FEDERATION OF PILING SPECIALISTS

FPS Guidance Note

Self-Drilling Hollow Bar Systems, Grouted Ground Anchors, Micropiles and Soil Nails: Application, Benefits and Limitations

Scope

This note provides an overview of self-drilling hollow bar systems, grouted ground anchors, micropiles and soil nails, their application, benefits and limitations, together with comment on their design as tension elements in the UK. All of these elements have their place within the design and execution of stabilisation or foundation works however their performance characteristics and durability considerations are different. Key features of the different systems are highlighted below.

Self-Drilling Hollow Bar Systems

Self-drilling hollow bar systems have been available in the UK since the late 1990s. With self-drilling hollow bars there are significant benefits in respect of installation cost and drilling time in certain ground conditions and as the system is ideally suited to loose overburden drilling their use has become widespread in recent years. The self-drilling technique combines the placement of reinforcement and grouting in a single pass, without the need for a casing in ground conditions where boreholes are prone to collapse.

- Typically installed with rotary percussion drilling, using the simultaneous drill and grout technique where grout is pumped through the bore of the bar to the sacrificial drill bit as drilling is advanced with the grout flush comprising a part injection / part flush system. Permeation of grout beyond the nominal borehole diameter can occur in granular soils but be very limited or non-existent in cohesive soils. Air flush, with very careful flush control, has been used in cohesive soil;
- Difficulty in achieving fully debonded free lengths because it is not possible to debond couplers in a practical way. Therefore the apparent free length (derived from the extension characteristic following stressing) is unlikely to correspond with the theoretical free length. A factor requiring consideration during testing. Because of incomplete free length debonding some load shedding will occur in the active zone or free length, with an element of bond capacity in the stable zone or fixed length possibly remaining unproven during load testing;
- Where sacrificial investigation testing is undertaken to assess the ultimate design bond stress the effects of load shedding within the free length/proximal section of the bar should be very carefully considered. Installation and testing to failure of bars of different lengths, subtracting the failure load of the shorter bars from that of the longer bars, can provide a robust way of isolating the load capacity at the distal (fixed length) of the bar;
- There are limitations in achieving corrosion protection as this can only be provided by sacrificial corrosion allowance, galvanizing or other steel coating and borehole grout cover (where cover has been achieved). Grout cover can be problematic at coupler locations particularly when long bar lengths are being used, so should not be relied upon. Epoxy coating or galvanising may be used to mitigate corrosion but will inevitably suffer some damage during installation into the ground. As a consequence,

it is not possible to achieve "double corrosion protection" to ground anchor standards with hollow bar systems.

Grouted Ground Anchors

- May be constructed with cased or un-cased drilling systems to form the borehole into which the anchor components (either bar or strand) are inserted and grouted in place;
- Have a defined *free length* which is isolated from the ground and is free to extend elastically when the anchor is stressed and then throughout its working life;
- Derive their resistance from a clearly defined *fixed length* which is bonded to the ground;
- Are stressed after installation and locked-off to a predetermined load to give an active resistance force which may be used to control deflection of the supported structure;
- For permanent works are constructed with two independent corrosion barriers to provide Double Corrosion Protection (DCP) to all the steel elements of the anchor over its design life, which may be up to 120 years. The barriers should either be plastic sheathing or factory applied grout within an encapsulation sheath. Borehole grout, sacrificial corrosion allowance or galvanizing are not acceptable as corrosion barriers as their integrity cannot be verified, hence they lack sufficient predictability of lifespan to fulfil the design requirements of permanent ground anchors. It is the area of least cover that defines the level of protection provided;
- All grouted ground anchors, installed to the standards listed below, undergo rigorous acceptance testing to demonstrate satisfactory performance, unlike other tension elements which are not suitable to such a stringent testing regime and hence cannot provide the same level of assurance to the designer.

The following standards cover the design and execution of grouted ground anchors.

BS EN 1997-1:2004 + A1:2013 Geotechnical Design (and relevant UK National Annex)
BS 8081:2015 Code of Practice for Grouted Anchors
BS EN 1537:2013 Execution of Special Geotechnical Works - Ground Anchors

Tension Micropiles

- May be vertical or inclined and constructed with cased or un-cased drilling systems to form the borehole into which the tension reinforcement is inserted;
- Do not have a debonded *free length* and are therefore fully bonded to the ground within the borehole over their entire length;
- Provide passive support, as they cannot be effectively stressed after installation due to the pile being fully bonded. Micropiles become loaded by movement of the supported structure and thus cannot offer the same degree of deflection control as grouted ground anchors;
- Corrosion protection options include sacrificial corrosion allowance, galvanizing/epoxy coating, use of a plastic sheath or double corrosion protection where the corrosion risk is high. Concrete or grout may crack under tension forces and the implications of this should be considered where appropriate.

The following standards cover the design and execution of tension Micropiles

BS EN 1997-1:2004 + A1:2013 Geotechnical Design (and relevant UK National Annex)
BS 8004:2015 Code of practice for foundations
BS EN 14199:2015 Execution of Special Geotechnical Works – Micropiles

Soil Nails

- May be constructed using either solid reinforcement within open-hole or cased boreholes, or self-drilling hollow bar. Bars are usually fully grouted within the borehole;
- Defined as reinforcing elements installed into the ground, usually at a sub-horizontal angle, that mobilise resistance with the soil along their entire length;
- Provide lightly loaded passive support, as they are not stressed after installation as grouted ground anchors are, but become loaded by movement of the slope or supported structure;
- Corrosion protection options include sacrificial corrosion allowance, galvanizing, epoxy coating, plastic sheath (providing it can be installed without damage), borehole grout or concrete cover, or occasionally double corrosion protection for aggressive soils conditions.

The following standards cover the design and execution of soil nails
BS 8006-2: 2011 Code of Practice for Strengthened / Reinforced Soils. Part 2: Soil Nail Design
BS EN 14490 : 2011 Execution of Special Geotechnical Works - Soil Nailing
CIRIA C637 2005 Soil Nailing - Best Practice Guidance

Summary

Whilst it is impossible to give hard and fast rules regarding the appropriateness of a defined system in a given situation, the following aspects should be considered when selecting and designing tension elements for geotechnical applications-

- Is the long-term durability of the tension element important? If so, either a grouted anchor with double corrosion protection or a tension pile with the reinforcement in a grouted encapsulation duct (impermeable corrugated plastic sheathing) may be required;
- Is a prestressing force required (to control the deflection of the supported structure)? A conventional grouted ground anchor, with its independent sheathing and coupler cover tubes within the free length, should provide the required level of debonding to enable a prestress to be applied and locked-off in the anchor tendon. Load testing can be used to check the required level of debonding is achieved. For temporary applications (where long term durability is not a concern) a self-drilling hollow bar system may provide a suitable solution, subject to the limitations of free length extension outlined above;
- Is passive (as opposed to pre-stressed) tension support sufficient? If so, a tension pile or self-drilling bar system may be acceptable;
- Re-classification of a permanent grouted ground anchor as a tension pile, in order that a lower level of corrosion protection may be applied, may reduce the lifespan of the installation, will affect the extension characteristic under service loadings and may preclude the use of effective pre-stressing which may be important in controlling deflection in the supported structure.