type f1 for both reinforcement and drainage and Type f2 for reinforcement only

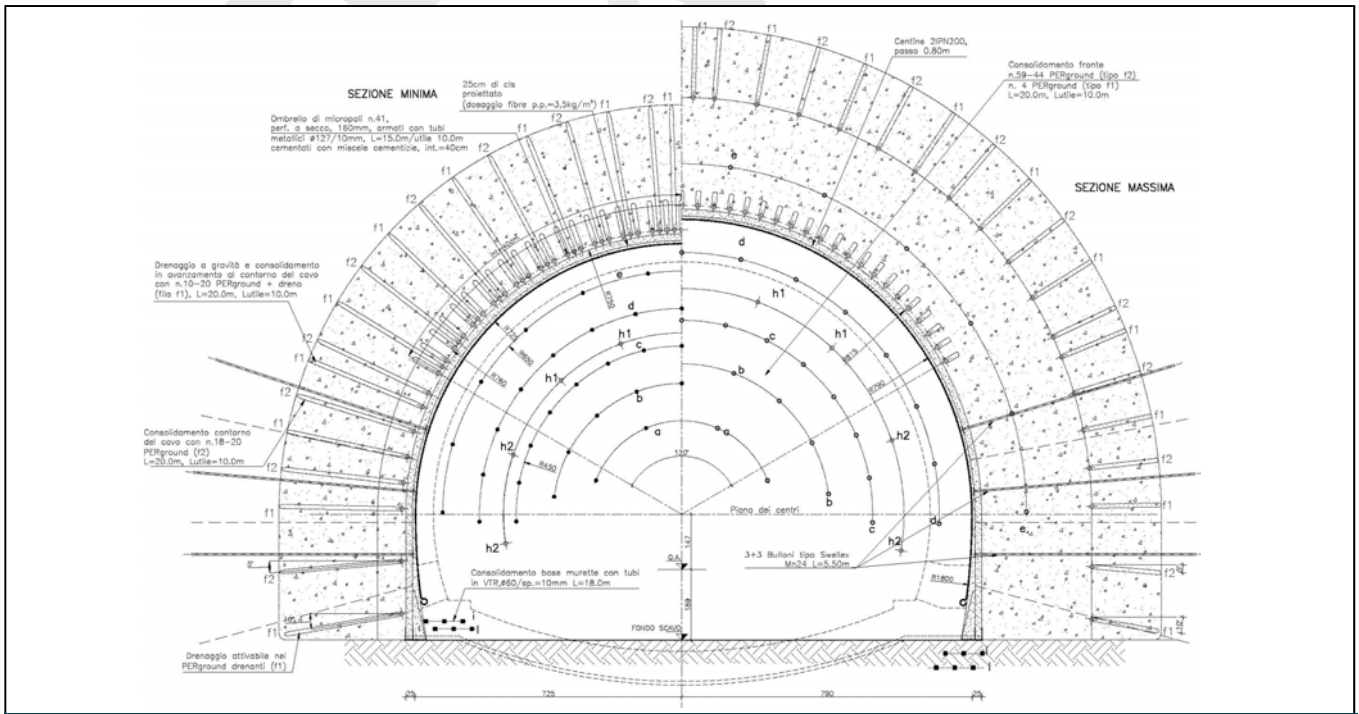
A series of field tests were carried out to evaluate the pull out resistance of the traditional and improved fibreglass soil nails. Two different soil nails were considered:

1. Traditional VTR / Glassfibre tube (60mm dia.) normally used for the reinforcement of tunnel faces, inserted within a previously drilled hole and subsequently filled with cement grout. The grout is injected at low pressure using a small pipe on the side of the tube. Using this system a maximum injection pressure equal to 4 bar can be reached.
2. Unique P.E.R.Ground System glassfibre tube, wrapped in a flexible textile sheath and sealed at the head of the tube. The grout is introduced, via an injection pipe, into the space between the tube and the sheath, filling it. Using this system an injection pressure up to 15 bar can be achieved.

Pull out test equipment



Pull out results



Heavy support section type D* prescribed for the tunnelling in soil like material using P.E.R. Ground

View of the excavated face showing the P.E.R. Ground reinforcement system, some partially excavated as the tunnel advances

Closing Remarks

Difficult tunnelling conditions in Southern Italy, caused by a poor quality rock mass and high pore-water pressures, required an innovative ground improvement technique; The P.E.R. Ground System. This new soil reinforcement solution provides high pull-out strength and the capacity to simultaneously provide a drainage function within a single drill -hole.

Field pull-out tests carried out to investigate its performance proved that P.E.R. Ground provides a pull-out capacity significantly higher than the one provided by conventional soil nails.

This is due to the potential to apply high injection pressures, without a loss of grout or the occurrence of claquage (fracture grouting), and therefore to create a homogeneous grout shaft and a continuous adherence at the interface between the reinforcement and the surface of the drill-hole.

The presence of an integral coaxial drain also reduces the pore water pressures ahead of the excavation surface, thus increasing the stability.

Finally, the successful performance of P.E.R. Ground system is less dependent upon the quality of grout and injection, leading to a more reliable soil treatment.

ELAS Geotecnica S.r.l.
Centro Commerciale San Felice – Lotto 3/21 – 20090 Segrate (MI)
C.F. - P.IVA 12491960154
t: +39 02 7533252 f: +39 02 7532991
www.elasgeotecnica.it