Introduction

Among the members of Norwegian Tunneling Network (NTN), there are 2 manufacturers of different types of rock bolts which they bring to the market both in Norway and abroad. The bolt types are used for a variety of different ground conditions and practical purposes, but in any case produced to standards and requirements implemented for Norwegian projects. The requirements apply both for temporary bolts, permanent bolts and combination type bolts. Acceptable methods of anchorage, corrosion protection, installation procedures and of course strength and ductility of steel used for rock bolts are specified and implemented as relevant.

This information is offered by NTN in support of supply of rock bolts to markets outside of Norway by providing specific information about quality requirements and usage strategies in the Norwegian domestic market, for potential foreign users to establish for their own purposes the suitability of rock bolts manufactured by any of our Members. This Memo provides an outline of normal use of rock bolts and the requirements that typically have to be satisfied in domestic projects.

Types of Rock Bolts – Manufacturing and Supply

The main public sector tunnel construction Owners are the Public Roads Administration (SVV) and the National Railway Authority (JV). These bodies have a dominant position in the national tunneling market and they only accept bolt types that are pre-approved for delivery and use on any of their projects. The manufacturers consequently produce different bolt types that are approved by SVV and JV and many other Owners are specifying and using the same types of approved bolts. There are also bolt types available that are not subject to the mentioned approval requirement.

The available range of bolts covers a wide variety of support situations, from pre-excavation bolting (spiling) for tunnel portals or at the tunnel face, to radial rock bolts in tunnels and caverns designed for immediate, permanent and combined purposes. Anchorage may be provided by end-point fixation by mechanical expansion shell, two-component resin cartridge or cement based cartridges. Bolts can be fully grouted or partly grouted as well as installed slack or pre-tensioned as required for the rock support case.

Based on the above, a closer description of approved bolt types gives the following details:

- It is normally required to use 20 mm diameter ribbed reinforcing bar ('rebar') rock bolts with minimum yield strength of 500 N/mm^2, minimum tensile strength of 600 N/mm^2 and minimum ductility A_{gt} of 8%, satisfying B500NC steel quality according to the requirements of NS 3576-3:2012, Norwegian Standard, or equivalent. However, bolts manufactured from steel satisfying other Standards have been approved based on SVV internal procedures.
- Spiling bolts shall be 25 or 32 mm diameter rebar.
- The rock bolts must be hot-dip galvanized with minimum 65 µm local coat thickness and mean coat thickness of minimum 70 µm according to NS-EN ISO 1461. Next, powder coated by epoxy with minimum 60 µm mean thickness according to EN 13438. The complete corrosion protection treatment is named "Combicoat" or "Pc-Coat" depending on the bolt manufacturer and the process consists in any case of hot-dip galvanizing, zinc manganese phosphate treatment and epoxy powder coating.

- Rock bolts for permanent support must be grouted by cement based mortar that ensures complete embedment in the selected grouting material over the full length. Any mortar for grouting of bolts must show a plastic stage expansion and minimum B20 strength class.
- Alternatively, combination bolts can be used. These are first end-anchored (for immediate support) and later fully grouted (post-grouted). Available combination bolts are CT-Bolt, Pc-Bolt and the NC-Bolt. The bolts must be tensioned at installation. To be approved as permanent support, rock bolts with a mechanical end-anchoring must be post-grouted. The post-grouting process must ensure a complete encapsulation of the bolt over its full length.
- In situations with very high rock stress, it is required to use resin cartridge end-anchored bolts and decision about acceptance or rejection as permanent bolts must wait until the load and deformation development over time can be evaluated. If approved for permanent support, full length grouting must be performed.
- The bolts shall have cold deformation rolled-on threads and be equipped with nut, angle adjustment hemisphere and bearing plate that ensures a stable contact against the rock substrate or the sprayed concrete surface. Bearing plates, hemispheres and nuts must be protected against corrosion in the same way as the bolt. The bearing plate must be spherical and minimum 190 mm diameter with a thickness of minimum 5 mm.

Installation of Bolts

Bolts may be placed locally on demand or systematic. By ‘on demand’ is meant placement without any particular pattern or system based on careful evaluation of the location of each individual bolt. By ‘systematic’ is meant bolt placement according to a pre-decided rectangular, square or diagonal pattern.

Systematic bolting is typically executed after sprayed concrete has been placed (if any). Local on-demand bolting is normally executed before application of sprayed concrete to make it easier to judge the best location and angle of each bolt.

Tensioning of bolts requires equipment that allows verification of the actually generated axial load in the bolt.

The borehole diameter must be selected to suit the chosen type of bolt. The most common hole-diameters are between 45 and 48 mm. This is of particular importance for end anchoring by resin cartridges, but mechanical anchors are also produced for a limited diameter range. Fully grouted bolts must be completely embedded in the grout material.

It is generally required that the protruding bolt end does not reach more than 150 mm on the inside of the theoretical rock excavation profile. In areas to be covered by precast concrete wall elements, the end of the bolt must not protrude more than 20 mm beyond the nut. Bolts that will be covered by sprayed concrete must be cut flush at the nut before concrete placement. The fresh cut of the bolt-end must first be coated by epoxy.

When the tunnel face has moved to a suitable distance, normally around 50 m, tightening of nut and bearing plate and re-tensioning of pre-tensioned bolts to specified load can be done.

Any testing and approval of end-anchored bolts for cases of very high rock stress must be specifically agreed with the Owner.

Quality control of fully grouted bolt installation is done by verifying that mortar is extruded around the bearing plate, along with measured and documented consumption of mortar with the correct properties. Grouted bolts shall be immediately marked as such to distinguish them from un-grouted bolts.

Quantity of each type and length of bolt must be established. Bolts that fail inspection or have been damaged or removed by blasting are not counted. Unit: Installed Pieces (pcs).

Reference documents used

The reference documents include parts of Norwegian Standards, handbooks and specifications issued by the Norwegian Road Authority as well as foreign specifications and standards. SVV implements an approval procedure for applications about use of additional standards and specifications. Available from SVV is a complete list of all combination bolts approved for use in Norwegian road tunnels. Some of the above mentioned material is in Norwegian without complete official translation into English.

Anybody with special interest in products offered by the NTN bolt manufacturers are invited to request supporting documentation as needed with translations of any Norwegian language parts. This is also recommended to cover possible changes of specifications and requirements implemented after the date of this document. Necessary detailed information will be provided by the bolt manufacturers.

Norwegian Tunneling Network

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List of main References

1. Norwegian Standard NS 3576-3:2012
2. Chinese Standard, Steel for the Reinforcement of Concrete, GB1499.2-2007
3. Hot dip galvanized coating on fabricated iron and steel articles – EN ISO 1461
4. Powder organic coatings for galvanized or sherardized steel products for construction purposes – EN 13438