

TECHNICAL USER MANUAL

for

SPRAYED CONCRETE LINING RENEWAL DETAIL FOR MASONRY ARCH TUNNELS

Standard Detail and Design Drawings

Summary

The purpose of this document is to provide background information, design guidance and typical construction methodologies for the application of a Sprayed Concrete Lining Renewal Detail for masonry arch tunnels as part of the suite of Network Rail Standard Tunnel Repair Details.

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
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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.

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I INTRODUCTION

- I.1 The purpose of this document is to provide background information, design guidance and typical construction methodologies for the application of a Sprayed Concrete Lining Renewal Detail for Masonry Arch Tunnels as part of the suite of Network Rail Standard Tunnel Repair Details as specified in the *Standard Detail Drawings NR/CIV/SD/550 to NR/CIV/SD/554* (herein referred to as SD Drawings).
- I.2 Owing to a wide variety of external factors which can affect the design, it is not practical to produce a standardised Sprayed Concrete Lining Renewal Detail (herein referred to as SCL Detail) which would cover all possible situations. However, the SCL Detail has significant scope for site specific development due to the numerous common design elements which can be easily amended to suit a range of circumstances.
- I.3 This document provides guidance on the design philosophy, criteria and assumptions adopted in the production of the SCL Detail as shown in the SD Drawings. This information is intended to allow future Scheme Designers to undertake their own assessment of the individual circumstances to which the SCL Detail is to be applied and to adapt the design accordingly. Thus they should be aware that some analysis and design will be required in its application in some instances.
- I.4 This document makes reference to *NR/CIV/SD/TUM/520, Technical User Manual for the application of Standard Tunnel Repairs* which serves as a useful guide in understanding the possible causes, and available solutions for the repair of typical defects in tunnels.

2 RENEWAL DETAIL DESCRIPTION

- 2.1 The installation of a sprayed concrete lining in conjunction with pinning of the masonry lining, and where required, rock bolting can be utilised to remediate two different masonry tunnel defects which can be categorised under either Material Defect or Structural Defect.

- 2.2 Typical configurations for the SCL Detail are shown on the SD Drawings with further information on typical arrangements contained in this document.

3 LIMITATIONS OF USE

- 3.1 The guidance given in this TUM, and the SCL Detail shown on the SD Drawings covers its application to remedy **Material** defect only. **Structural** defect is outside of the scope of a standard detail and specialist design advice should be sought. It is envisaged that the details given here, and layout outlined, will be useful in developing a scheme to remedy a structural defect.

4 DEFECTS TO BE REMEDIED

4.1 Material Defect

- 4.1.1 The primary application of the SCL Detail is as an alternative to the relining of the tunnel using brickwork, where a large proportion of the existing masonry lining has degraded and requires replacing.

4.1.2 Material Defect Typical Features

- 4.1.2.1 The following is a list of typical material defects for a masonry tunnel. Where these features are prevalent over large areas of the lining, the use of the SCL Detail could be considered.

- Soft / Spalling Brickwork
- Degraded Mortar
- Open Joints
- Loose Brickwork
- Drummy / Hollow Brickwork

4.1.2.2 For further information on material defects refer to *NR/CIV/SD/TUM/520, Technical User Manual for Tunnel Repairs* which contains guidance on identifying defects in tunnels, their underlying causes and typical remediation measures.

4.1.3 **Application of Detail**

4.1.3.1 The installation of a sprayed concrete lining can prove to be more economical than relining in brickwork where a large area is to be covered, particularly when the time constraints and restricted working of rail possessions are taken into consideration. An assessment of the most viable solution, based on the area to be covered and the time available is required.

4.2 **Structural Defect**

4.2.1 The secondary application of the SCL Detail is part of a scheme to remedy a structural defect. However, it must be stressed that this standard detail is not to be used to remedy structural defects on its own.

4.2.2 It should be noted that guidance given in this TUM, and the SCL Detail shown on the SD Drawings covers its application to remedy Material defect only, and structural defect is outside of the scope of a standard detail and specialist design advice must be sought.

4.2.3 **Structural Defect Typical Features**

4.2.3.1 Structural defect is evident by bulging and distortions in the profile of the tunnel or tension or shear cracking. The nature of the defect will need to be ascertained through the analysis of visible defects, monitoring, profiling, and intrusive investigation. Structural defects are characterised by deformation due to changes in loading conditions in excess of the capacity of the existing lining and/or due to material deterioration at such severity that the existing lining is significantly weakened resulting in large deflections and cracking.

4.2.3.2 Guidance information on structural defects can be found in the *1996 BR Research and Railtrack PLC Document, Guide to Tunnel Maintenance*.

4.2.4 **Application of Detail**

- 4.2.4.1 It is considered that the opportunities for standardisation of design are in this case limited as each circumstance will require a significant degree of assessment including a detailed analysis to ascertain the loads acting on the existing lining and the nature and extents of deformation.
- 4.2.4.2 In extreme cases, the sprayed concrete lining may need to be combined with steel lattice girders or similar bracing to be effective, an area which is outside the scope of a Standard Detail.

5 **DESIGN PHILOSOPHY**

5.1 **General**

- 5.1.1 The philosophy for the design of a standard detail is to produce an all encompassing design, or series of designs which will be applicable in wide range of situations.
- 5.1.2 Owing to a wide variety of external factors which can affect the design, it is not practical to produce a standardised Detail to cover all possible situations. However, the SCL Detail has significant scope for site specific development due to the numerous common design elements which can be easily altered to adapt the design to suit a range of circumstances.
- 5.1.3 Typical variations include tunnel profile, lining thickness, loading conditions, material type and condition, and, most critically, the nature of the defect(s) to be remedied.

5.2 **Design Criteria**

- 5.2.1 For the production of the Standard Detail Design and Drawings, it was necessary to assume certain parameters to allow the design(s) to be progressed. These assumptions were derived based on experience gained on previous works or typically accepted values and were selected to give a range of designs so as to ascertain the suitability of the standard detail over a wide range of applications. It

should be noted that although four different configurations of the SCL Detail are shown on the SD Drawings, a range of different cases were analysed.

5.2.2 Nature of Defect to be remedied

5.2.2.1 The nature of the defect to be remedied, be it material or structural will be the primary factor in determining the overall configuration of the SCL Detail.

5.2.2.2 The SCL Detail as featured on the SD Drawings was designed for its primary application to remedy material defect which comprises providing restraint to and in some instances replacement of, the existing masonry lining.

5.2.3 Nature of Tunnel Lining

5.2.3.1 The nature of the masonry tunnel lining can be classified as either structural or cosmetic, dependent upon the geology through which the tunnel was driven.

5.2.3.2 The masonry lining of tunnels in “soft” ground such as sands or clays will tend to be structurally load bearing and of 5 to 6 (or more) rings of brick thick. The masonry lining of tunnels in “hard” ground such as competent rock will tend to be a cosmetic lining only to prevent localised rock falls onto the track and for the control of water ingress and as such will probably be 2 to 5 rings thick and in many cases there will be voids between the lining and the rock.

5.2.3.3 For the purposes of the production of the SD drawings, it was assumed that the existing tunnel lining was cosmetic, with two variations in ring thickness being allowed for, these being 4 rings of brick thick and 6 rings of brick thick.

5.2.4 Imposed Loadings

5.2.4.1 For the production of the SD drawings, to give a reasonable application and as applicable for a cosmetic lining, it was assumed that the sprayed concrete lining in its various configurations was required to carry the weight of *either* 2 no. rings of engineering brickwork or 1.0 metre of broken rock mass (at 20kN/m³) in addition to its own self weight.

5.2.4.2 The weight of 2No. brickwork rings represents typical loading due to delamination of the brickwork lining. The weight of 1.0 metre of rock mass represents a circumstance whereby the tunnel lining had been constructed as cosmetic in a competent self supporting rock mass, however over time, degradation of the rock mass has occurred, and 1.0 metre of rock mass has become unsupported and is now broken loose and is resting upon the tunnel lining.

5.2.5 Tunnel Lining Profile

5.2.5.1 A full discussion on the various types of tunnel profile in existence are outside the scope of this document, however the size and layout of the profile will affect the spanning arrangements of the sprayed concrete lining, the clearance envelope requirement, the spacings of rockbolts and the imposed loadings applied.

5.2.5.2 For design purposes, two tunnel profiles were utilised, the first representing a typical five centred arch tunnel profile taken from *Simms; Practical Tunnelling*, and the second representing the most extreme/worst case (in height and width) taken from Whiteball Tunnel between Taunton and Exeter on the Great Western Route.

5.2.6 Rockbolt Spacings and Capacities

5.2.6.1 Rockbolts are utilised as part of the SCL Detail to carry the self weight of the SCL lining so as to not impose this additional load on the existing lining. Rockbolts provide support to the sprayed concrete lining by anchoring in to the surrounding rock mass. Where the sidewalls of the tunnel do not have voiding behind them, or this voiding has been grouted (refer to *SD drawing NR/CIV/SD/554*) and the existing lining has been assessed as having adequate strength, rockbolts may be omitted. This is only applicable for the arrangement of the SCL as shown in *SD Drawings NR/CIV/SD/551, 552 and 553* where the SCL extends to the haunch and sidewalls. Where the SCL overspray is applied in the crown only, rockbolts must be used.

5.2.6.2 The allowable loads that the rockbolts can carry is dependent upon the nature of the surrounding strata, and capacities must be ascertained by insitu testing. Previous experience has shown that rock bolt capacities can vary by a factor of 10, and the spacing of rock bolts will be dependent upon allowable capacities. Further