

TECHNICAL USER MANUAL

for

ROCKBOLT CONSUMABLES AND TESTING

Standard Detail and Design Drawings

Summary

The purpose of this document is to provide background information on Rockbolt Consumables and Testing to be used for Tunnel Renewals as part of the suite of Network Rail Standard Tunnel Repair Details. The aim is to utilise cost efficient rockbolting systems based on standard off the shelf rockbolting consumables and their compatible off the shelf standard drilling consumables.

Issue record

This technical user manual will be updated when necessary by distribution of a complete replacement. A vertical black line in the margin will mark amended or additional parts of revised pages.

Revision	Date	Comments
A	July 2010	First Issue

Disclaimer

In issuing this document for its stated purpose, Network Rail makes no warranties, express or implied, that compliance with all or any documents it issues is sufficient on its own to ensure safe systems of work or operation. Users are reminded of their own duties under H&S legislation.

Supply

Copies of documents are available electronically, within Network Rail's organisation. Hard copies of this document may be available to Network Rail staff on request to the relevant controlled publication distributor. Other organisations may obtain copies of the document from IHS (Technical Indexes Ltd) tel: 01344 328 039

Comments

The applicability and content of this standard will be reviewed on a regular basis. Written comments on the accuracy and utility of this standard will be taken into account when assessing the need for a new issue of the standard; such comments should be sent to the Principal Policy and Standards Engineer (Civil Engineering) at 40 Melton Street, London NW1 2EE.

CONTENTS

Section	Description	Page
1	INTRODUCTION	01
2	RENEWAL DETAIL DESCRIPTION	01
2.1	Common usages for rockbolts	01
2.2	Useful Definitions	01
2.3	Rockbolt Material Types	03
2.4	Material Choice – Performance under Loading	04
2.5	Material Choice – Electrical Conductivity	04
2.6	Bond Mediums	04
2.7	Selection of Bond Medium	06
2.8	Mechanical Components	08
3	LIMITATIONS OF USE	10
3.1	Rockbolting and Voiding	10
3.2	Weak Tunnel Lining	13
3.3	Weak Rock Strata	13
4	DEFECTS TO BE REMEDIED	14
4.1	Introduction	14
4.2	Rock Reinforcement in Unlined Tunnels	14
4.3	Material Defect in Masonry Lined Tunnels	14
4.4	Structural Defect in Masonry Lined Tunnels	15
5	DESIGN PHILOSOPHY	15
5.1	Introduction	15
5.2	Rock Reinforcement in Unlined Tunnels	15
5.3	Material Defect in Masonry Lined Tunnels	15
5.4	Structural Defect in Masonry Lined Tunnels	16
6	INVESTIGATION AND TESTING	16
6.1	Introduction to SEPT	16
6.2	SEPT Historical Background	16
6.3	SEPT Testing – Other Information	17
7	HEALTH AND SAFETY	18
7.1	Collapse of Existing Lining	19
7.2	Rockbolt Failure during Testing	19

7.3	Considerations to adequate Ventilation	19
8	FURTHER GUIDANCE	19
8.1	Headroom and Gauge Clearance	19
8.2	Overhead Line Electrification	19
8.3	Installation	20
8.4	Definitions of Sub-Standard Installation	20
8.5	Overcoming Potential Problems	21
8.6	Quality Control	24
ANNEXE I	Schedule of Standard Drawings	26
ANNEXE II	List of References	26
ANNEXE III	SEPT Testing Pro Forma	27

I INTRODUCTION

The purpose of this document is to provide background information on Rockbolt Consumables and Testing as used for Tunnel Renewals as part of the suite of Network Rail Standard Tunnel Repair Details as specified in the *Standard Detail Drawings NR/CIV/SD/590* and *NR/CIV/SD/591* (herein referred to as SD Drawings). The Standard Details aim is to ensure a cost efficient system based on the utilisation of standard, off the shelf rockbolting consumables & their compatible off the shelf standard drilling consumables. These systems have been developed to allow easy and practical application on site with high productivity and high system performance which relies on the application of simple on site quality controls.

2 RENEWAL DETAIL DESCRIPTION

2.1 Common usages for Rockbolts

Rockbolts are a common element used in tunnels and are also applicable in shafts, cross passages, adits and portals. The system applies to the following applications of rockbolts:-

- Spotbolting
- Pattern bolting
- Pattern bolting with mesh
- Pattern bolting with shotcrete

2.2 Useful Definitions

Definitions are given below for some of the common terms used through out this Technical User Manual, and featured on the SD Drawings.

2.2.1 Rockbolt System

The combination of rockbolts, their associated mechanical components (i.e. end plates, nut, washer, couplers) and consumables (i.e. resins or grouts) is given the term; “*Rockbolt System*”. Rockbolt Systems should not be confused with Anchor Systems, Anchor Bolts, Ground Anchors or similar and the following distinction is made between these systems.

For the purposes of this SDD and TUM “Rockbolts” are fully encapsulated throughout their installed length in resin or grout which provides a bonding medium between the rockbolt and the ground. Load is transferred through the bonding medium throughout the embedded length with less reliance on load transfer through the end plate assembly, although nominal tightening loads may be applied through the end plates during bolt installation where two speed resin systems are applied. In extreme cases where ground movement results in the dilation of the strata within the rockbolted length, end plates may also become loaded in service.

Anchor Systems are not generally fully encapsulated in a bonding medium and, as the name suggests, rely on the anchorage and the end plate to tension the anchor for ground support. Large pre-stressing loads may be applied to these systems.

2.2.2 Short Encapsulation Pull Test - SEPT

Short Encapsulation Pull Test or SEPT is the name given to the testing methodology for rockbolt systems. Further detail on the SEPT is given in **Section 6**

2.2.3 Bond Medium

“Bond Medium” refers to the resin or grout that provides the bond between the rockbolt and the surrounding strata. Refer to **Section 2.6** for further information on bond mediums.

2.2.4 Anchor Zone

“Anchor Zone” is a term used with anchor systems or with rockbolt systems where a two speed bonding medium is used. For rockbolt systems the “Anchor Zone” refers to the initial length of the rockbolt in which the *Fast Set Resin* is utilised to provide an initial anchorage for bolt tensioning whilst the *Slower Set Resin* or grout cures. This allow for the rapid installation of rockbolt systems. Reference is also made to the anchor zone in the SEPT where a reduced bond length (i.e. a measured *short encapsulation*) is required for testing purposes. In construction rockbolts the length of the anchor zone can vary dependent upon performance requirements and capsule sizes.

2.2.5 Bolt Free Length

The “Bolt Free Length” refers to the length of rockbolt that is not bonded to the surrounding rock. In SEPT tests this refers to the length of rockbolt between the encapsulated end anchor zone and the inside face of the loading nut. The dimension is indicated on SD Drawing NR/CIV/SD/590.

2.2.6 Bolt Diameter

Rockbolts are typically produced with a continuously threaded or ribbed profile to improve bond performance. Where the Standard Detail Drawings refer to “*Bolt Diameter*” this should be taken as the “*Outside Diameter*” of the rockbolt, i.e. to include the threaded or ribbed diameter. Typically, the manufacturer’s stated classification of the rockbolt (i.e. 24mm Dia.) includes the thread / ribbed diameter in this measurement.

NOTE FOR SEPT Testing : Both the outer diameter and the core diameter of profiled rockbolts need to be measured and recorded for SEPT testing, (see **Section 6** for more details on this).

2.2.7 Scheme Designer

“Scheme Designer” refers to the party responsible for specifying the detail to be used. The Scheme Designer may be a third party consultant or in some instances, a Network Rail representative. Input from the Scheme Designer is required for specifying the rockbolt system design parameters including rockbolt type, rockbolt length, rockbolt density and pattern, required bond stress, mesh specification or SCL specification and for matters such as mitigation actions for voiding or allowable bond performance criteria.

2.3 Rockbolt Material Types

The rockbolts selected for use with this SD Design are made from corrosion resistant materials, typically Glass Reinforced Plastic (GRP), Galvanised Steel or Stainless Steel. They come in a range of diameters and lengths dependent upon the application in question and the required load capacities.

2.4 Material Choice – Performance under loading

The choice of rockbolt type will depend on the nature of the applied loading and how the rockbolt is required to perform when subject to shear or tensile loading.

2.4.1 Shear Resistance

Where resistance to shear forces is critical, steel rockbolts may provide a performance advantage over GRP rockbolts.

2.4.2 Tensile Strength

Where mobilising the tensile strength of the rockbolt is critical either steel or GRP rockbolts may prove effective. However, GRP rockbolts may provide an advantage over steel bolts in terms of their lightweight nature (for manual handling), flexibility during insertion, and long term corrosion resistance.

2.5 Material Choice – Electrical Conductivity

GRP rockbolts are suitable for applications in which electrical non-conductivity is a desired material characteristic such as for use in tunnels where OHLE is present.

2.6 Bond Mediums

The strength of the rockbolts is mobilised through the use of a “bond medium” which allows load transfer (shear or tensile forces) between the rockbolt and the surrounding rock strata. The bond medium can comprise high strength, high stiffness resins, grouts or a combination of the two. The design is based on full encapsulation of the rockbolt using the selected bond medium or mediums as described below.

2.6.1 Two Speed Resin System

For Two Speed Resin Systems, full encapsulation is provided through utilisation of a combination of resins with differing setting speeds, whereby an end anchor zone provides an initial bond using a *Fast Set Resin* and the remaining encapsulated length utilises a *Slow Set Resin*. With this system the *Fast Set* anchor zone provides initial support to the rockbolt whilst the slow set resin cures. The system was developed to allow rapid installation times for rockbolting when used in conjunction with torque breakout nuts, where the completed rockbolt and end assembly are installed and tightened in a one-pass operation. The system also allows nominal pre-tension to be applied to the rockbolt. Typical setting times for the fastest and slowest resin are 15 seconds for the fastest and 2 minutes or 10 minutes for the slowest. Resin systems rely on there being a relatively small annulus between the drilled hole and the inserted bolt, with a typical annulus size being between 2mm to 3.5mm by radius.

2.6.2 Grout Only Systems

For Grout Systems, full encapsulation is achieved through the use of cementitious column grouting. Due to the increased set time, temporary support may be needed to support the rockbolt during the setting period. Two grout systems are commonly used. A pumped grout system requires a grouting and breather tube to ensure full encapsulation and quality of installation. With this system the grouting is carried out after the rockbolt or anchor has been installed (post grouting). Pumped systems require much larger diameter boreholes to accommodate the grout and breather tubes needed for installation and consequently the bond performance of these systems tends to be much lower than resin systems.

An alternative system utilises Thixotropic Grout where the grout is tremmied into the hole before the rockbolt or anchor is inserted. Because grout and breather tubes are not required for the installation, borehole sizes can be much smaller than for pumped grout systems potentially giving better bond performance, though the holes still tend to be larger than the hole sizes required for resin systems. This system is much simpler and easier to apply than the pumped system but hole diameter is important, particularly when installing vertical rockbolts as the grout can fall under gravity if the hole diameter is too large. Grout suppliers should be consulted to determine appropriate system parameters.

2.6.3 Combined Resin and Grout Systems

Combined Resin and Grout Systems utilise a *Fast Set Resin* in combination with a column grout system. The configuration is similar to the Two Speed Resin System, but the *Slow Set Resin* is replaced with cementitious grout. This system utilises the *Fast Set* performance of the resin to remove the need to provide temporary support to the rockbolt system whilst the grout sets. Thixotropic grout is commonly used for combined systems. The system requires the borehole to be drilled to two diameters, a smaller diameter for the resin bonded section and a larger diameter for the grouted section.

Combination resin and grout systems were developed for use with longer rockbolt installations where the two speed resin systems become difficult to install and have been used successfully in installations up to 8m long using flexible stranded rockbolts.

2.7 Selection of Bond Medium

The advantages and disadvantages between Resin and Grout Systems for key performance criteria are outlined below.

2.7.1 Set Time

The primary advantage of the use of the two speed resin system or the combined resin and grout system is that these allow rapid installation times and provide a completed installation immediately the endplates are tightened. This can be of particular benefit where working time is restricted (i.e. during possessions).

2.7.2 Ease of Preparation

Resin systems can offer ease of installation over grout systems. Resins are supplied in pre-prepared capsules which offer ease of transportation and handling. Resin capsules are factory prepared and so offer assurance and a high degree of quality control of the resin / catalyst mixture. Grouts require a degree of onsite preparation. Grout is supplied in bagged powder form and is mixed with water using

site mixing machinery and apparatus. Rigorous quality control measures are required to ensure the correct water to solids ratio is observed at all times. Once prepared, grouts have to be used almost immediately (within hours) whilst resin capsules can be stored until ready for use. Resin capsule have a shelf life of between 3 to 6 months and users should ensure that capsules are in date before use.

2.7.3 Ease of Installation

Insertion of resin capsules into drill holes is easier than grout insertion, especially in circumstances where rockbolts are installed at height, for example for the installation of bolts in the crown or haunches of a tunnel.

2.7.4 Cost

Grout Systems can offer cost advantages over Resin Systems. It is recommended however that the Scheme Designer give due consideration to the performance advantages of Resin Systems as the benefits listed above may outweigh the higher cost.

2.7.5 Length / Depth of Installation

For applications envisaged by this TUM, Rockbolts will typically be 2.0 metres to 6.0 metres in length. Increased lengths might be required to improve pull-out strengths by increasing encapsulation length, or by extending into a stronger horizon. The Scheme Designer should assess the loading performance required and select an appropriate length. Longer length bolts will have an increased installation time and cost over shorter lengths.

The limitation on the use of resin-only systems is often the contractors' ability to install long rockbolts into small annulus holes due to the inherent viscosity of the resin. The resistance offered by the resin and the friction from contact of the rockbolt with the borehole wall may defeat the thrust provided by some rockbolting rigs. In such cases either a higher performance rockbolting rig is required or the use of the combined resin and grout, or, grout only systems may be more suitable. Table / below indicates the typical rockbolt lengths applied with each bonding system.