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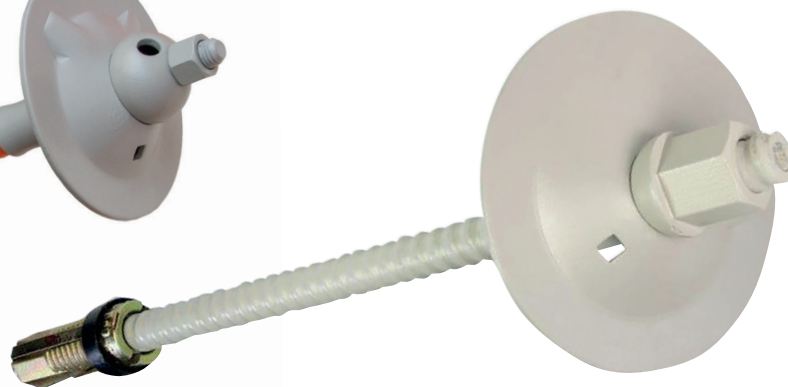
Grouting

**Recommendations for cementitious grout for
NC-Bolt and Pc-Bolt™**





NC-Bolt



PC-Bolt™

Introduction

The grout used for the two types of combination bolts, NC-Bolt and Pc-Bolt™ has a dual purpose of:

1. Transforming the end-anchored and therefore elastic bolt into a full-length mort embedded bolt with a stiff response to loading and deformation.
2. Complete and full-length mortar embedment for additional corrosion protection.

Grout used for the combination bolts must have suitable rheological properties to allow controlled and complete filling of the targeted empty volume along the bolt, must provide good adherence to all surfaces along the bolt length, demonstrate minimal or no shrinkage and minimum 30 MPa compressive strength after 28 days.

Practically, the most important issue is linked to providing suitable rheology both for the controlled and complete embedment of the bolt and at the same time allowing problem free mixing and pumping of the grout. To ensure the satisfaction of all requirements, it is strongly recommended to follow these recommendations and to execute pre-construction tests on site, using locally available cement, water reducing admixture and the production equipment planned for mixing and pumping of the bolt grout underground.

Type of grout to be used

Grouting of rock bolts is sometimes executed using simply a mixture of cement and water, may be with added filler or fine sand. This approach is not recommended because the w/c-ratio will be high to provide required viscosity for pumping and even fine sand will increase the pumping resistance and add an extra step to the mixing process with increased risk of quality variation.

There are in the market, pre-bagged special mortars that may be technically and practically excellent choices, but the cost may become an issue and pre-construction testing to verify suitability will anyway have to be carried out.

The recommendation for bolting grout can be listed as follows:

1. Select a common standard cement available at the job-site. This may be a pure Portland cement or a blended type cement typically used in the area for general concrete works.
2. Water reducing admixture must be used to reach a pumpable grout at w/c-ratio in the range of 0.3 to 0.4, which brings mortar shrinkage down to a minimum and will produce compressive strength much higher than actually required. Locally available liquid admixture normally used for mixing of concrete may be tested and used. A better choice will be powder form admixture specially designed for bolting and cable anchor grouts. Such admixture will typically contain also components for plastic stage expansion and shrinkage reduction and may contain silica fume for improved bond and grout thixotropy.

Equipment for mixing and pumping

When mixing pure cement and water (with admixture), not all types of mixers will be suitable. As can be expected, cement will easily stick to mixing paddles and container sides and build lumps before the water and admixture has been well distributed into the grout.

To avoid this kind of problem, the mixer should be of the vertical axis type, offer a high speed of rotation and the mixing vanes should typically be round steel bars, may be combined with rubber scrapers against stationary parts in critical areas.

Mixing vessel bottom outlet works best and the grout pump should be connected as directly as possible (short piping with large internal diameter). The typical grout produced as outlined above can be pumped by many types of pumps, but at the correct viscosity and through partly small diameter connections and conduits, the pump chosen must offer sufficient problem-free maximum pumping pressure. Depending on equipment set-up, bolt details and borehole diameter and length, the pressure capacity of the pump should be > 30 bar. Piston pumps are probably the safest choice, but multi-stage progressive cavity pumps (also called mono-pumps) and peristaltic pumps may work very well.

Grouting of NC-Bolt

As shown to the right and in the grouting video on www.pretec.no grout is pumped through the hole in the grouting head, through the annulus between bolt steel and the bubble deformed plastic grouting pipe and up to the expansion shell at the end of the bolt.

The grout then continues top-down between plastic pipe and rock until grout is expelled through the hole in the bearing plate.

The viscosity of the grout used in vertical bolts, must be high enough that grout is flowing top-down by pumping action and not by gravity. Too low viscosity (too fluid grout), will cause the grout to partially drop from the expansion shell end to the bearing plate and grout will appear through the bearing plate prematurely (before the plastic-pipe/-rock annulus has been properly filled).



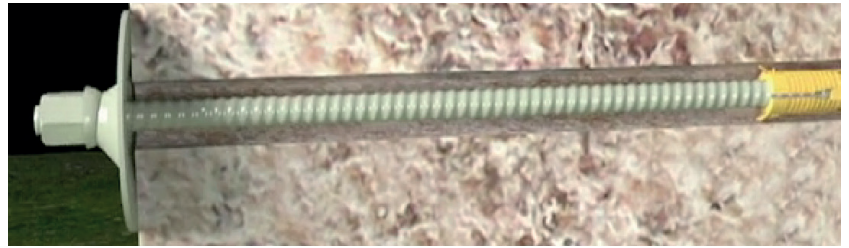
Grouting of PC-Bolt™ in dry boreholes

The Pc-Bolt™ is a steel tube as shown to the right and in the Pc-Bolt™ grouting video on www.pretec.no.

This bolt type does not have the plastic grout pipe, so grout is pumped in through the central hole in the bolt steel to enter the annular space at the top end around the expansion shell and will fill the annulus between steel and rock top-down until grout appears through the hole in the bearing plate.

The viscosity of the grout used in vertical bolts, must be high enough that grout is flowing top-down by pumping action and not by gravity. Too low viscosity (too fluid grout), will cause the grout to partially drop from the expansion shell end to the bearing plate and grout will appear through the bearing plate prematurely (before the annulus has been properly filled).

The Pc-Bolt™ may be used in borehole diameter as large as 68 mm, which in vertical holes will increase the risk of partial filling of the annulus, if the grout is too liquid.



Grouting of Pc-Bolt™ with Pc-Packer in wet boreholes

The above outlined standard grouting method works well in dry holes, but if the grout flowing top-down along the annular space is hitting water flow from the rock, the grout may be diluted and will easily be washed down to the bearing plate without properly filling the annular space. In such cases, it is simpler and more reliable to use the 'opposite' grouting approach with the Pc-Packer at the borehole collar, as shown in the brochure. Pc-Packers are available for different bolt and drill hole diameters.

By using the metall pipe inserted through the bearing plate and the Pc-Packer for grout injection, the annulus can be safely filled bottom-up, thus lifting and pushing water ingress on top of the grout front and channels and cavities in the rock may even be partially filled by grout, while water ingress is blocked. When the annulus is completely filled, water through the bolt central hole will be replaced by cement grout and the injection is complete. The bolt end will then be sealed by a cap nut.

Even though the metall pipe through the Pc-Packer has limited diameter and cross section, thus requiring a relatively low viscosity grout, this does not cause any problems regarding complete filling of the annular space or risk of grout dilution. The pumping process simply has to run until normal consistency grout appears through the bolt center hole.



NTN

NORWEGIAN TUNNELLING NETWORK

Norwegian Tunnelling Network (NTN) has issued a “Best Practice / the Norwegian way” document regarding installation of rock bolts:
www.norwegiantunnelling.com

Look under “Elements of Norwegian tunneling” and “Temporary and permanent rock bolts”.



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