Application Summary Sheet 3

Title: Ground Anchors, Rock Anchors and Soil Nails.

Target Audience: Geotechnical Engineers

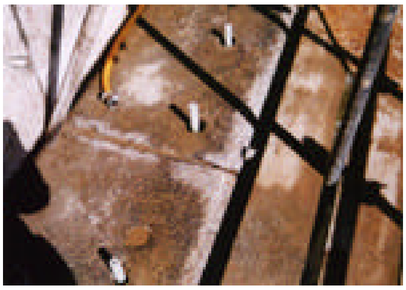
Keywords: Ground anchor, rock anchor, soil nails, slope stabilisation, tunnels, cuttings, retaining walls

Overview of application / summary:

Ground and rock anchors are used to stabilise tunnels, rock faces, cuttings and slopes. A pre-stressed tendon or cable installed inside a borehole applies a restraining force to the rock face or slope via a plate. The end of the tendon is grouted or locked mechanically deeper into sound strata. Ground anchors can also be used to provide support to retaining walls. Soil nails work on a similar principal and are used for slope stabilisation.

Wall stabilisation with soil nails

The use of FRP tendons instead of steel offers advantages of low weight, ease of handling and corrosion resistance, with the ability to use conventional jacking systems. Aramid FRPs have a lower modulus of elasticity than steel, thus load loss due to relaxation of the anchorage system is lower. FRP tendons can also incorporate fibre optic strain sensors for monitoring.



Reinforcement of dock wall

Case Study - Conisborough Tunnel

Conisborough tunnel is 235 metres long on the main line between Doncaster and Sheffield. The 6.1m wide tunnel was causing speed restrictions on the line due to inadequate clearances and repairs were required in two areas. The repairs involved taking out the existing brick lined steel arch reinforcement from previous repairs carried out in the late 1800's. Before this work could be carried out the areas to be repaired had to be reinforced. A system of stainless steel rockbolts was used for this. However, the strata behind the brick lining was very wet and the lower 12m long rockbolt holes, which dipped at 5 degrees to the horizontal, penetrated the water table. This made grouting the steel bolts very difficult. To improve the strata reinforcement in the sides of the tunnel, Weldgrip Gripforce® fibreglass rockbolts were used. The Gripforce® rockbolts were 31/15 OD/ID tubes with a tensile strength of 480kN. The tubes, 12 metres long, were installed in 60mm diameter holes 1 metre above track height and dipped at 5 degrees to the horizontal. Four stainless steel centralisers were used to hold the rockbolts central to the hole, these were positioned equidistant along each bolt. A 200 kN rated high load nut assembly secured each end plate. A Gripforce® tube was installed immediately into each hole after drilling and grouted with Sulphate resistant cementitious grout. This was to eliminate any build up of water and sludge and prevent degradation of the holes.

The grout was pumped through the centre of the tube filling the hole from the bottom. It was noted during grouting operations, that water was displaced from the bottom of the hole before grout flowed out. A total of 100 rockbolts were installed at 1 metre above rail height 50 on either side of the tunnel. Pull out test on the rockbolts gave significantly better results than the equivalent stainless steel bolts. An additional 10 rockbolts 10 metres long, were used at 3 metres above rail height inclined into the roof, to reinforce a fractured section of the existing brickwork. These were installed using the internal bore of the rockbolt as a breather tube. The rockbolt and a plastic grout tube was installed into each inclined hole and expanding foam used to form a seal. Cementitious grout was pumped through the grout tube filling the hole from the sealed entrance to the top of the hole, until grout started to flow from the tube. The orifice of the tube was then plugged with a stainless steel peg.

The advantages of using Gripforce® fibreglass rockbolts
in Conisbrough tunnel were:

- Ease of installing 12 metre lengths by being able to bend the bolts in the confined space of the 6.1m Wide tunnel.
- Tube delivers the cementitious grout to the back of the hole and displaces build up of water.
- Ease of transportation into the tunnel.
- High tensile strength.
- High corrosion resistant particularly important in the wet conditions.
- Improved tube/grout interface bond strength.

Impact of Application

Financial:

FRP tendons, particularly CF tendons, are more expensive than steel, however this cost can be offset by ease of handling and installation.

Environmental:

Alternative to steel

Engineering:

High tensile capacity
Lightweight and bendable - easy to handle in tunnels and areas with difficult access.
Lightweight - minimal addition of dead load to system
Corrosion resistant - may be installed in smaller diameter borehole (high tensile capacity plus protective sheathing not required)
Load loss due to relaxation of the anchorage system is lower with FRP than steel - less need for re-application of pre-stress.
Non conductive
May incorporate fibre optic sensors (see Monitoring)

Where to get further information

References:

Aramid and carbon fibre-reinforced plastic prestressed ground anchors and their field applications
Benmokrane, B, Xu H, Nishizaki I. (1997)
Canadian Journal of Civil Engineering 24,6,968-985

Tensile properties and pull-out behaviour of fibre reinforced plastic ground anchors
Chennouf A, Benmokrane B (1997)
Annual Conference of the Canadian Society for Civil Engineering, Sherbrooke, Quebec, 27-30 May 1997.

Websites:

WTEC http://wtec.org/loyola/compce/03_08.htm

Weldgrip http://www.weldgrip.com/civilsset.htm