TS 01722:1.0

ESC 340

Standard

Tunnels

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1.0	17/12/2025	First issue

Preface

This standard is the first issue as TS 01722 and supersedes ESC 340 *Tunnels*, Version 2.3.

This document sets the requirements for all transport mode-related tunnels and associated infrastructure within the TfNSW transport network.

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1 Scope

This standard specifies the requirements for tunnels within the NSW transport network.

The requirements pertain to safety, human factors, tunnel alignment, spatial requirements, civil, structural, fire engineering, mechanical, electrical, signalling and intelligent transport systems aspects of tunnel design as well as protection of the environment, heritage and ongoing operations and maintenance of tunnels.

The purpose of this document is to provide a consistent approach to the design and construction of new tunnels as well as for the repair, refurbish, upgrade or extension of existing tunnels, in order to achieve levels of safety, interoperability, robustness, reliability, resilience and maintainability so far as is reasonably practicable.

2 Application

This document is intended to be used by planners, engineers, designers, contractors, operators and maintainers of tunnels within the NSW Transport network.

This document applies to all transport related tunnels and their associated ancillary underground structures and shafts within the TfNSW transport network. This includes road tunnels, rail tunnels (heavy rail, light rail, metro), and active transport tunnels.

This document applies to all stages of the asset life cycle, such as project initiation, planning and development, procurement, delivery, operate/maintain, renew/disposal.

For the purpose of interpretation and applicability of the requirements of this document, the terms tunnel, tunnels and underground infrastructure mean:

- main tunnels
- adits, stub tunnels and connection passages
- caverns
- ventilation tunnels and ventilation shafts
- emergency egress passages (longitudinal and cross passages)
- vehicle cross passages
- FRNSW passages and shafts
- underground stations and platforms
- underground facilities, buildings and rooms
- underground plant and equipment rooms
- cut and cover structures

- underpasses
- buried structures (not including drainage and utilities buried in pipes)
- tunnel portal, and tunnel approach and exit structures
- underground substations
- tunnel enlargements, local rebates, trenches
- below ground structures and retention systems including diaphragm walls and contiguous piled walls associated with tunnels
- other structures as deemed necessary by TfNSW.

Culverts are not covered by this standard.

The requirements described in this standard are minimum requirements. All sections are applicable to all new tunnels and underground infrastructure. Requirements relevant to existing tunnels and underground infrastructure will be identified by TfNSW.

3 Referenced documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

International standards

ASTM A820/A820M *Standard Specification for Steel Fibers for Fiber-Reinforced Concrete*

ASTM C1116/C1116M *Standard Specification for Fiber-Reinforced Concrete*

EN 14889-1 *Fibres for concrete – Part 1: Steel fibres – Definitions, specifications and conformity*

EN 14889-2 *Fibres for concrete – Part 2: Polymer fibres – Definitions, specifications and conformity*

EN 1992 (series) *Eurocode 2: Design of concrete structures*

EN 1992-1-2 *Eurocode 2: Design of concrete structures – Part 1-2: Structural fire design*

ISO 14837-1 *Mechanical vibration – Ground-borne noise and vibration arising from rail systems – Part 1: General guidance*

PAS 8810 *Tunnel design – Design of concrete segmental tunnel linings – Code of practice*

Australian standards

AS 1170.4 *Structural design actions Part 4: Earthquake in Australia*

AS 1428 (all parts) *Design for access and mobility*

AS 1428 (series) *Design for access and mobility*

AS 1742.2 *Manual of uniform traffic control devices – Part 2: Traffic control devices for general use*

AS 2312.1 *Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings – Part 1: Paint coatings*

AS 2444 *Portable fire extinguishers and fire blankets – Selection and location*

AS 4624 *Combination controls for gas*

AS 4678 *Earth-retaining structures*

AS 5100 (series) *Bridge design*

AS 5100.2 *Bridge design – Part 2: Design loads*

AS 5100.5 *Bridge design – Part 5: Concrete*

AS 5216 *Design of post-installed and cast-in fastenings in concrete*

AS 61386.1 *Conduit systems for cable management – Part 1: General requirements*

AS/CA S009 *Installation requirements for customer cabling (Wiring Rules)*

AS ISO 354 *Acoustics – Measurement of sound absorption in a reverberation room*

AS ISO 14044 *Environmental management – Life cycle assessment – Requirements and guidelines*

AS ISO 15489.1 *Information and documentation – Records management – Part 1: Concepts and principles*

AS/NZS 1158 (all parts) *Lighting for roads and public spaces*

AS/NZS 1170 (series) *Structural design actions*

AS/NZS 2293 (all parts) *Emergency lighting and exit signs for buildings*

AS/NZS 3000 *Electrical Installations (known as the Australian/New Zealand Wiring Rules)*

AS/NZS 3015 *Electrical installations – Extra-low voltage power supplies and service earthing within telecommunications networks*

AS/NZS 4641 *Electrical equipment for detection of oxygen and other gases and vapours at toxic levels – General requirements and test methods*

AS/NZS 60079 (series) *Explosive atmospheres*

AS/NZS 80079 (series) *Explosive atmospheres*

AS/NZS 61386 (all parts) *Conduit systems for cable management*

AS/NZS ISO 9001 *Quality management systems – Requirements*

Transport for NSW standards

TS 00005 *Application of Telecommunications Standards to Engineering Works and Services*

TS 00008 (all parts) *Fire Life safety*

TS 00008.1 *Fire Life Safety – Part 1: Principles*

TS 00008.3 *Fire Life Safety – Part 3: Tunnels*

TS 00014 *Risk Assessment for Transport of Dangerous Goods through Tunnels*

TS 00028 *Accepted Road Safety Barrier Systems and Devices*

TS 00031 (all parts) *OT10 Threat-Based Cyber Security Controls*

TS 00050 *Video Surveillance System Architecture*

TS 00077 *Supply and Placement of Steel for the Reinforcement of Concrete, ATS 5310, Ed 1.0 IDT*

TS 00103 (all parts) *25 kV AC Traction System*

TS 00145 *Formwork for Concrete, ATS 5305, ED 1.0 MOD*

TS 00146 *Supply of Special Class Concrete, ATS 5315, Ed 1.0 MOD*

TS 00149 *Placement of Concrete, ATS 5320-23, Ed 1.0 MOD*

TS 00151 *Code of Practice for the Management of Alkali Aggregate Reactivity (AP-C112-23 MOD)*

TS 00169 *Pedestrian underpass design guideline – Design guideline to improve the safety and appearance of underpasses in NSW*

TS 01455 *Configuration Management*

TS 01462 (T MU AM 06006 GU) *Systems Engineering (guide)*

TS 01471 (T MU AM 06006 ST) *Systems Engineering Standard*

TS 01472 *Operational Concept Definition*

TS 01497 *Metadata spreadsheet for Engineering Documents*

TS 01505 (T MU AM 01001 ST) *Life Cycle Costing*

TS 01506.1 Development of Technical Maintenance Plans – Part 1: Development Process

TS 01515.1 *Asset Information – Part 1: Management of Asset Information*

TS 01517 (all parts) (T MU AM 01002 MA) *Maintenance Requirements Analysis Manual*

TS 01547.1 (T MU MD 00006 ST) *Engineering Drawings and CAD Requirements*

TS 01547.2 (T MU MD 00006 TI) *Technical Information for CAD and Engineering Drawings*

TS 01547.3 (T MU MD 00006 F1) *Metadata Spreadsheet for Engineering Drawings*

TS 01572.1 (TfNSW Q6) *Quality Management (Major Works) – QA*

TS 01636 (T MU CI 12140 GU) *Geotechnical Instrumentation and Monitoring Guidelines*

TS 01638 (T HR CI 12130 ST) *Track Drainage (standard)*

TS 01641 *Track Drainage (manual)*

TS 01642 (T HR CI 12002 ST) *Durability Requirements for Civil Infrastructure*

TS 01713 (T HR CI 12020 ST) *Underbridges*

TS 01714 (T HR CI 12021 ST) *Bridge Impact Protection*

TS 01717 (T HR CI 12051 ST) *Development Near Rail Tunnels*

TS 01723 *Earthworks for Bridgeworks, ATS 5110-23, Ed 1.0 MOD*

TS 01734.2 (IC-DC-B82) *Shotcrete work – DC*

TS 02014 (BTD 2008/12) *Provisions for Concrete Structures in Acid Sulphate Soils*

TS 02038 (all parts) (SDDM, all sections) *Structural Drafting and Detailing Manual*

TS 02138 (C-G-003) *Geotechnical Instrumentation and Monitoring*

TS 02174.2 (IC-DC-R163) *Tunnel Ventilation Axial Fans – DC*

TS 02175.2 (IC-DC-R164) *Tunnel Jet Fans – DC*

TS 02176.2 (IC-DC-R165) *In-Tunnel Air Quality Monitors – DC*

TS 02401 (T HR CI 12071 ST) *Guard Rails*

TS 02402 (T HR CI 12072 ST) *Track Slabs*

TS 02403 (T HR CI 12073 ST) *Safe Places*

TS 02404 (T HR CI 12090 ST) *Airspace and External Developments*

TS 02642 *Supplement to Austroads Guide to Road Design*

TS 02715 (GTD 2020/001) *Excavation adjacent to Transport for NSW Infrastructure*

TS 03389 (IC-QA-TS020) *ITS Communications System*

TS 03499 (ESC 210) *Track Geometry and Stability*

TS 03500 (ESC 215) *Transit Space*

TS 03505 (SP 207) *Track Monitoring Requirements For Undertrack Excavation*

TS 03510 *Track System*

TS 03609 (T HR TR 00192 ST) *Ballast*

TS 03612 *Sleepers and Track Support*

TS 03647 (TSI-SP-011) *Integrated Speed Limit and Lane Use Signs*

TS 03750 (T HR EL 20003 ST) *Underground Installation Configurations for High Voltage and 1500V DC Cables*

TS 03789 (T LR EL 00001 ST) *Traction Power System Requirements*

TS 03802 *(T HR EL 08009 ST) Designations of Overhead Wiring Conductor Systems*

TS 03863 (T HR EL 11001 TI) *SCADA Standard I/O Schedule*

TS 03864 (T HR EL 11003 ST) *Electrical SCADA System*

TS 03865 *Electrical SCADA Interface Requirements*

TS 03866 *Electrical SCADA System Remote Terminal Unit*

TS 03867 (T HR EL 11001 PR) *Design Technical Reviews for Electrical SCADA Equipment*

TS 03873 *(T HR EL 90003 ST) Heavy Rail Traction System – Current Ratings of 1500 V dc Equipment*

TS 03954 *Low Voltage Electrical Installations*

TS 04935 (T HR SS 80001 ST) *Infrastructure Lighting*

TS 04936 (T HR SS 80003 ST) *Infrastructure Emergency Lighting*

TS 04955 (series) *Services, Systems and Equipment*

TS 04955.1 *Services, Systems and Equipment – Part 1: Principles*

TS 04978 *Human Factors Integration – General Requirements*

TS 04981 *System Safety Standard for New or Altered Assets*

TS 04982 *Risk Criteria for Use by Organisations Providing Engineering Services*

TS 04989 *Public Transport Closed Circuit Television Functional Requirements Standard*

TS 04990 (T MU SY 10010 ST) *Cybersecurity for IACS – Overview*

TS 04991 (T MU SY 10012 ST) *Cybersecurity for IACS – Baseline Technical Cybersecurity System Requirements and Countermeasures*

TS 04992 *Surface Transport Fixed Infrastructure Physical Security Standard* (This document is not publicly available. To obtain access email standards@transport.nsw.gov.au)

TS 04993 (T MU SY 10013 PR) *Cybersecurity for IACS – Cyber Risk Management Procedure*

TS 05164 *Construction of Signalling Cable Routes*

TS 05165 *Installation of Trackside Equipment*

TS 05167 (SPG 0708) *Small Buildings and Location Cases*

TS 05171 (SPG 0714) *Compressed Air Systems*

TS 05268 *Cables for Railway Signalling Applications*

TS 05300 (SPG 1571) *Light Signals*

TS 05301 (SPG 1572) *Emergency Telephone Location Lights for Underground Railway*

TS 05333 (series) (T HR SC 10006 ST) *Signalling Design Principle*

TS 05373 (EGG 1656) *Balise Placement and Metal Mass Assessment Guide*

TS 06201 (T MU CY 05000 GU) *Competency Guideline – Systems Engineering*

TS 06205 (T HR TE 61001 ST) *Emergency Telephone Systems*

TS 06218 *Packet Switched Networks – Wired Networks*

TS 06220 *Packet Switched Networks – Wireless Local Area Networks*

TS 06225 (IC-DC-TS901) (series) *Motorway Systems*

TS 06225.00 (IC-DC-TS901*) Motorway Systems Overview and General Requirements*

TS 06225.01 (IC-DC-TS902) *Systems Engineering Processes*

TS 06225.03 (IC-DC-TS912) *Motorway Systems – Traffic Management and Control System*

TS 06225.05 (IC-DC-TS914) *Motorway Systems – Electrical Power Supply and Distribution System*

TS 06225.06 (IC-DC-TS915) *Motorway Systems – Motorway Network Communications System*

TS 06225.07 (IC-DC-TS916) *Motorway Systems – Electronic Toll Collection System*

TS 06225.09 (IC-DC-TS918) *Motorway Systems – Road Tunnel and Underpass Lighting*

TS 06320 (RMS 17.168) *Smart motorway design guide – Tunnel traffic management*

TS 06339.1 (17.177) *Smart motorway supplements – Austroads report AP-R341-09: Freeway design parameters for fully managed operations – Section 9: Lane use management systems (LUMS) including variable speed limits (VSL) (2009)*

Legislation

Protection of the Environment Operations (Waste) Regulation 2014 (NSW)

Rail Safety National Law (NSW) 2012 (NSW)

State Emergency and Rescue Management Act 1989 (NSW)

Work Health and Safety Act 2011 (NSW)

Work Health and Safety Regulation 2025 (NSW)

Other referenced documents

Australian Building Codes Board, 2020, National Construction Code Handbook: *Structural robustness*

Austroads, *Guide to Road Design* (all parts)

Austroads, *Guide to Road Design – Part 3: Geometric Design*

Austroads, *Guide to Road Design – Part 5: Drainage – General and Hydrology Considerations*

Austroads, *Guide to Road Design – Part 6: Roadside Design, Safety and Barriers*

Austroads, *Guide to Road Design – Part 6A: Paths for Walking and Cycling*

Austroads, *Guide to Road Tunnels – Part 1: Introduction to Road Tunnels*

Austroads, *Guide to Road Tunnels – Part 2: Planning, Design and Commissioning*

Austroads, Research Report AP-R475-15, *Level of Service Metrics (for Network Operations Planning)*

Austroads research report AP-R639-20 *Updating Austroads Pedestrian Planning and Design Guidance in line with International Best Practice*

British Tunnelling Society, 2011, *Monitoring Underground Construction – A best practice guide*

British Tunnelling Society, *Specification for Tunnelling, Fourth edition*

British Tunnelling Society, Specification for Tunnelling

CIRIA R185 *The Observational Method in ground engineering: principles and applications*

CIRIA C766 – *Control of cracking caused by restrained deformation in concrete*

Commonwealth of Australia, 2023, Australia-New Zealand Counter-Terrorism Committee, *Australia's Strategy for Protecting Crowded Places from Terrorism*

Commonwealth of Australia, 2015, Australia-New Zealand Counter-Terrorism Committee, *National Guidelines for Protecting Critical Infrastructure from Terrorism*

Commonwealth of Australia, 2000, NOHSC: 1007 *National Standard for Occupational Noise*

Commonwealth of Australia, 2004, NOHSC: 2009 *National Code of Practice for Noise Management and Protection of Hearing at Work*

Concrete Society, 2007, Technical Report 63 *Guidance for the Design of Steel-Fibre-Reinforced Concrete*

fib (International Federation for Structural Concrete), *fib Model Code for Concrete Structures*

International Tunnelling and Underground Space Association (ITA) and the International Association of Engineering Insurers (IMIA) *A Code of Practice for Risk Management of Tunnel Works*

Mobile Carriers Forum (MCF) *2018 Design Specification for Distributed Antenna Systems*

National Construction Code 2022 – Building Code of Australia Class 2 to 9 buildings, Volume 1, Part B1 Structural provisions

NSW Telco Authority *Digital Connectivity Principles*

National Heavy Vehicle Regulator, *Common Heavy Freight Vehicle Configurations*

RILEM TC 162-TDF: *Test and Design Methods for Steel Fibre Reinforced Concrete*

State of NSW and Environment Protection Authority, 2017, *Noise Policy for Industry*

State of NSW through Department of Trade and Investment, Regional Infrastructure and Services, 2012, *NSW Aquifer Interference Policy*

Transport for NSW, 2021, A9177757 *Asset Resilience Strategy* (This document is not publicly available. To obtain access email standards@transport.nsw.gov.au)

Transport for NSW, CP23006 *Net Zero and Climate Change Policy*

Transport for NSW, IP-294-PR *IP Configuration Management (CM) Procedure* (This document is not publicly available. To obtain access email standards@transport.nsw.gov.au)

Transport for NSW, SD-081 *TfNSW Climate Risk Assessment Guidelines*

Transport for NSW, ST-114 *TfNSW Sustainable Design Guidelines*

Transport for NSW, 2019, *TfNSW Guidelines on External and Developer-led Works Affecting Transport Assets*

Transport for NSW, *Traffic Signs Register*

Transport for NSW, *Transport Sustainability Plan 2021*

4 Terms, definitions and abbreviations

The following terms, definitions and abbreviations apply in this document.

ancillary site tunnel support facility constructed at surface level that includes plant room, workshop or other facility required for the normal operation and emergency operation of the tunnel

BEDC bridge earthquake design category

bored tunnel a tunnel constructed using a tunnel boring machine

brownout period partial outage of electricity where system capacity is reduced, and the voltage is typically reduced by at least 10% to 25%

BTS British Tunnelling Society

CIRIA Construction Industry Research and Information Association

CRCP continuous reinforced concrete pavement

cross passage tunnel which is nominally perpendicular to and connects two main tunnels to provide emergency egress and act as a place of safety. A cross passage may be provided by mined, bored or cut and cover construction.

culvert for the purpose of application of this standard, a culvert is defined as a fully enclosed structure with a maximum length of 10 m, wingwalls excluded

cut and cover tunnel reinforced concrete structure which includes:

- continuous, integral box structure constructed within a trench or excavation and then backfilled over
- retaining walls, cuttings, covered with roof bridging structure including bridge deck

DDA *Disability Discrimination Act 1992* (Cth)

design documentation includes all documentation developed while undertaking design, procurement, construction, operations and maintenance activities of the tunnel project

design life the specified period of time for which an asset, structure or a component is to be used for its intended purpose or performs its intended function without replacement, refurbishment or major repair

drainage system the measures, or combination of measures, used to collect and convey stormwater, groundwater and tunnel water flows. Includes the stormwater, groundwater and tunnel drainage systems as well as the portal sump, tunnel sump and water treatment facility and outflow system.

drained tunnel a tunnel or section of tunnel that allows drainage of the external groundwater into the tunnel drainage system and hence limits the build-up of external hydrostatic pressures

dry the absence of moisture, dampness, wetness, liquid, water, drips, flows, seepage and seepage by-products, condensation, high humidity (exceeding 60% relative humidity), steam, mist, fog or ice caused by groundwater. This does not include surficial water resulting from fire hydrant or deluge water system testing or regular maintenance wash down or flushing water.

EEC emergency equipment cabinet

emergency egress cross passage emergency egress passage that connects main tunnels

emergency egress passage dedicated, fire isolated passageway, necessary for the safe evacuation of occupants during an emergency. Emergency egress passages may be emergency egress cross passages, emergency surface egress passages and longitudinal emergency egress passages.

emergency services include Fire and Rescue NSW, NSW Rural Fire Service, NSW Environment Protection Authority, NSW Police Force and SafeWork NSW

FEEP Fire and Rescue NSW emergency equipment point

FRL fire resistance level; expressed as structural adequacy/integrity/insulation and expressed in that order. Structural adequacy is the ability of a structure to maintain its load-bearing capacity during a fire. Integrity is the ability to prevent the passage of flames and hot gases. Insulation is the ability to resist the transfer of heat during a fire.

FRNSW Fire and Rescue NSW

ground support includes temporary or permanent and includes rock reinforcement, soil reinforcement and structural linings. Temporary ground support is provided to support the ground and enable the tunnel to be excavated safely and includes spiling bars, canopy tubes, lattice girders and steel sets as well as rock and soil reinforcement. Permanent ground support allows the tunnel to be operated and maintained safely for the duration of the required design life of the tunnel.

good industry practice means that degree of skill, care, prudence, foresight and practice which would reasonably be expected of a skilled and experienced person or organisation, engaged in the same or similar type of undertaking as that of the contractor in Australia

groundwater control system measures, or a combination of measures, used to control the groundwater impact on the tunnel structural lining or elements within the tunnel such as mechanical and electrical devices and support. Measures may include water resisting membranes (sprayed or sheet), geotextiles or similar lining elements, grouting and drainage systems including strip drains or equivalent.

IACS industrial automation and control systems

IFC issued for construction; the status of design documentation that is achieved when all reviewers' comments have been addressed and closed satisfactorily, and the final design documentation has been certified by the proponent and the independent certifier

IMT immersed tube tunnel; an underwater reinforced concrete box structure comprising pre-constructed segments which are linked together in a manner which provides movement articulation, structural continuity and waterproofing that may be floated and towed to their proposed location and sunk into place, or incrementally launched from the bank of a large water body

limit state a condition:

- beyond which the asset, structure (whole, composite, member or element) or component ceases to satisfy the provisions for which it was designed
- of a structure beyond which it no longer fulfills the relevant design criteria, intent or function

maintainability the probability that a given active maintenance action, for an item under given conditions of use can be carried out within a stated time interval when the maintenance is performed under stated conditions and using stated procedures and resources

main tunnel main thoroughfare tunnel or tunnels, also called mainline, running or carriageway tunnels

major geological structure geological structure that provides uncertain or complex ground conditions, including but not limited to fault zone, dyke, joint swarm, grouted zone, variable or deep weathering zone, zone affected or predicted to be affected by contaminated or saline groundwater or leachate, zone where heavy rainfall could cause an adverse change in water inflow conditions

mechanical ventilation ventilation that depends on fans and other air movement devices to induce air movement within the tunnel, by directing outdoor air to locations where it is needed using fans

MEEP motorist emergency equipment point

mined tunnel a tunnel excavated using traditional mining methods including mechanical means (using excavator or road header machines (or both)) or by drill and blast as well as the placement of temporary ground support in a cyclic process. The tunnel advance sequence may include the excavation face split into multiple headings and benches.

NCC National Construction Code

NOHSC National Occupational Health and Safety Commission

non-structural lining any concrete or shotcrete lining that is not required to support a ground, groundwater, mechanical, electrical or structural load, or a fixture or fitting, for example, a smoothing layer of shotcrete

open space a large space outside of the tunnel that is deemed a place of safety for fire engineering purposes

pedestrian and cycleway tunnel shared path multi-user tunnel as part of the NSW Government's *Active Transport Strategy*

permanent asset an asset that has a design life exceeding the temporary design life limit for the asset

place of safety an area where people are safe from a tunnel incident, such as a designated place of safety outside of the tunnel portals

PMF probable maximum flood

project documents the tunnel project contract or deed, request for tender, scope of works and technical criteria, general and interface specifications, clients brief and all other associated documents that comprise a contract or request for tender

reliability ability to perform as required, without failure, for a given time interval, under given conditions (Source: IEC 60050-192:2015, 192-01-24)

RIM rail infrastructure manager

rock reinforcement structural elements to strengthen rock masses and enable the tunnel to be excavated safely for the duration of the tunnel construction period

RWS (curve) RWS (Rijkswaterstaat) design fire curve

segmental lining a permanent structural lining comprising precast reinforced concrete segments typically installed by a tunnel boring machine

SLS serviceability limit state; the limit state for acceptable in-service conditions such as deflections, displacements, rotations or damage that ensures the structures or elements remain serviceable for the duration of the required design lives

structural lining any reinforced concrete lining that is required to resist and support ground, groundwater, structures, mechanical and electrical services, traffic loads, temperature, shrinkage, fire design action effects and blast forces. Structural linings may be temporary or permanent and composed of cast-in place, precast systems, members and segments as well as sprayed concrete (also referred to as shotcrete). Where sprayed concrete is used, the lining may be composed of a series of layers sprayed on each other.

structures tunnel structures, structures for buildings, bridges, barriers, posts and poles, culverts, pipes and other civil and civic structures

TBM tunnel boring machine

temporary element has a design life of no more than five years. This may include ground support (rock reinforcement and structural linings).

TfNSW Transport for NSW

TfNSW transport network the transport system (transport services and transport infrastructure) owned and operated by TfNSW, its operating agencies or private entities upon which TfNSW has power to exercise its functions as conferred by the *Transport Administration Act 1988* or any other Act

tunnel a longitudinal underground space with limited access and egress, which is continuously enclosed above, below and on both sides, by ground support and reinforced concrete structures (linings) that are covered or surrounded by building developments, bridging structures, natural ground, rock, fill or water (or both). Tunnels include all road, rail, pedestrian, emergency egress, ventilation and services tunnels as well as underground facilities, spaces and buildings.

tunnel drainage system the measures, or a combination of measures, used to collect and convey any water flows within tunnels from sources including but not limited to the fire suppression deluge system, fire hydrants, maintenance cleaning (washdown) of wall panels, water carried in by vehicles, overflows and bypass flows from the upstream surface drainage infrastructure

tunnel lining see ‘structural lining’

tunnel user includes all customers, passengers, pedestrians, cyclists, drivers, TfNSW, operations, maintenance and emergency services personnel

ULS ultimate limit state; the capacity of a structure as a whole or individual elements to resist ultimate design actions and to prevent failure, collapse or major damage as a result of breaking, cracking or instability of the structure, ground, reinforcement or other components

undrained tunnel a tunnel or section of tunnel where the structural lining resists prevailing external hydrostatic pressures and there is no groundwater drainage system. That is, groundwater external to the tunnel is prevented from entering the drainage system.

vehicle includes all light rail, heavy passenger rail, metro, cars, buses, taxis, light commercial automobiles, utes, vans and trucks, maintenance machines and equipment, carts, bicycles and other personal mobility devices including wheelchairs, scooters and segways. These vehicles include all trailers, caravans and carriages.

vehicle cross passage fire isolated connection between the main tunnels that can be used for vehicle movement from one tunnel to the other

ventilation shaft a vertical excavation or structure (or both) used to convey air and smoke to or from (or both) the main tunnels and ventilation facilities, and to or from (or both) the ventilation facilities to outside

ventilation tunnel a tunnel or structure used to convey air and smoke to or from (or both) the main tunnels and ventilation facilities

wall panel architectural element placed to the side wall of a tunnel (modular prefabricated and painted panel) which aids light diffusivity, hides services so as to minimise distraction to tunnel users and provides improved aesthetics

5 General requirements

5.1 Project design – general

Tunnel planning, design and construction shall ensure:

- health and safety and human factors are taken into account for all tunnel users
- maximised flexibility in operations
- optimal functionality of the service
- the solution permits future extension, enhancement, strengthening, repair, replacement, refurbishment
- the solution provides structural robustness, reliability and resilience.

Tunnels shall be developed, designed, procured, constructed and maintained in accordance with the TfNSW principle to provide best value for money taking into account whole of life costs.

The whole of life cost for tunnel projects shall be determined in accordance with TS 01505.

5.2 Design records and documentation

Design documentation shall demonstrate how requirements of this document have been met.

The following documents provide requirements and guidance on design records and documentation management:

- AS ISO 15489.1
- TS 01515.1
- TS 01497
- TS 01547.1 (for rail tunnels)
- TS 01547.2 (for rail tunnels)
- TS 01547.3 (for rail tunnels)
- TS 02038 (all parts) (SDDM, all sections) (for road tunnels).

5.3 Systems engineering

5.3.1 General

Planning, design, construction, operations, maintenance and management of all tunnel projects shall be conducted in accordance with systems engineering approaches and requirements stipulated in the TfNSW system engineering standards. This requirement applies to all tunnel infrastructure assets and processes involving those assets and includes the tunnel structure.

The system engineering standards and guidelines that apply are as follow:

- TS 01471 (all transport modes)
- TS 01462 (for rail tunnels)
- TS 06201 (all transport modes)
- TS 06225.01 (for road tunnels)
- TS 06225.00 (for road tunnels).

5.3.2 Configuration management

Configuration management for the tunnel project shall follow TS 01455 and IP-294-PR *IP Configuration Management (CM) Procedure*.

As part of the tunnel project's systems engineering management plan, a configuration management plan shall be developed to address the control gates required by the TfNSW standards and the project documents.

5.4 Safety

5.4.1 General

The *Work Health and Safety Act* (NSW), *Work Health and Safety Regulation* (NSW) and relevant Codes of Practice set out the health and safety requirements and risk management for tunnel design and construction.

Tunnels shall be provided with adequate space for all traffic, vehicles, facilities, equipment, machinery, other assets and tunnel users to allow for safe access, use, inspection and maintenance so far as is reasonably practicable.

In the event of an emergency, all tunnels shall provide tunnel users with safe, equitable and dignified egress in accordance with the principles of the DDA. Tunnel egress design shall allow all tunnel users adequate time to evacuate to a safe place without being overcome by the effects of an emergency so far as is reasonably practicable.

All emergency egress shall be designed to satisfy the requirements of the relevant parts of AS 1428 (series) so far as is reasonably practicable.

5.4.2 System safety engineering approach

The safe and efficient operation of tunnels requires the application of principles and concepts of a system safety engineering approach. The system safety engineering approach involves different elements of the system coordinated together to minimise the risk of fatal and serious injury so far as is reasonably practicable.

System safety engineering shall be in accordance with TS 04981.

The requirements for each element (including but not limited to ventilation, lighting, and operations, management and control systems) of the system shall be based on a risk assessment encompassing the design, construction, safety and security elements as well as the operational uses of the tunnel. The risk assessment shall take into account the length of the tunnel as one attribute, among others.

5.4.3 Health and safety in design

The design of tunnels, including the refurbishment and upgrade of existing tunnels, shall allow for safety for workers during construction, operations, maintenance, decommissioning, and the users of the structures.

All safety issues, hazards and risks and requirements relating to safety during construction, commissioning, operation, maintenance and decommissioning of the tunnel project works and the temporary works shall be addressed in design documentation. Safety shall be addressed in all aspects of the development and production of the design documentation, including, at a minimum, all the following:

- identification and analysis of safety issues, hazards and risks in relation to the construction, commissioning, operation and maintenance of the tunnel project works and hazards and risks associated with the operation of the tunnel project works as part of the greater network
- identification, implementation and management of the requirements of the work health safety legislation, safety goals and objectives and generic hazards associated with the tunnel project works and temporary works
- identification of all applicable safety standards and codes of practice to be applied to the design
- identification of hazards and risks that cannot be eliminated, managed or mitigated by the design and proposed measures to be adopted in the construction, operation, maintenance and decommissioning phases to manage and mitigate these hazards and risks
- identification of hazards and risks that require the development of specific procedures in the construction, operation, maintenance and decommissioning phases to eliminate the risks to safety so far as is reasonably practicable. Where elimination any risk to safety is not reasonably practicable, minimise those risks so far as is reasonably practicable
- identification and analysis of safety issues related to potential repairs, upgrading and decommissioning of the tunnel

The proponent shall establish and implement a design process that manages safety across the full life cycle of the structure. Designs and the design process shall comply with TfNSW system safety standards, particularly TS 04981.

The requirements of formal safety in design workshops shall:

- be held to identify and assess safety issues, hazards and risks
- document the outcomes of those workshops
- be held at the start of the development period for design documentation (including both development and delivery stages) and then progressively at key stages throughout the development of design documentation
- be chaired by an independent facilitator and be attended by suitably experienced representatives of relevant design disciplines, suitably experienced operations and maintenance activities personnel and suitably experienced work health and safety personnel
- record all safety issues, hazards and risks identified in the workshop in a safety in design register including how the issues and risks are proposed to be addressed and mitigated.

Design documentation shall ensure and demonstrate that all safety issues, hazards and risks identified in relation to the construction, commissioning, usage, operation and maintenance of

the tunnel project works are eliminated or minimised in accordance with the hierarchy of hazard controls so far as is reasonably practicable.

5.4.4 Dust diseases and work health and safety in tunnels

To manage the risks of dust diseases, particularly those associated with crystalline silica exposure, the development, design and construction of tunnels shall align with industry best practices and comply with Transport's Safety Management System. Additional requirements are set out in relevant legislation and standards.

Industry best practice includes, but is not limited to:

- application of an accredited safety management system
- systems, processes and controls to manage the health risks of crystalline silica
- documentation that demonstrates the system is implemented and effective.

5.4.5 Dangerous goods

A dangerous goods risk assessment shall be undertaken prior to allowing dangerous goods to transit a tunnel. Refer to TS 00014 for further details.

5.5 Security

5.5.1 Physical security

TfNSW recognises that the security controls implemented are proportionate to achieve a balance between requirements of safety, security, operations and tunnel user expectations. To achieve this, a risk assessment shall be conducted during the project's development stage. Additionally, the risk assessment shall identify controls that are holistic, risk based and account for the whole-of-life cycle of the asset.

The risk assessment process is detailed in TS 04992.

Risk assessments shall only be undertaken by competent and qualified individuals as specified in TS 04992.

Security threats shall be identified and recommendations made for security measures and controls to all parts of the tunnel system, including but not limited to the tunnel structure, tunnel control system, ventilation system and the tunnel communication and surveillance system.

In addition, the risk assessment shall determine if the assets form part of a crowded place or critical infrastructure. For more information refer to the Australia-New Zealand Counter-Terrorism Committee (ANZCTC) publications *National Guidelines for Protecting Critical Infrastructure from Terrorism* and *Australia's Strategy for Protecting Crowded Places from Terrorism*.

Further advice and information should be sought from Transport's security and emergency management branch.

5.5.2 Closed circuit television

See Section 22.4 for CCTV requirements.

5.5.3 Cybersecurity

Cybersecurity design shall use a security-by-design approach to minimise system vulnerability and prevent attacks through all asset life cycle phases.

Refer to TfNSW IACS cyber security requirements in TS 04993, TS 04991 and TS 04990, and cyber security controls requirements in TS 00031 (all parts).

5.6 Heritage

Where required, heritage considerations and classifications shall be followed in tunnel designs. This may have application in circumstances where an existing structure is being refurbished, upgraded or modified, or where a new structure is being proposed in the vicinity of existing heritage items.

5.7 Human factors

Human factors shall be taken into account for all aspects of the tunnel design and construction to ensure safety, ease of use and efficient functionality for all customers, users, traffic, operations and maintenance personnel and emergency services workers.

The tunnel design development shall include the human factors integration process in TS 04978 to systematically identify and address functionality, safety, efficiency and practical ease of use for all tunnel assets. Human factors shall be taken into account for each stage of the project life cycle and demonstrated in design documentation.

5.8 Quality

A quality management plan shall be prepared and implemented at the development, delivery and operational stages of all tunnel projects.

For road tunnels, a quality management plan shall be prepared and implemented in accordance with TS 01572.1 and be adapted for rail tunnels and active transport tunnels where necessary.

5.9 Protection of the environment and sustainability

5.9.1 General

Tunnels shall include measures to minimise environmental impacts and achieve sustainability outcomes throughout the tunnel's life cycle.

Depending on requirements of the tunnel project, the project shall use either the Infrastructure Sustainability Council ratings system or the *TfNSW Sustainable Design Guidelines (*ST-114) at each stage of the asset's life cycle to determine the project's sustainability objectives, targets and guidelines. The project shall address the sustainable outcomes by monitoring the performance of the tunnelling activities.

The design of tunnels shall take into account the full life cycle of the tunnel project, to maximise sustainability of the tunnel in accordance with the *Transport Sustainability Plan 2021*, the TfNSW's *Net Zero and Climate Change Policy* (CP23006) and the *TfNSW Sustainable Design Guidelines* (ST-114).

Where there is an ambiguity or conflict between safety, durability and protection of environment or sustainability, safety and durability requirements shall take precedence. Where ambiguities still remain, TfNSW shall determine the appropriate requirement.

5.9.2 Climate change

Climate change risks shall be assessed for each tunnelling project using the *TfNSW Climate Risk Assessment Guidelines* (SD-081) to inform design to ensure the project works are resilient to predicted effects of climate change over the relevant design life.

Climate change risks shall be identified, assessed and managed in accordance with the *Transport Enterprise Risk Management* standard.

All necessary baseline adaptation measures shall be developed that comprehensively address the climate change risks identified. Design documentation shall describe how climate risk adaptations will be implemented.

5.9.3 Carbon management and energy efficiency

All vehicles, plant and equipment associated with tunnel construction, operations and maintenance activities shall:

- be selected and operated for optimum energy efficiency
- be fitted with catalytic converters, diesel particulate filters or equivalent devices, where relevant
- use electric or battery plant wherever possible

- be well maintained and serviced in accordance with relevant equipment maintenance documentation to reduce emissions due to poor engine performance.

5.9.4 Water efficiency

At the development stage, a water balance study shall be undertaken that identifies the sources, uses and estimated quantities of potable and non-potable water that will be either created or used during the construction and operation stages of the tunnel project. The water balance study shall identify initiatives to reduce water demand such as:

- using water efficient controls, fixtures and fittings
- harvesting rainwater wherever available
- using water from recycled water networks where available
- collecting, treating and reusing stormwater and wastewater
- metering and sub-metering water use.

The study shall identify relevant water efficiency targets to be implemented in the delivery stage.

Potable water as a substitute for non-potable water shall not be used where onsite or local sources of non-potable water are suitable for the tunnelling activities and where allowed in accordance with TfNSW standards.

Water supplied for the tunnelling activities from both recycled water networks and potable sources shall be metered to report against the targets set out for each project and to demonstrate the effectiveness of the water sustainability practices.

5.9.5 Waste management

Waste minimisation initiatives shall be identified and implemented for material selection strategies to minimise the embodied carbon and life cycle impacts of waste and materials associated with any tunnelling activities. The principal objectives shall be to:

- minimise the generation of spoil and over excavation of tunnels
- demonstrate waste minimisation initiatives through recycling and resource recovery, design refinement, construction planning and construction methodology
- identify and implement opportunities for recycling and reuse of non-putrescible general solid wastes
- use compostable or reusable temporary erosion control devices where practicable
- avoid the production of hazardous waste where practicable.

5.9.6 Material selection

Where safe and practicable to do so, material selection shall minimise embodied carbon and life cycle impacts of materials associated with the tunnelling activities. Material selection strategies shall:

- include life cycle assessments in accordance with AS ISO 14044 to assist in selection of safe, durable and low embodied carbon-impact materials for the tunnelling activities
- reduce materials use through materials avoidance and reduction strategies
- minimise construction material volumes through design refinement, construction planning and construction methods, where safe and practicable to do so
- minimise embodied carbon and life cycle impacts by using, where practicable and explicitly permitted by TfNSW standards:
    - blended cement that contains supplementary cementitious materials, such as fly ash, ground granulated blast furnace slag and silica-fume
    - low carbon concrete
    - aggregate containing recovered products such as glass, plastic and concrete
    - recycled steel
    - spoil generated onsite.

5.9.7 Spoil management

Initiatives shall be identified and implemented to both reduce spoil quantities which will be generated during the tunnelling activities and beneficially reuse reusable spoil, including topsoil. *Protection of the Environment Operations (Waste) Regulation 2014* contains requirements that apply to approval of operation purposes.

Over excavation shall be minimised as far as is reasonably practicable.

5.9.8 Noise and vibration

The tunnel and associated systems shall be designed for acceptable noise and vibration impacts during construction and operation. Operational noise and vibration issues for tunnel projects include:

- environmental noise and vibration arising from the operation of trains, vehicles and tunnel plant and equipment that can affect third parties outside the tunnel
- noise and vibrations within tunnels and associated structures arising from the operation of trains, vehicles and tunnel plant and equipment that can affect tunnel users in terms of:
    - comfort and noise exposure when travelling in the tunnel or waiting at stations

- noise levels that can interfere with effective communication or the use of audible warning systems during normal operations and in emergencies.

Environmental noise and vibration criteria shall be provided in accordance with good industry practice at the development stage of a project and complied with throughout construction and operation.

Health and safety criteria for workplace noise are specified in NOHSC:1007 *National Standard for Occupational Noise* and NOHSC:2009 *National Code of Practice for Noise Management and Protection of Hearing at Work*.

5.9.9 Ground-borne noise and vibration

Ground-borne noise and vibration shall be taken into account in the design of the tunnels.

A project specific noise and vibration management plan shall assess the impacts of ground-borne noise and vibrations and identify mitigation measures to be implemented during the construction and operation stages.

5.9.10 Air-borne noise

The tunnel shall be designed so that operation of the tunnel complies with the NSW Environment Protection Authority's Noise Policy for Industry. In addition to these requirements, the tunnel shall be designed so the air-borne noise levels set out in Table 1 are not exceeded when the tunnel is operating in publicly accessible locations.

Table 1 – Maximum air-borne noise levels during operation in publicly accessible locations

Environment	Location	Maximum noise level
Rail tunnel	Concourse and platforms (normal fan operations)	55 dBA
Rail tunnel	Concourse and platforms (emergency fan operations)	75 dBA
Rail tunnel	Concourse and platforms (congested fan operations)	75 dBA
Rail tunnel	Nearest property (train noise breakout from ventilation openings)	60 dBA at commercial facade, 55 dBA at residential facade
Rail tunnel	Within 10 m of any jet fan (in tunnel for emergency and congested operation)	90 dBA. At a distance of 10 m, 85 dBA
Road tunnel	During normal operation ventilation system noise emitted to the external environmental form: • ventilation facilities • ventilation outlets • tunnel portals	Refer to project specific environmental requirements

Environment	Location	Maximum noise level
Road tunnel	Tunnel ventilation system during emergency and maintenance mode operations	Noise rating NR85 plane 1.5 m above road surface at any location

5.10 External and third-party infrastructure development

The design of tunnels and associated structures shall permit future developments above, below and adjacent to the tunnels. This includes third-party external developer-led works, for example other tunnels, utilities, basements and footings.

The size of the future development permitted shall be the maximum permitted under relevant local environmental plans or other planning and zoning tools.

For requirements and guidelines refer to *TfNSW Guidelines on External and Developer-led Works Affecting Transport Assets* and the following TfNSW standards:

- TS 01717 (for rail tunnels)
- TS 02404 (for rail tunnels)
- TS 02715.

Where there are ambiguities in the standards referenced, TfNSW shall determine the appropriate requirement.

5.11 Resilience

The development and delivery of tunnel projects shall account for resilience throughout the life cycle of the project with reference to TS 04982.

The tunnel shall meet the TfNSW's *Asset Resilience Strategy*. Factors that shall be taken into account include as a minimum:

- climate change
- cost of recovery
- time duration of recovery
- performance before and after – full recovery of the tunnel after an event or degraded operation
- brownout periods
- maximum outage period
- ratio of performance recovery to loss – recovery time divided by downtime
- time duration of failure

- resource resiliency – degradation of capability that occurs after successive contributing assets are lost.

5.12 Robustness

All tunnel structures shall:

- be designed to be robust in accordance with the requirements of AS 5100 (series) and the Australian Building Codes Board's NCC handbook *Structural robustness*, where applicable
- include provision for redistribution of loads and alternative load paths where practicable
- ensure that a local failure does not lead to progressive collapse and that failure mechanisms perform in a ductile and controlled manner so that tunnel users, operators and maintainers and emergency services personnel are provided with adequate warning of failure
- be designed with an appropriate degree of robustness to be able to sustain local damage with the structural system as a whole remaining stable and not being damaged to an extent disproportionate to the original local damage.

5.13 Space proofing

Tunnel design shall provide space proofing for all tunnel systems, including allowances for future provisions, whereby functional spaces are provided for all elements of the tunnel infrastructure, systems and functionality and these elements are fully integrated such that future rework or expensive new work costs are avoided. Where possible, design arrangements shall not preclude future expansion, duplication or augmentation.

Provisions shall also be made for accommodating services owned by TfNSW, such as electrical and signalling cables, or services owned by other authorities and utilities. The design shall consider these holistically and ensure that there is adequate spatial provision for unhindered functionality such that all systems, tunnel users and personnel are fit for purpose and can operate with ease, efficiency and safely for the whole of the asset life cycle. The space proofing considerations and allowances for future provisions (future proofing) shall be demonstrated in design documentation including how they have been addressed or mitigated.

Services shall be positioned as follows:

- outside of any vehicle or kinematic envelope
- outside of any authorised users' transit space
- clear of any walking areas that can present a trip hazard
- without interference or obstruction to exit paths

- so that future access for maintenance and repair and replacement of the services is not impeded.

See Section 16 to Section 18 for mode specific requirements for inputs into space proofing.

6 Design classification

NCC 2022 Volume One outlines various importance levels in Section B. These importance levels are assigned based on the function and use of a structure.

All tunnels and underground infrastructure structures and buildings shall:

- perform adequately under all reasonably expected design actions
- withstand extreme or frequently repeated design actions
- be designed to sustain local damage, with the structural system as a whole remaining
- be stable and not be damaged to an extent disproportionate to the original local damage
- avoid causing unacceptable damage to other properties
- provide an appropriately risk assessed and acceptable level of safety during construction and use for their design life.

All tunnels and associated structures shall be designed to satisfy the following importance levels:

- tunnels and underground mined structures, cut and cover and tunnel approach and exit structures – importance level 4
- underground stations and associated buildings (including services facilities) – importance level 4
- station buildings – refer to TS 02404
- over station developments – refer to TS 02404
- other buildings or structures, unless noted otherwise – refer to TS 02404.

All tunnels and underground infrastructure structures and buildings shall be designed to satisfy an ULS event with an annual probability of exceedance not less than that provided in NCC 2022 Volume One Part B1.

At the development stage of level 4 structures with a design life of 100 years or more, a risk assessment shall be undertaken to determine the annual probability of exceedance for wind, flood and earthquake design events. These design events shall have probabilities less than or equal to relevant Australian standards.

All BEDC-4 and importance level 4 structures shall be designed for service performance levels defined in AS 5100.2 and AS 1170.4 for design earthquake events.

All parts and components within a building or structure shall be designed for the same earthquake design event as the building in which they are contained.

7 Design life and durability

7.1 Design life of permanent assets

7.1.1 General

This section prescribes the minimum design life to be used for the various elements in the tunnel structure and ancillary permanent infrastructure during the planning, design and construction, operations and maintenance phases of the tunnel.

This section shall be read in conjunction with the definitions for regular maintenance and significant maintenance (see Section 4) as well as Section 7.3.

Alternative design life may be determined during the development stage of the tunnel based on an optimal outcome. Any changes in design life shall be approved by TfNSW.

7.1.2 Structural and civil assets

The minimum design life for all new civil infrastructure shall be in accordance with TS 01642 as well as the specified design lives of asset items and sub-items provided in Appendix A of this document which are in addition to items not addressed in TS 01642.

The design life for civil and structural elements specified in this document and TS 01642, where these differ from those specified in AS 5100 (series), shall be applied only for durability and fatigue requirements. Design actions, load factors or material reduction factors shall not be increased because of design life greater than 100 years.

Where a component of an asset, including asset items and asset sub-items, is not readily accessible for maintenance or replacement, it shall satisfy the design life requirements of the asset of which it forms a part.

The asset or sub-asset shall be designed and constructed to achieve the required design strength capacity, serviceability and durability performance throughout the design life.

Elements of structures that are integral (not removeable) or composite with a main structure shall have the same design life as the main structure they are integral with or connected to. If the removal of part of a structure will result in damage to the main structure (including other structure elements or sub-structures) and subsequent repairs, then it shall be deemed as being integral.

Embedments, fasteners, fixings, connectors and fittings shall have the same design life as the main structure they are cast in, fastened or connected to.

Where a component of an asset, including asset items and asset sub-items, is not readily accessible for maintenance or replacement, it shall satisfy the design life requirements of the asset of which it forms a part.

Items that are proposed as being accessible shall include detailed explanation and justification in the durability plan and design documentation.

Where proprietary products are used and rely on manufacturer's warranties to demonstrate compliance with the design life, the manufacturer of the proprietary product shall be consulted throughout the design and construction process to ensure their warranties remain valid. This approach shall be documented in the durability plan.

7.2 Design life of temporary works and assets

At the project development stage, major temporary works and assets, and their proposed design lives shall be identified.

7.3 Durability

Durability shall be addressed throughout the design and construction of all tunnel assets and asset components for their nominated asset design life and location. The durability requirements for tunnels shall be determined from a durability plan prepared in accordance with TS 01642. Compliance to durability requirements and TS 01642 shall be demonstrated in design documentation.

To meet the specified design life requirements for each tunnel asset and sub-asset component the durability assessment as a minimum shall allow for:

- the micro-environment, including ground conditions, groundwater conditions, contamination and exposure conditions including temperature, humidity, carbon dioxide level and atmospheric pollution
- operational conditions including drying and wetting, vibration, temperature, moisture, humidity and stray current effects
- potential deterioration mechanisms in the micro-environment including penetration of aggressive substances into structural elements through cracks, joints or by wick action, and deterioration of tunnel asset elements within the tunnel environment and micro-environments due to chemical reactions resulting from changes in groundwater conditions and groundwater ingress
- rate of deterioration
- the likely material life
- risk and variability of the constructed product
- hidden or inaccessible components

- the feasibility and cost of in situ monitoring, maintenance, repair and replacement
- the necessity of providing additional protection including coatings at the time of construction as well as also at interventions throughout the asset life cycle
- the significance of failure including (but not limited to):
    - the impacts on the functionality and operations of the tunnel service
    - the risk to health and safety
    - the ability to safely and efficiently repair and replace
    - the impact on emergency service workers
    - disruption to the public
    - loss of revenue as well as the costs to repair and replace assets
    - the effects on TfNSW reputation.

Suitable controls shall be implemented for all assets and sub-asset components to achieve the design life for each asset. These controls shall be included in the durability plan, design documentation and operations and maintenance plans.

Conformance with the durability requirements in this section may not be sufficient to ensure a durable structure. Where necessary, additional mitigation measures and controls above the minimum requirements of the relevant standards shall be provided to ensure that adequate durability is provided to all tunnel asset elements and systems.

Design documentation and relevant project plans shall demonstrate how the selected design, materials, construction, and maintenance methods will achieve the durability requirements for each asset and asset component and the design life for each asset.

Exposure classification used for the durability design shall allow for the aggressiveness of the ground and groundwater as well as the internal environmental conditions. The effects of groundwater seepage through concrete, including through cracks and joints or by wick action, shall also be addressed by the durability design.

Any concrete of a road tunnel that has the potential to be exposed to acid sulphate soils shall be designed and specified in accordance with TS 02014.

7.4 Minimum exposure categories

The minimum tunnel exposure categories described in this section shall apply for all tunnels and underground facilities.

Conformance to the minimum requirements shall be demonstrated in the delivery stage and verified throughout the operation stage.

For all materials used within tunnels, the following minimum atmospheric exposure conditions shall be adopted:

- Concrete (in accordance with AS 5100.5 exposure classifications):
    - For structural linings:
        - B2 where in contact with non-aggressive ground material and non-aggressive groundwater)
        - U-C1/U-C2 where in contact with ground material and groundwater testing indicates the presence of aggressive chemicals, acidity, salinity, contaminants, waste leachate, ammonia or when groundwater is predicted via hydrogeochemical modelling to contain aggressive chemicals, acidity, salinity, contaminants, waste leachate, ammonia anytime during the design life.
    - B2 for other concrete in tunnels
- Metallic items including steelwork (in accordance with AS 2312.1)
- For all steel and metal structures, fixings and fittings, ducts and pipes, hangars and cable trays:
    - C4 (high).

8 Materials and workmanship

8.1 General

Project works shall be constructed using durable materials and workmanship undertaken in accordance with good industry practice.

Any changes to materials or standards of workmanship that would result in a lower standard or quality than that specified shall not be implemented.

8.2 Concrete, shotcrete and grout

The supply, placement and testing of materials for concrete, shotcrete and grout shall be in accordance with the relevant TfNSW standards and AS standards.

8.3 Steel reinforcement

Conventional steel bar reinforcement for all reinforced concrete structures shall be supplied and placed in accordance with TS 00077.

All steel fibres used to reinforce concrete and structural linings shall comply with one of the following:

- ASTM A820/A820M

- EN 14889-1.

8.4 Plastic, macro-synthetic or glass reinforced plastic reinforcement

The default reinforcement shall be as per Section 8.3. However, plastic, macro-synthetic or glass reinforced plastic reinforcement may be used if superior performance benefits are demonstrated and with prior approval of TfNSW through the concession process. The performance benefits, include safety, strength, durability and sustainability.

8.5 Other structural reinforcement

Reinforcement materials not described in Section 8.3 and Section 8.4 can only be used with the approval of TfNSW. Approval may be granted if there are demonstrated superior performance benefits, including safety, strength, durability and sustainability.

8.6 Precast segments and gaskets

The manufacture and construction of segmental precast lining segments shall comply with the following requirements:

- The segment manufacturer shall be certified in accordance with AS/NZS ISO 9001.
- The control of production procedures shall be undertaken by experienced specialist personnel familiar with the manufacture of high strength, durable, dimensionally accurate precast concrete elements.
- Manufacturing of the segmental precast concrete linings shall be conducted within a suitable facility to produce high quality precast concrete elements.

Segmental precast concrete linings shall comply with relevant requirements of the BTS *Specification for Tunnelling*.

To achieve the specified waterproofing for the segmental precast concrete lining, gaskets shall comply with the following requirements:

- All gaskets associated with segmental precast concrete linings shall be supplied by a specialist gasket supplier certified to AS/NZS ISO 9001.
- Gasket materials shall be durable and manufactured to withstand the ground or groundwater exposure of the specific tunnel environment.
- Gaskets shall accommodate wet and dry cycles of groundwater exposure without compromising the required waterproofing function.

- Gasket materials shall withstand chemical attack, biological degradation, wet and dry cycles of groundwater exposure, such that the gaskets comply with the design life requirements.
- Gaskets shall function under all combinations of displacement encountered in the segmental precast concrete linings, including permissible tolerances.
- Gaskets shall be compressed during the segmental precast concrete lining installation and prior to grouting of the annulus between the segmental precast concrete lining and the excavated perimeter.

Precast concrete lining connectors are installed to facilitate the installation of lining segments within the shield of the TBM. The lining connectors shall comply with the following requirements:

- Lining connectors shall achieve and maintain the required gasket compression until the precast lining segments are permanently secured in place by the annulus grout.
- Removable lining connectors may only be removed after the annulus grout has acquired its specified target strength.

Non-removable lining connectors shall be designed to consider the load effects during segment installation and tunnel operation.

8.7 Permanent fasteners and fixings

Permanent fasteners and fixings are any fastener or fixing utilised for attaching any permanent component to the structure or transition structures. Fasteners and fixings can include mechanical and chemical anchors. Chemical anchors may be used, provided they are not subject to long term creep and have appropriate fire resistance.

Permanent fasteners and fixings shall satisfy the following:

- Fasteners and fixings for use in concrete shall be designed in accordance with AS 5216.
- Fasteners and fixings shall be electrically isolated from the reinforcement. The designer shall specify testing requirements and methods for validating electrical isolation where required.
- Fasteners and fixings shall not be placed closer than 50 mm to concrete spacers or formwork anchor holes.
- The distance between the edge of any holes and the face of any reinforcement bar shall not be less than 25 mm.
- The depth of fasteners and fixings shall be less than the distance to any corner, edge or box-out. The depth of fasteners and fixings shall be in accordance with manufacturer requirements. A fire certificate shall be provided for each fastener and fixing type, in accordance with its use. The fire certificate shall state:

  - the maximum allowable working loads during the relevant design fire at 30-minute intervals
  - the type of fastener and fixing
  - the concrete subgrade.
- For fasteners and fixings designed for significant cyclic, fluctuating or pulsating loads, evidence of tests to confirm performance under these loads shall be provided.
- Fasteners and fixings shall meet all loading and design requirements for the specified use design life.
- Fasteners and fixings shall not compromise the fire resistance of the tunnel lining.
- Permanent fasteners and fixings shall be embedded in the structural lining only. Where this is not reasonably practicable, for example, jet fan fixings, the anchorage details shall allow for the as found geotechnical conditions where the fixing is required.

8.8 Temporary fasteners and fixings

Temporary fasteners and fixings are fasteners and fixings used for attaching any component to the structure or the transition structure that form part of the temporary works. They shall satisfy both of the following:

- Temporary fasteners and fixings shall be removed prior to completing the permanent works.
- The design of temporary fasteners and fixings in concrete as part of a permanent structure shall comply with the design requirements for permanent fasteners as set out in Section 8.7.

8.9 Cast-in inserts and anchor channels

Inserts and anchor channels cast into the concrete shall be kept in position by electrically insulated connections. They shall satisfy each of the following:

- The insert or anchor channel's fixing point shall be a minimum distance of twice the nominal concrete cover from the free edge of the concrete member to the centre line axis of the fastener.
- If a fixing frame or frames are used to position a group of inserts or anchor channels, the form of the frame or frames shall not cause trapped air voids during concreting.
- If the concrete surface is covered by passive fire protection, the insert or anchor channel shall protrude through to the surface of the passive fire protection. The part of the insert or anchor channel outside the concrete surface shall be assumed to be cantilevered in the design. Any space or gap around the insert or anchor channel that protrudes through the

passive fire protection board shall be sealed with fire resistant sealant of an equivalent rating to the fire protection.

9 Project wide design reports

9.1 General

The following project wide design reports specific to tunnel projects shall be provided to TfNSW, as applicable:

- lessons learned report from a study of similar previous projects (development stage)
- tunnel space proofing design report (all stages)
- geotechnical factual data report (all stages)
- geotechnical and hydrogeological interpretative reports (all stages)
- asset management strategy (development stage)
- settlement impact assessment report (all stages)
- future development load study (all stages)
- design methodology and criteria or basis of design reports (all stages)
- concrete and shotcrete repair methodology report (delivery stage)
- noise and vibration report (all stages)
- monitoring and infrastructure protection report (all stages)
- instrumentation and monitoring report (all stages)
- project wide reports shall be completed before any design packages that rely on information in the project wide reports are prepared.

10 Construction methods

10.1 Effects of tunnelling activities

Tunnelling activities shall have no adverse impacts on existing ground conditions, including existing surface water and ground water conditions, or on the performance, constructability or durability of any infrastructure (including roads, railways, tunnels, structures, utility services, buildings, and potential future developments that could be approved under existing planning or zoning restrictions). This includes any impact, other than the impacts that are acknowledged in the planning approval, relating to:

- amenity
- aesthetics

- durability
- function
- user benefits
- safety during construction and operation
- sustainability and environmental performance.

A detailed and rigorous engineering analysis (including numerical modelling) shall be undertaken that:

- predicts the zone of influence of the project
- predicts the effects (predicted effects) of the tunnelling activities on existing ground conditions and infrastructure (including roads, railways, utilities and other services and buildings)
- identifies the limits of accuracy of the prediction, sensitivity of key design inputs and the expected range of predictions
- determines the extent to which the existing ground conditions and infrastructure may be acceptably affected (acceptable effects), consistent with satisfying the requirements listed in Section 10.

Where adjacent tunnel projects occur, the cumulative impacts of adjacent projects shall not result in adverse impacts. The effects of tunnelling activities on various assets as mentioned above shall be approved by TfNSW and relevant stakeholders.

10.2 Tunnel monitoring

For all tunnels, the contractor shall prepare an instrumentation and monitoring plan to monitor the actual effects of the tunnelling activities during construction and operation. Instrumentation and monitoring of the tunnel shall comply with the following documents in order of precedence:

- BTS *Monitoring Underground Construction − A best practice guide*
- TS 01636, TS 03505 (rail only) and TS 02138 (any tunnel project).

Throughout tunnel construction and operation, the actual effects shall be monitored in accordance with the monitoring plan and compared with the predicted and the acceptable effects.

Monitoring of the actual effects of the tunnelling activities on existing ground and infrastructure shall be undertaken by qualified and experienced surveyors, geologists, geotechnical engineers, structural engineers, noise and vibration specialists and environmental specialists. The qualification of each specialist shall be determined at the beginning of each project and approved by TfNSW.

Regular monitoring of the effects of tunnelling shall continue until the effects have fully materialised. Once effects have fully materialised, background monitoring shall continue including during the operation stage to confirm that actual impacts are within acceptable effects.

In the event that the actual effects of the tunnelling activities exceed the predicted effects, the contractor shall review and notify all relevant parties in accordance with the monitoring plan. Additionally, the contractor shall re-evaluate the predicted effects and make any adjustment subsequently to any aspects of the tunnelling activities to ensure that the acceptable effects are not exceeded.

Notwithstanding any predicted effects, repair and reinstatement of infrastructure shall occur at the earliest opportunity.

10.3 Mined tunnels

A sequential excavation plan and specification(s) shall be developed and complied with by contractors using conventional mining techniques, including road header and drill and blast construction methods. The sequential excavation plan and specification(s) shall be approved by TfNSW before excavation activities commence.

Where explosives are used for the excavation of a mined tunnel, profile control shall be achieved by adopting perimeter blasting techniques.

All ground conditions shall be mapped by a qualified professional engineering geologist or professional geotechnical engineer or both as approved by TfNSW, in accordance with a project specific ground classification and assessment method.

Where an observational approach is used as part of the design approach to mined tunnels, the approach shall include the development of contingency measures, alternative construction methodologies or design solutions that can be used to address the situation where the ground conditions encountered are more adverse than those expected. The contingency measures, alternative construction methodologies or design detail solutions shall be provided in the relevant design documentation. In the absence of any standard methodology for observational approach, an approval shall be requested from TfNSW for an individual project.

An experienced surveyor shall conduct all surveying of tunnel support, including all ground reinforcement elements and as built tunnel lining thickness.

10.4 Bored tunnels

10.4.1 General

A tunnel boring machine excavation and support plan and specification(s) shall be developed and complied with by contractors when using tunnel boring techniques, including tunnel boring, pipe jacking or box jacking construction methods. The tunnel boring machine excavation and

support plan and specification shall be approved by TfNSW before excavation activities commence.

TBMs shall be capable of drilling probe holes ahead of the face to locally investigate the nature and characteristics of the ground conditions ahead.

Probing investigations shall be undertaken to detect the presence of hazardous gases and contaminated materials.

The annulus between any segmental precast concrete lining and the excavation profile shall be fully grouted immediately after leaving the TBM shield tail skin.

Grouting shall completely fill the annulus space.

10.5 Cut and cover tunnels and shafts

Common support elements for cut and cover tunnel construction methods include, box culverts, diaphragm walls, secant, soldier and contiguous pile walls and shotcrete walls.

The walls and roof of all cut and cover structures shall remain dry at all times. Any leak or damp patch shall be repaired as soon as possible after detection

Diaphragm walls, secant, soldier and contiguous pile walls are considered to be temporary elements only and shall not be relied on by permanent elements.

A waterproof membrane shall separate any temporary element from permanent elements.

The design documentation for cut and cover tunnels shall include sequencing drawings that clearly identify the proposed construction method, staging, sequencing and the installation timing of the various structural elements.

10.6 Other construction methods

Other construction methods including but not limited to immersed tube, box jacking and other innovative methods are not covered by this document. If these methods are proposed, requirements shall be developed in line with good industry practice in a project's development stage.

11 Groundwater control

11.1 General

During the development stage the project shall identify which sections of tunnels are drained or undrained and the reasons for those decisions. See Section 12.2 for details of the groundwater control assessment.

The internal face of all structural linings (roof and walls and where provided, the floor) shall be dry and free of damp patches and seepage by-products.

In the delivery stage, the contractor shall demonstrate how the contractor's proposed groundwater control system achieves all groundwater control requirements, both during temporary construction periods and in the permanent state. At the delivery stage, groundwater control specifications shall be provided to TfNSW for approval.

Furthermore, at the development and delivery stage, the groundwater control methodology shall be identified on long sections. Any changes to the nominated groundwater control methodology shall follow the project's design change process as a significant change.

The contractor shall implement all recommendations provided in the contractor's durability assessments, geological interpretive reports and hydrogeological interpretive reports related to risks associated with the migration of groundwater, including, but not limited to contaminated groundwater, leachate, and saltwater intrusion, that affect the project works.

No changes to the groundwater regime are permitted that adversely impact the natural environment or existing infrastructure.

11.2 Groundwater control and drainage assessment

Drained sections of tunnels shall only be permitted where a comprehensive project assessment in the development stage can demonstrate that the following conditions and requirements are met. This assessment is subject to approval by TfNSW and shall demonstrate the following:

- Sufficient geotechnical investigation for detailed interpretation of the geology, geotechnical and hydrogeological conditions of the project's area of influence.
- That a drained tunnel solution provides best value for money allowing for whole of life cycle considerations including maintenance of groundwater control systems, drainage systems, groundwater treatment and wastewater disposal costs.
- The whole-of-life cost shall be minimised consistent with the design life of the tunnel.
- Likely inflow effects during construction and operation:
    - the effects of groundwater inflow and quality on the tunnel and excavated tunnel face, walls and crown stability
    - the cost and program impact of ground improvement solutions to reduce inflow levels
    - an estimate of the amount of inflow during construction and operation that requires pumping, storing, treating, and disposed and the viability of measures to control, store and treat inflow
    - the water inflow quality into the tunnel and the health and safety implications for workers and tunnel occupants
    - treatment plant consumables and overall cost of the operation and maintenance

  - the continued operation and maintenance of the drainage system for the specified tunnel design life.

- Drawdown and depressurisation effects ensuring:
  - compliance with the *NSW Aquifer Interference Policy*
  - no adverse environmental effects caused by drawdown of the groundwater table
  - no adverse effects on existing water systems including but not limited to rivers, springs or lakes
  - no adverse impacts caused by depressurisation and consolidation of geological units over the design life of the project
  - no permanent recharge wells.
- Contamination and groundwater chemistry:
  - whether a change in water flow direction or velocity will result in migration of existing contaminants
  - if the groundwater is deleterious to the tunnel support elements
  - if the groundwater will corrode internal installations in the tunnel
  - whether groundwater has the potential to clog the drainage system resulting in excessive maintenance and or unintended loads on the tunnel structure
  - how contaminants in the water (including salt) are to be disposed and the cost of disposing them
  - EPA water quality discharge requirements
  - Draft and where possible, final Conditions of Approval requirements.
- Design loads arising from groundwater:
  - the groundwater loads acting on the tunnel structure
  - the hydraulic head required to drive the water to the drainage system and the corresponding load on the tunnel structure.

11.3 Undrained tunnels

Undrained tunnels and sections of undrained tunnels are required where the project development stage deems them necessary using the comprehensive drainage assessment required in Section 11.2.

Where undrained tunnels are provided, the following requirements apply:

- Groundwater pressure relief systems shall not be used in undrained tunnels.

- All undrained tunnels shall be provided with a waterproof membrane to the full external perimeter and length (extrados) of the tunnel permanent structural lining or reinforced concrete structure (applicable also to IMT tunnels structures but excluding bored tunnel segmental linings). Refer to Section 211 and Section 212 of BTS *Specification for Tunnelling Fourth edition*.

For waterproofing requirements of undrained segmental precast concrete linings, see Section 13.4.3 of this document.

Notwithstanding the outcomes of the comprehensive drainage assessment required in Section 11.2, undrained solutions shall be provided where any of the following situations occur:

- where soft ground tunnelling methods are required
- if grouting is unable to reduce groundwater inflow to meet the compliance criteria given for drained tunnels in Section 11.5
- where groundwater chemistry can increase the internal exposure class to more severe than B2 for concrete
- if groundwater drawdown is predicted to result in adverse impacts to the natural environment or existing infrastructure.

11.4 Drained tunnels

Drained tunnels or sections of drained tunnels are permitted in accordance with the comprehensive drainage assessment required in Section 11.2.

At the delivery stage, design documentation shall demonstrate how the outcomes and recommendations in the groundwater control assessment are addressed.

11.5 Acceptance criteria

Section 11.5 provides maximum allowable groundwater inflow limits. These limits apply for all tunnels unless the conditions of the planning approval provide more onerous criteria.

Criteria in Section 11.5 shall be validated throughout construction and operation. They are not design criteria.

The proponent’s activities shall not cause adverse contamination or change in water quality or levels of existing groundwater. Movement of existing contamination shall be minimised so far as is reasonably practicable.

Permanent dewatering and lowering of the existing water table shall not be allowed, except for:

- dewatering that does not result in adverse impacts to the existing environment and infrastructure

- dewatering resulting from a drained tunnel constructed in compliance with the maximum groundwater ingress limits.

Permanent recharge wells shall not be used.

The groundwater maximum inflow limits shall apply:

- independently to drained tunnel or undrained tunnel sections and may not be averaged across combined sections of drained tunnel and undrained tunnel
- at all times including during the construction and operations phases.

The achievement of these limits shall be demonstrated to TfNSW. The measurement method or methods shall be provided in the project's specification(s) for groundwater control.

11.5.1 Maximum ground water inflow limits − road tunnels

Construction and operation shall ensure that the maximum groundwater ingress into tunnels does not exceed:

- for undrained tunnels:
  - 0.2 litres per square metre of tunnel surface area per day for any 100 m length
  - 0.4 litres per square metre of tunnel surface area per day for any 10 m length
  - groundwater seepage through the pavement and floors shall be nil (zero litres per second)
- for drained tunnels:
  - 1 litre per second for any given kilometre of tunnel
  - 0.3 litres per second in any given 120 metres of tunnel
  - groundwater seepage through the pavement and floors shall be nil (zero litres per second)
- for tunnel equipment spaces and plant rooms:
  - 0.01 litres per square metre per day.
- No drips or flow onto or over road pavements, walkways and cycleways, egress passages, prefabricated buildings, or mechanical and electrical equipment.

11.5.2 Maximum ground water inflow limits − rail tunnels

Construction and operation shall ensure that the maximum groundwater ingress into tunnels does not exceed:

- for undrained tunnels:

- an average of 2.0 ml per hour per m^2 of the concrete lining intrados surfaces for any section between high points as measured in a low point sump
- a maximum of 5.0 ml per hour per m^2 of the concrete lining intrados surfaces for any 10 metres length of concrete lining
- No drips are permitted on mechanical and electrical services and rail systems and associated supporting structures including walkway and egress passages

- for drained tunnels:
  - 1 litre per second for any given kilometre of tunnel
  - 0.3 litres per second in any given 120 metres of tunnel
  - groundwater seepage through the track formation and other floors shall be nil (zero litres per second)
  - No drips are permitted on mechanical and electrical services, rail systems and associated supporting structures including walkway and egress passages.
- for tunnel equipment spaces and plant rooms:
  - 0.01 litres per square metre per day.

11.5.3 Groundwater quality

Groundwater quality and its management shall be in accordance with relevant environmental approvals.

Contaminated water from tunnel sumps and outlets shall be treated and disposed of in accordance with the relevant environmental approvals.

The collection and treatment of contaminated groundwater (including leachate), including all measures to safely manage the potential effects from the inflow or generation of elevated levels of gas, shall be in accordance with the relevant Australian standards which include:

- relevant parts of AS/NZS 60079 (series) and AS/NZS 80079 (series)
- AS 4624
- AS/NZS 4641.

Sediment traps shall be provided at all groundwater collection low point sumps.

11.6 Groundwater control systems

Groundwater control systems shall be provided for all tunnels to ensure dry tunnel linings and dry internal atmospheres.

Any permitted groundwater ingress into tunnels shall be through the groundwater control system only.

Groundwater control systems shall:

- be made of non-combustible materials
- be self-extinguishing in the event of a fire
- not include components which leach out and deleteriously affect the durability of the elements of the groundwater control system, ground support or structural lining
- be installed behind structural linings. Drainage elements shall not be used on the intrados surface of a structural lining
- for road tunnels, be installed behind road barriers and below the pavement
- for road tunnels, include a membrane on the roof and walls of all tunnels containing carriageways and mechanical and electrical equipment.

Any waterproofing membrane used in a groundwater control system shall:

- comply with the requirements of Section 211 and Section 212 of the BTS *Specification for Tunnelling, Fourth edition*
- be installed by qualified professional as approved by TfNSW
- be installed and tested in accordance with the proponent's specifications
- for commonly used membranes, be of a type that has demonstrated satisfactory performance in tunnels under similar groundwater conditions
- for any newly developed membranes, be clearly demonstrated as superior to commonly used lining systems prior to their acceptance as a suitable product
- allow for wet and dry cycles of groundwater exposure
- not rely on concrete additives to replace a sheet or spray membrane
- have sealing details that achieves the same durability requirements and design life of the membrane
- not contain any penetrations that cannot be sealed through secondary means
- have an associated drainage system that meets the requirements of this section
- resist hydrostatic water pressure. For undrained tunnels, this shall include full hydrostatic water pressure determined from flood levels or the groundwater table, including fluctuation resulting from significant storm events. For drained tunnels this shall include hydrostatic pressure from the water table resulting from blockage to the groundwater control system. A minimum value of 10 kPa shall be adopted or higher value as determined from engineering analysis.

Groundwater pressure relief systems shall not be used in undrained tunnels.

In drained tunnels or sections of tunnels, groundwater control systems shall be installed at the location of geological structures including faults, dykes, bedding planes and joints that are, or have the potential to be, water bearing at any time during the required design life of the tunnel.

As a minimum, any of the following geological structures are deemed as having the potential to be water bearing at any time during the construction period and the required design life of the tunnel:

- geological structures that have or show evidence of past water flowing or seeping from them, whether observed during or after geological face mapping as required by this document
- joint swarms, shear zones, fault zones, dykes, open joints or open bedding planes
- geological structures that can be affected by seasonal changes
- any geological structures that require grouting to restrict water inflow.

Where different types of groundwater control are provided on a project, a suitable transition zone between different types of groundwater control systems shall be provided. This shall be based on a detailed and rigorous engineering assessment to provide the minimum length of transition zone and prevent migration of water from one system type to the adjacent system.

Seals used in association with groundwater control systems shall allow for wet and dry cycles of groundwater exposure.

Any drainage elements used in a ground water control system, including but not limited to strip drains and drainage mats, shall:

- collect, convey and discharge groundwater directly into the tunnel groundwater drainage system
- be of a type that has an extensive history and proven reputation for a demonstrated satisfactory performance in tunnels within similar groundwater conditions and similar groundwater chemistry, or for any newly developed drainage elements, be clearly demonstrated as superior to commonly used drainage elements prior to their acceptance as a suitable product
- not permit water pressure to increase behind a membrane or structural lining
- require minimal maintenance
- incorporate a hose flushing system as a primary means of flushing the groundwater drainage elements
- ensure that shotcrete or concrete cannot enter the strip drains or drainage mats during structural lining application. Site trials shall be undertaken to demonstrate compliance with this requirement to the satisfaction of TfNSW

- be installed with free-flowing drainage gradient across the crown and vertical down walls and with access point locations that allow for safe and efficient maintenance access
- ensure water ponding in a strip drain or drainage mat does not occur
- ensure that any joints and the end points utilise prefabricated connections and caps
- be installed and tested in accordance with TfNSW design and construction specifications and the manufacturer's specifications.

Where strip drains and drainage mats are installed:

- the location of all drainage elements shall be readily and quickly identifiable and accessible by any maintenance teams
- the cleaning system for drainage elements shall enable safe and efficient maintenance, be installed integral or adjacent to the drainage element, include fittings for attachment of a flushing system and be able to be easily rodded
- the access points for manual rodding shall be located to ensure ease of access and rodding to clear blockages
- the location of strip drains and drainage mats shall be accurately captured by survey and included on as-built drawings and digital models.

The proponent shall submit all details of the groundwater control system elements including membranes, drainage elements, gaskets, equipment and processes to TfNSW for review.

The proponent shall undertake pre-production site trials of the groundwater control systems in the presence of TfNSW to demonstrate their suitability. The trials shall include installation of membranes and drainage elements, flushing of drainage elements and gasket testing.

Unsealed penetrations into the groundwater control system shall not be allowed. Any seals used shall not compromise the effectiveness of the groundwater control system.

The migration of fine particles into a drained tunnel from within the ground shall be prevented.

11.7 Grouting

Where grouting measures are adopted by the proponent for groundwater control, the grouting measures shall:

- be undertaken ahead of the excavated face (pre grouting)
- adopt only grout mixes that are durable
- adopt only grout mixes that do not support the propagation of fire
- be accompanied by the installation of a structural lining with a waterproofing membrane that complies with Section 11.7. Design documentation shall identify zones where grouting may be required and the process to initiate grouting in the zones.

As a minimum, the process to initiate grouting shall include:

- forward probing requirements
- mandatory forward probing locations, including at all anticipated major geological structures
- inflow criteria from probe holes to initiate pre grouting and inflow criteria to commence excavation
- criteria to undertake post grouting of discrete geological defects, including the maximum time to commence post grout to ensure that impacts associated with groundwater drawdown do not occur.

Forward probing shall also be undertaken where there are uncertainties in the project's geotechnical model.

Chemical grouts that are expansive by nature (for example, foaming polyurethane grouts) cannot be used as a permanent method of groundwater control.

12 Tunnel drainage system

12.1 General

A tunnel drainage system shall be provided for the tunnel project works which complies with the environmental documents and planning approval.

Surface storm water run-off from the approach roadways outside the tunnel portals shall be collected and prevented from entering the tunnel.

The tunnel drainage system shall accommodate the credible combination of stormwater, incident spillage, groundwater, maintenance, deluge, firefighting and other water ingress events.

The proposed combination of events shall be identified and demonstrated in the design. These events include, but are not limited to, the following:

- surface stormwater run-off from portal areas
- stormwater carried into tunnels by vehicles
- waste water effluent from tunnel cleaning
- subsurface water seepage
- fire suppression system operation
- accidental rupture of a fire main or hydrant
- accidental spillage of fuel and chemicals from damaged tankers and other vehicles and the wash-down of such products.

The tunnel drainage system shall ensure that all tunnels, structural linings, plant rooms, electrical equipment cabinets and substations, plant and equipment, cross passages, emergency egress passages, walkways and all other underground infrastructure are drained at all times. For road tunnels, this includes after operation of a deluge system.

An assessment shall be undertaken of the maximum stormwater run-off from tunnel portals inflows combined with deluge flows to demonstrate that the proposed drainage system ensures the surface flows can be drained.

Gravity drainage systems shall be utilised as much as possible. Additionally, the drainage system shall be designed to allow for surface water run-off into the tunnel and any deluge events or testing from fixed firefighting systems. Sag vertical alignment tunnel geometry shall be avoided where possible to eliminate possible water ponding. The drainage system design and configuration shall take into account the need for maintenance personnel to access adjacent equipment without having to stand in the drain.

Tunnel portals shall be designed to take into account the PMF flood level. This may require the tunnel portal to be above the PMF or have passive flood protection or barrier included as part of the design.

Water from any source shall be prevented from entering emergency egress passages and from ponding in front of egress doors.

As a minimum, for road tunnels, the tunnel drainage system shall provide:

- the capacity to deal with a 1% annual exceedance probability storm (for tunnel approach and exit structures) so that water flows do not encroach onto the traffic lanes
- a portal sump with capacity to capture and temporarily store all surface flows with a 1% annual exceedance probability such that water flows do not enter the tunnel portal
- collection at portals and inside main tunnels through inlet pit grates (gullies) at 40 m maximum spacings or closer intervals, with longitudinal pipework to sumps. Gullies shall be flame proof, explosion resistant and capable of capturing and conveying spills of hazardous or flammable liquids with minimum propagation
- pit grates or lids to gullies that do not encroach more than 300 mm into the carriageway shoulders
- all components of inlets (gullies, pit grates or lids). All components shall be designed to carry the same traffic loading as the pavements and other components of the tunnel
- the geometry of the gullies and the roadway levels in the vicinity of the gullies. These shall be such that the water flow from the activation of deluge over sufficient zones to cover a minimum length of 60 m of roadway is all captured within 120 m of the end of the last active deluge zone

- collection of water from ventilation tunnels, ventilation shafts, tunnel equipment spaces and other spaces such as equipment rooms, substations, egress passages and stairwells. The drainage system shall be hidden behind structural linings and connected directly to the main tunnel drainage system
- In addition to the above requirements the project team may consider guidelines provided by Austroads *Guide to Road Design Part 5: Drainage – General and Hydrology Considerations*.

Tunnel subsurface drainage (excluding stormwater drainage) pipes shall have a minimum internal diameter of 150 mm.

The tunnel drainage system shall be easily maintained and cleaned (flushed and rodded) to remove any blockages including those caused by iron bacteria or oxide sludge, whereby:

- the locations of the collection and tunnel drainage system for maintenance and cleaning shall be provided at regular intervals to facilitate proper functioning of the system, and at all locations that would be prone to collecting debris that could clog the system
- access to the collection and tunnel drainage system shall not be impeded by sub framing, structural supports, services or architectural panels.

12.2 Tunnel drainage sumps

As a minimum, the tunnel drainage sump system shall provide:

- pumps that are easily retrievable by vertical slide rails or block and tackle equipment
- sump access manholes. These shall not be located on carriageways
- minimum sump, holding tank and pump configurations and pump capacity compatible with the maximum inflow rate. The capacity of these systems shall address the requirements of Section 12.1 and Section 12.2, and be sized to manage the largest combination of flows
- adequate space in pits and sumps to allow cleaning and maintenance of pipes, pumps and all associated equipment.

The tunnel drainage sumps shall:

- be lined, sealed, and vented to the atmosphere or to the tunnels (or both). Design documentation shall demonstrate that the materials, lining methodology and construction details are suitable to ensure the required design life criteria is achieved for the expected water quality and groundwater chemistry
- provide options to discharge water to:
    - the tunnel water treatment facility where necessary
    - the surface water drainage system or road tanker, while directing groundwater to the water treatment facility

- holding tanks that similarly provide the options to discharge to the above items in this list.

12.3 Tunnel water treatment facility

Treatment of tunnel water may be required. Water management and water quality requirements shall be determined in consultation with TfNSW and external agencies.

Where a water treatment facility is required, it shall be:

- designed to take into account the possibility of contaminated groundwater ingress into the tunnel drainage system
- capable of processing effluent from tunnel cleaning procedures
- capable of treating (at a minimum of once a year, following regular testing of the deluge systems) the water held in the first flush chamber and used deluge water storage compartment of the tunnel sump following a fire event (or systems test) in addition to the daily groundwater inflows
- designed to be easily maintainable and replaceable
- designed, located and arranged so that maintenance access to any such treatment facilities does not require traffic management.
- Water quality shall meet environmental project requirements.

13 Tunnel structures

13.1 Permanent ground support

All tunnel excavations shall be provided with permanent ground support.

Ground support includes rock and soil reinforcement and structural linings. Ground support may be temporary or permanent.

Temporary ground support for tunnels shall not be used as measures to relieve loads on permanent structural linings.

If there is a risk of stray currents, permanent ground support shall include mitigation against the effects of stray currents.

Ground support shall not extend beyond the tunnel substratum. This shall be demonstrated during the design process and documented as part of the as-built records for the project.

Ground support shall not egress into any vehicle or kinematic envelope.

The design of ground support for tunnels and associated structures shall be undertaken by a TAO or as approved by TfNSW design organisation experienced in the design of similar structures in NSW or elsewhere.

All designs of ground support, including the actual support type distribution shall be certified by the same design organisation, and approved by TfNSW.

The design of ground support shall adhere to the recommendations of and follow the requirements of a project specific basis of design or design criteria report that shall be applied consistently on the tunnel project. This basis of design or design criteria report shall as a minimum, incorporate design requirements from:

- The International Tunnelling Association – *A Code of Practice for Risk Management of Tunnel Works*
- AS 5100 (series) wherever possible
- other codes and standards as approved by TfNSW on a case-by-case basis. Where other codes and standards are proposed to be used by the contractor for the design and construction of ground support, the contractor shall clearly demonstrate how the design rules as well as load and material factors specified in those codes and standards are consistent with and complement AS 5100 (series) requirements.

Where the contractor adopts an observational approach to design and construction of ground support, that observational approach shall be in accordance with CIRIA Report R185 (The Observational Method in Ground Engineering: Principles and Applications) and any limitations imposed by TfNSW related to post IFC design change approvals.

AS 4678 shall not be used for the design of ground support.

Tunnel long sections drawings shall include as a minimum:

- all geological and geotechnical units
- all major geological structures and any uncertainty in their positions
- simplified borehole stick logs and other investigations that provide sufficient detail to verify interpretations on the long sections (for example rock mass classes, sheared zones, rock strength, weathering)
- the interpreted groundwater table
- proposed ground support types
- groundwater control system types
- locations where probing and grouting is required.

Ground support shall be constructed in accordance with design documentation that has achieved IFC status. Any post IFC change to ground support shall receive IFC status before it may be used.

Suitable instrumentation and monitoring shall be designed and installed to validate the condition and performance of the ground support in the tunnels throughout the construction and the design life of the ground support. The design and monitoring requirements shall be included in

the relevant design documentation and operations and maintenance manuals.
See Section 10.2 for further details.

All concrete or shotcrete structural linings reinforced with steel fibre shall comply with any one of the following:

- RILEM TC 162-TDF *Test and Design Methods for Steel Fibre Reinforced Concrete*
- Concrete Society, Technical Report 63 *Guidance for the design of steel-fibre-reinforced concrete*
- PAS 8810 *Tunnel design. Design of concrete segmental tunnel linings. Code of Practice* (segmental linings only).

Design documentation for ground support shall include calculation and numerical analysis to demonstrate that failure of the ground support will not occur, including under the following ULSs:

- collapse or localised failure of tunnel crown or sidewalls or both due to fall of blocks or slabs of rock under gravity loading and lower bound natural in-situ rock stresses
- collapse or localised failure of tunnel crown due to induced stresses where such stresses are sufficient to cause compressive or shear failures or both within the rock mass under upper bound natural in-situ stresses
- heave of the tunnel floor due to induced stresses where such stresses are sufficient to cause compressive or shear failures or both within the rock mass under upper bound natural in-situ stresses
- collapse of the tunnel when exposed to the design fire curve for the design fire resistance period or when exposed to the design earthquake events
- collapse of the tunnel caused by progressive collapse initiated by the failure of any one element or system.

Design documentation for ground support shall include calculation and numerical analysis to demonstrate the following SLS:

- Ground surface and existing infrastructure movements that occur as a result of the project works shall be limited to criteria in Section 10.1. This includes movements resulting from groundwater depressurisation caused by the project works until a steady state groundwater equilibrium has been reached and associated consolidation settlements have stabilised. Minister Conditions of Approval will also set out requirements.
- Deformation of tunnel structural linings shall be limited to not compromise its integrity, capacity, robustness, durability, design life or allow the ingress of groundwater into the tunnel.

Design ground and groundwater loads imposed on ground support elements shall be calculated using good industry practice and as accepted by TfNSW, including using appropriate unit weights of the geological materials, the upper and lower bound natural in-situ stresses, conservatively assessed kinematic blocks formed by the potential combinations of geological features and conservatively assessed groundwater pressures.

Fire resistance of ground support shall ensure robustness, safety and stability in the event that a design fire event occurs.

Observational approaches including the observational method of CIRIA R185 cannot be used for construction of groundwater control systems, grouting processes or other similar construction observation methods without seeking approval from TfNSW.

13.2 Rock reinforcement

Rock reinforcement shall not be located within 2 metres of the finished surface level of any road surface or any other ground surface without TfNSW approval.

With the exception of project works, permanent rock reinforcement shall not be located within 2 m of the excavated profile of other tunnels or any other existing infrastructure or known future infrastructure.

Excavation undertaken shall not be located within 2 metres of existing ‘permanent’ rock reinforcement installed by a previous project or any other pre-existing infrastructure.

If compliance with the above clauses is not feasible because of road or track geometry constraints for the project works, a bridging structure or passive ground support shall be designed and constructed.

Maximum shear displacements after installation of rock reinforcement shall not exceed 10 mm at the locations where rock reinforcement intersect any bedding planes or joints in the rock mass.

Rock reinforcement elements required for temporary purposes, shall have a minimum design life of 5 years. If these elements are required to be in service for longer than 18 months, they shall be designed as permanent elements.

If rock reinforcement elements are assessed to yield, then load sharing to adjacent rock reinforcement elements shall be demonstrated in a manner that ensures the adjacent elements do not yield and there is no risk of progressive failure. Design verification testing of elements expected to yield in construction shall be undertaken.

Steel sets and lattice girders shall be designed as temporary support elements only and may be placed in combination with sprayed concrete linings to form a composite structure that provides immediate overhead ground support to sections of excavated tunnels.

In situations where flexible support is necessary, both steel sets and lattice girders may be installed with sliding connections, allowing deformations to occur prior to installing permanent structural linings.

Steel sets and lattice girders shall be designed and installed in accordance with good industry practice.

13.3 Shotcrete ground support

Shotcrete applied in tunnels shall only be applied by the wet spraying method.

The contractor shall provide a high-performance shotcrete specification consistent with and supplementary to TS 01734.2. The specification shall demonstrate that construction achieves design and project technical requirements. This specification shall be approved by TfNSW. Materials and workmanship shall be in accordance with Section 8.2.

The initial layer of shotcrete shall be considered temporary only and is provided to ensure a safe work environment. It shall be a minimum thickness of 50 mm. This layer can rely on adhesion to the substrate if safe to do so, but any permanent shotcrete layer that is applied to the initial layer shall not rely on adhesion after 28 days of spraying the permanent lining.

Any shrinkage cracks from temporary shotcrete linings or non-structural linings (such as smoothing layers) shall not adversely impact permanent linings.

13.4 Permanent structural linings

13.4.1 General

All tunnels shall be provided with a permanent and durable structural lining for the tunnel roof (crown), haunches, side walls, end walls and where required, the floors, that is a minimum of 100 mm thick.

The internal inside face of all structural linings and the internal atmosphere of all tunnels and underground facilities and spaces shall be designed and constructed to be dry.

All structural linings shall be reinforced with steel fibres, reinforcing mesh or reinforcing bars. Plain unreinforced concrete or reinforcement methods not listed in this section shall not be used.

New or innovative reinforcement methods not listed in this section require approval by TfNSW.

The design of all tunnel structural linings shall provide best value for money, taking into account the whole of life cycle costs, sustainability as well as providing a safe and durable support system.

Where permanent ground support includes permanent rock reinforcement elements and a permanent shotcrete lining, the shotcrete lining shall be structurally connected to the rock reinforcement elements so that all loads on the lining, whether from the ground, groundwater, or

from temperature and shrinkage effects, are transferred to the rock reinforcement elements or transferred to abutments by compressive arch action. The adequacy of the structural connection shall be demonstrated by the contractor using calculations and through evidence of suitability testing and approved by TfNSW.

Where structural linings, including those formed by segments, rely on arch action, design assessments shall demonstrate that the lining remains in compression throughout the design life and provide methods to validate the assessment.

Permanent structural linings shall comply with the following requirements:

- a design crack width of no greater than 0.2 mm
- provide measures and mechanisms to control shrinkage and the control of cracking. The measures to address the control of shrinkage and cracking shall be demonstrated in the design documentation
- provide no design reliance on allowable cracks as means to relieve stress or groundwater pressures
- provide no reliance on autogenous healing or other forms of self-healing of cracks
- provide a minimum fibre capacity loss allowance of 25 mm for any structural lining that contains steel fibres as reinforcement.
- provide a minimum 100 mm cover to ground support elements and drainage elements
- shall not assume any long-term bond to drainage elements or membranes
- be designed for the following loads as a minimum:
    - blocks or slabs of rock isolated between pattern rock bolts that have a nominally 3% or greater chance of occurring along any length of tunnel or underground excavation
    - stresses caused by rock-mass movements
    - groundwater pressures as computed by seepage analyses but with a minimum value of 10 kPa
    - loadings from services or equipment attached to the structural lining.

Non-structural linings such as surface finishes or smoothing layers shall adhere to a structural lining. The connection shall be demonstrated through evidence of suitability testing. The self-weight load of the non-structural lining shall be incorporated into the load requirements of the structural lining.

13.4.2 Cast in situ linings

Cast in situ linings shall be constructed as permanent structural linings and designed to support all permanent loads including ground, live, seismic, groundwater loads and loads from internal structures and services and to sustain the design fire events.

Cast in situ linings shall confine and protect a waterproofing membrane that is required between any initial and temporary lining and the permanent secondary structural lining.

Cast in situ linings shall be designed in accordance with AS 5100.2 and AS 5100.5.

13.4.3 Precast segmental linings

The design of precast segmental linings for bored tunnels shall meet the minimum requirements of PAS 8810 subject to the following:

- The capacity shall be calculated in accordance with:
  - relevant parts of EN 1992 (series)
  - *fib Model Code for Concrete Structures* for steel fibre reinforced concrete, with ultimate condition requirements modified to use Fr_4 rather than Fr_3.
- The following requirements shall be adopted instead of the relevant provisions in PAS 8810:
  - the relevant Australian standards for concrete and steel materials
  - this document, relevant parts of AS/NZS 1170 (series) and the relevant parts of AS 5100 (series) for load types, load values, load factors and material reduction factors as well as load combinations
  - this document, other TfNSW standards and AS 5100.5 for durability.

The Contractor shall provide a specification or series of specifications for precast segment linings to demonstrate that construction achieves design and project technical requirements. These specifications shall be approved by TfNSW.

The designer shall determine the configuration of rings, segmentation and details of joints and fixings, and so forth, to suit ground conditions, loadings, methods of construction and all functions in the completed works as described in this section.

13.5 Cut and cover, tunnel approach and exit structures

The design of cut and cover tunnels and tunnel approach and exit permanent structures shall be in accordance with AS 5100 (series).

The designer shall use design methods for the analysis of the cut and cover tunnel structures that take into account, but are not limited to:

- the method of construction, including temporary works
- the ground to structure interaction, including the effects of temporary works
- All ULSs and SLSs.

Cut and cover structures shall remain dry.

The walls of cut and cover structures and tunnel approach and exit structures shall have a waterproof membrane to prevent groundwater egress into the tunnel structures.

A sheet waterproof membrane shall be used under the base slab of the cut and cover and on the roof of the structure. The membrane shall be protected by a durable concrete protection layer.

Waterproofing membranes under base slabs shall prevent groundwater from entering the pavement laid over the base slab.

Where groundwater cut-off is required, cut and cover and shaft structures shall provide an effective groundwater barrier during construction that prevents adverse impacts on construction and the surrounding environment.

Groundwater cut-off may be achieved with temporary elements such as sheet pile, diaphragm, secant pile and slurry walls or with special ground improvement techniques such as, but not limited to, jet grouting and deep soil mixing.

Ground improvement techniques should not be relied on to provide permanent groundwater control or long-term ground improvement.

Where necessary, temporary recharge wells may be required during construction to maintain the groundwater levels outside the underground structure.

Early-age thermal strain and long-term shrinkage strain shall be modelled in design following the recommendations of CIRIA C766 – *Control of cracking caused by restrained deformation in concrete*. The design shall limit cracks due to restraint against shortening to achieve long-term limiting design crack widths in accordance with the requirements of this section.

Special waterproofing details shall be developed for the construction joint between base slab and wall and include the provision of regroutable grout tubes.

The special waterproofing details shall also address the areas where the construction joints of the wall elements meet the construction joint of the base slab to avoid groundwater from bypassing the proposed waterproofing elements in the construction joint between the two elements.

The proposed waterproofing detail of this construction joint shall also be able to accommodate shrinkage of the base slab without adversely affecting the waterproofing performance of the joint.

Backfill, including fill adjacent to, within and on top of cut and cover and shaft structures shall be provided in accordance with the section on backfilling against structures in TS 01723.

Contaminated material, foreign material or material classified as acid sulphate soils (ASS) or potential acid sulphate soils (PASS) or treated material originally classified as ASS or PASS shall not be used as backfill adjacent to, within or on top of any cut and cover or shaft structure.

13.6 Tunnel portals

Ground support design at tunnel portals shall allow for the following:

- arched sprayed concrete linings that may be reinforced with structural fibres, bar or mesh reinforcement, lattice girders, or steel sets or a combination of these elements
- inclusion of temporary pre-support such as grouted spiles or canopy tubes
- tunnel face support such as face nails, berms or temporary shotcrete
- portal specific excavation sequence.

The portal excavation, including any batter slopes above, shall be stable and prevent erosion, scoring or detachment of material from the excavated surfaces.

13.7 In-tunnel structures

In-tunnel structures include but are not limited to walkways and stairs, walls and roof decks, culverts, platforms, pits, ventilation structures, egress structures as well as support structures for services, architectural panels and jet fans.

The tunnel fire resistance design of these in-tunnel structures shall be determined by a risk assessment in accordance with the fire engineering brief of the tunnel project.

The design of architectural panels commonly used in road tunnels shall consider the minimum vertical height and the minimum gap between the traffic barrier and the panel to facilitate inspection and maintenance. The panels shall be attached to the wall panel system in a way that facilitates frequent removal and reattachment for the duration of the required design life of the panels. Screws or glue shall not be used.

If architectural panels are provided, they shall be non-combustible and stable at 450°C for a duration of one hour.

13.8 Fire resistance of tunnel structures

All permanent structural linings shall be designed and constructed to:

- ensure global tunnel stability at all times
- ensure no failure of permanent tunnel structures and structural linings for the ULS load combinations
- sustain only repairable damage after a design fire event
- limit spalling to a depth no greater than 25 mm (measured at any one point) when exposed to fire represented by the design fire curves.
- Fire resistance for structural linings shall follow the design procedures in EN 1992-1-2.

For FRL of tunnel structures, refer to TS 00008.3.

The designer shall:

- provide evidence of suitability testing that the structural lining system nominated for use in tunnel linings satisfies the fire safety performance required by this section
- ensure that the evidence of suitability testing specified in Section 13.8 includes a project specific test procedure authored by a NATA accredited testing authority identifying the concrete and shotcrete mixes, placement method, and proposed testing procedure. The proposed testing procedure shall be based on Efectis and EFNARC recommendations and be provided to TfNSW for approval before undertaking any testing
- ensure that the evidence of suitability testing specified in Section 13.8 includes a project specific test report authored by the same testing authority that developed the test procedure, confirming that the approved test has been undertaken and setting out the results of the tests and any other relevant information that demonstrates the evidence of suitability of the proposed structural lining.

All permanent structural linings shall contain a minimum of 1.0 kg/m^3 of micro-synthetic fibres (polypropylene fibres). Micro-synthetic fibres shall comply with either EN 14889-2 fibre class 1a or ASTM C1116/C1116M fibre type III.

Fire tests on precast segments shall allow for any loads required by design, for example, follow a loaded test procedure.

Shotcrete linings and cast in place linings may utilise unloaded test methods.

14 Construction

The design of tunnels shall take into account the construction methodology, staging and sequencing as well as account for construction constraints, including physical and contract limits as well as plant and machinery capabilities. The management and coordination of the construction methodology, staging and constraints shall be demonstrated in the design documentation.

TfNSW standards include a number of technical specifications that are applicable to civil construction of tunnels, including but not limited to:

- TS 00077
- TS 00145 (for road tunnels)
- TS 00146 (for road tunnels)
- TS 00149 (for road tunnels)
- TS 00151 (for road tunnels)
- TS 01734.2 (for road tunnels).

Project specific specifications shall be prepared in a similar format to existing TfNSW specifications and include the following requirements as a minimum:

- list of codes and standards used in the specification
- technical requirements compliance matrix
- list of definitions used in the specification
- documents to be included in the QMP and testing and construction records to be kept
- Hold Points and Witness Points as defined in TS 01572.1 (TfNSW Q6)
- for project works elements (where applicable):
    - material requirements, including testing
    - construction tolerances
    - durability requirements
    - acceptance criteria
    - testing requirements to demonstrate the suitability of the construction methodology
    - monitoring and testing requirements during the construction phase to demonstrate that design assumptions have been achieved
    - inspection, testing and maintenance requirements for the required design life
    - remedial actions or repair of non-conformances
- for temporary works elements and products, where applicable:
    - material requirements, including testing
    - construction tolerance
    - acceptance criteria
    - testing requirements to demonstrate the suitability of the construction methodology
    - monitoring and testing requirements during the construction phase to demonstrate that design assumptions have been achieved.

All project specifications shall be approved by TfNSW. They shall not include any content that does not comply with TfNSW standards and specifications.

15 Operations and maintenance

An operations and maintenance strategy shall be developed for all tunnels. Operations and maintenance manuals and plans shall be developed during the design and construction phase to be consistent with the overall operations and maintenance strategy.

Operation and maintenance manuals shall detail how maintenance is undertaken and include:

- technical maintenance plans developed in accordance with TS 01506.1 through the maintenance requirements analysis as described in TS 01517 (all parts).
- design and construction documentation including safety in design registers, supplier information, drawings, design report and plans
- register of design assumptions and limitations and how they are to be validated throughout the design life
- performance standards, damage limits, and repair standards, supported by documentation demonstrating the basis for these requirements.

Maintenance requirements shall be developed by the proponent in consultation with the maintenance service provider and TfNSW. Tunnels and ancillary infrastructure shall be designed and constructed so that the asset can be inspected, maintained, renewed or replaced, effectively, safely, with minimum whole-of-life costs and without adversely affecting its availability for operation.

Adequate maintenance access shall be provided to allow for ease of maintenance. All equipment shall have sufficient clear space to allow for safe and efficient maintenance and replacement activities to take place. The clear access space shall be sufficient to ensure that all maintenance activities including any repair works, removal and replacement of equipment does not require the removal and later replacement of any other associated, adjoining, proximal, nearby or surrounding tunnel assets including but not limited to cladding, services, service supports, plant and equipment, support structures and fittings, other fixtures and structural systems. Components, materials and finishes shall be chosen to minimise future maintenance taking into account the design life and the whole-of-life costs.

16 Specific requirements for rail tunnels

16.1 General

The design of rail tunnels shall allow for constructability constraints, including live rail operating conditions and track possession constraints.

16.2 Civil

16.2.1 Design loads

The dynamic load allowance on track slabs shall be in accordance with TS 02402.

Tunnels shall be designed for derailment loads and protection requirements in AS 5100.2. Where tunnel walls are discontinuous, for example, where there is a crossover to the track in the adjacent tunnel, derailment containment devices in accordance with TS 01713 shall be provided.

16.2.2 Sound absorption treatment

Operational air-borne noise levels within tunnels, and consequently within trains and at station platforms, are influenced by the extent of sound absorption. For tunnels with slab track and direct fix fasteners, the project's environmental requirements for sound levels shall be adhered to. The use of tunnel sound absorptive linings may be required to improve the sound absorption in excess of conventional railway ballast which has moderate sound absorption characteristics. The sound absorption properties of the lining shall be the more onerous requirements between the project's environmental requirements and Table 2.

Table 2 – Sound absorption properties of tunnel linings

Octave band frequency, Hz	Minimum sound absorption (metric Sabines) per 10 m of track
125	5
250	10
500	7

Note: For this document, a metric Sabine is defined as the product of the surface area (in m^2) and the sound absorption coefficient derived in accordance with AS ISO 354.

16.2.3 Drainage and groundwater control systems

Drainage systems shall be designed to collect and dispose of any seepage and surface water that enters the tunnel to ensure that the track infrastructure is kept well-drained to minimise maintenance.

The drainage system shall be configured so that in the event of a blockage, any overflow will not affect train operations or the reliability of the infrastructure.

Track drainage shall be in accordance with the requirements in TS 01638 and guidance in TS 01641.

16.3 Rail tunnel configuration, geometry and clearances

16.3.1 Configuration

Rail operating classes are specified in TS 03510.

Unless otherwise stated, new rail tunnels shall be designed as specified in TS 03500 or through an equivalent requirement approved by the RIM.

The tunnel shall be sized to accommodate the safe construction, operation and maintenance of the rail assets, including transit space requirements, services, plant and equipment.

Tunnel services, plant and equipment shall include:

- overhead wiring system

- power supplies
- signalling equipment, including point machines and compressed air supply
- communication cables and equipment, including emergency telephones
- electrical supply and service cables
- tunnel lighting and small power outlets
- tunnel walkway
- tunnel ventilation system
- fire protection systems
- noise and vibration mitigation measures
- tunnel drainage, including pumping stations and sumps
- tunnel water discharge limits, treatment and trade waste discharge
- under track crossings
- stray current and electrolysis mitigation
- storage and charging of emergency trolleys
- condition monitoring equipment.

16.3.2 Clearances and space proofing

Equipment such as cabinets and signs shall be located so as not to obstruct access to or reduce the capacity of refuge areas.

16.4 Rail tunnel access and egress

16.4.1 General

Tunnel access and egress shall be provided to all tunnels in accordance with the requirements of AS 1428 (all parts) ,TS 00008.3 and Section 16.4 which includes minimum requirements for underground platforms access and egress, walkways and safety refuges.

Access and egress to tunnels shall be via connected stations, tunnel portals, tunnel services buildings or cross passageways between tunnels unless it can be demonstrated to TfNSW that an alternative optimum point for access and egress to a tunnel can be provided. In this case, an intervention shaft for access or egress may be used, subject to TfNSW approval.

Where twin tunnels are specified, the tunnels shall be linked with cross passages for the purpose of emergency egress.

Egress provisions shall provide for safe efficient egress in the event of an emergency requiring detrainment within a tunnel.

Egress points shall be determined by taking into account all factors that impact emergency provisions including, but not limited to, the ventilation system, egress strategy, communication facilities, emergency lighting, type of walkway provided, passenger characteristics, passenger mobility impairment, tunnel configuration and emergency services provisions.

Where an existing railway is being extended, the evacuation strategy shall interface and be integrated with the existing strategy.

16.4.2 Signage

Signage shall clearly identify emergency exit facilities. Suitable instructions for use of all emergency telephone equipment, emergency stairs and landings shall be provided.

Where cross passages are provided, signs shall be provided at regular intervals indicating the direction and distance to the nearest cross passage.

Details and locations of the emergency signage shall be agreed with the relevant stakeholders.

Signage shall be designed in accordance with relevant Australian standards and TfNSW standards.

All emergency signs shall be of luminous or reflective type material. They shall be fire-rated and have an anti-graffiti coating.

16.4.3 Walkways

Walkways shall meet the following performance criteria:

- Provision of the walkways shall take into account rolling stock types and associated detrainment facilities and the TfNSW evacuation procedures.
- Walkways shall provide a safe, uniform, smooth, slip resistant walking surface and meet the requirements of emergency services personnel.
- The design of walkways shall take into account the normal function and maintenance of the railway track and associated facilities.
- Walkways shall allow safe efficient egress from a train in the event of an emergency.
- The minimum clear width of the walkway shall be a minimum of 1000 mm between handrails. If increased width is required, this shall be agreed with the relevant TfNSW stakeholders. The 1000 mm clear width shall extend in an envelope 2100 mm above the walkway level. The 1000 mm by 2100 mm envelope shall be clear of all services, handrails, guiderails, barriers and any other obstructions to allow for a clear, unimpeded egress.

- The walkway level shall be agreed on by the relevant TfNSW stakeholders. Additionally, it shall be designed to allow the optimum, safe efficient egress.

If elevated walkways are to be provided, the following criteria, in addition to those identified in above, shall apply:

- The provision of elevated walkways shall take into account access control measures and delineation at areas with public access points to prevent unauthorised access.
- Elevated walkways shall have a handrail on the tunnel wall side of the walkway. The walkways shall not obstruct egress from the train or access to cross passages if provided.
- Elevated walkways shall be of non-combustible material and designed so that, in the event of a local failure, no greater than 10 m of walkway collapses. As rail carriages are typically 20 m long, the 10 m is based on half the length of a typical carriage. Therefore, if local collapse occurred due to the effects of heat weakening the walkway structure, egress would still be available from at least one carriage side door.
- Elevated walkways shall have ladder access from track level at no greater than 90 m centres. Ladder centres of 90 m are based on the maximum centres of the emergency telephones.
- If elevated walkways are to be used for maintenance purposes, then track access shall be taken into account.
- The design shall take into account the height of the elevated walkway. It may be beneficial to locate elevated walkways a convenient stepping height below the train door opening. This reduces the elevation difference between the walkway and track bed, making track bed access easier in an emergency and reducing potential injuries from possible falls from the walkway. Increased headroom is also achieved and can provide better separation between persons evacuating the tunnel and hot smoke which rises to the tunnel ceiling during a fire incident in the tunnel.
- Where cross passages are provided, elevated walkways shall provide for unobstructed access to the cross passage.
- Where a crossover to an adjacent tunnel exists, the elevated walkway shall ramp down to the crossover.
- The design shall take into account the impact of a derailment and provide measures to ensure the elevated walkway does not constitute an unacceptable risk to passengers and staff in the event of a derailment.
- The design of elevated walkways shall take account of the potential for corrosion due to stray traction currents.
- Elevated walkways shall not obstruct signal sighting or signal equipment.

- Services shall not be mounted onto walkways.

16.4.4 Evacuation stairs

Where elevated walkways are not provided, stairs and landings for detrainment shall be provided within the tunnels. They shall be fitted on brackets to the tunnel walls.

Stairs and landings shall be designed to achieve a minimum detrainment rate of 40 persons per minute. The minimum width of stairs and landings shall be 1000 mm between handrails.

Materials for the stairs and landings shall be non-combustible.

16.4.5 Safe places

Safe places in tunnels shall be in accordance with TS 02403, or equivalent requirements to be approved by the RIM.

Safe places shall take into account other obstructions, including extended retaining wall structures at tunnel portals.

Refuges may be provided in tunnels for infrastructure staff and other authorised staff to stand during the passage of a train.

Where refuges are not provided, tunnels shall have ‘NO SAFE PLACE’ signs in accordance with TS 02403. The sign shall be attached to tunnel portals and at locations along the tunnel where access is available to the tunnel.

If access is only available from the ends of the tunnel, signs shall not be required along the tunnel.

16.4.6 Refuges and handhold devices

Where refuges and handhold devices are required, they shall be in accordance with TS 02403.

16.5 Track

16.5.1 Geometry and gradients

Track geometry and vertical grades shall be as specified in TS 03499, or through an equivalent requirement approved by the RIM.

Where provision is to be made for underground platforms, the track vertical grade through the length of the platform shall be constant and not exceed 0.7%.

The maximum length of continuous track within 30% of the maximum grade shall be assessed taking into account the capability of the rolling stock. Additionally, the continuous track shall be subject to the approval of the RIM or TfNSW.

16.5.2 Trackform

Ballastless trackform or ballasted trackform shall be utilised for new rail tunnels.

For ballasted trackform, refer to TS 03609 for the design of the ballast within tunnels.

Ballastless trackform types may include:

- direct fixation track
- single slab
- base slab with top (infill) slab
- embedded polymer or reinforced concrete monoblocks and embedded full reinforced concrete sleepers
- floating slab
- type approved proprietary slab system.

Ballastless track shall be in accordance with TS 02402 for all proposed tunnel works.

Track fastenings shall be approved fastenings for track slabs in accordance with TS 03612.

Track slabs shall be in accordance with TS 02402.

Transitions shall be provided between different types of track forms. Additionally, transitions shall be in accordance with TS 02402.

16.5.3 Guard rails

The design of guard rails within tunnels, if deemed required, shall be in accordance with TS 02401.

16.5.4 Direct fixation

Where direct rail fixation is provided, requirements shall be in accordance with TS 02402.

16.5.5 Ground-borne noise and vibration

Methodologies for assessment and mitigation of ground-borne noise and vibration shall be consistent with those described in ISO 14837-1 which provides general guidance on prediction and design methods.

Ground-borne noise and vibration is likely to have a significant bearing on the tunnel alignment or track design (or both). Operation and maintenance factors that can influence ground-borne noise and vibration from tunnels shall be taken into account, including:

- track design features such as curves and crossovers, as these increase levels of ground-borne vibration generated at source

- ongoing maintenance of rolling stock, particularly wheels
- ongoing maintenance of track, particularly the rail running surface.

Source vibration levels are dependent on the dynamic interaction of the train with the track support system. It is possible to vary the vibration spectrum generated at source by varying the track support stiffness. Reduction in the track support stiffness results in a reduction in source vibration and a reduction in ground-borne noise and vibration in surrounding buildings. However, the effect of varying track support stiffness has a frequency-dependent ('tuning') effect. While there may be vibration reductions at most frequencies, a reduction in track support stiffness actually results in an increase in vibration at certain low frequencies. Therefore 'tuning' of the track support system results in redistribution of vibration energy from one part of the frequency spectrum to another.

The selection and design of such track support systems for ground-borne noise and vibration control shall take into account maintenance and performance aspects including as a minimum:

- modes of vibration of floating slab elements which can lead to a significant increase in low frequency radiated noise
- transitions between track sections with differing support stiffness characteristics
- wheel and rail interface issues, such as corrugation development
- access, inspection and maintenance of resilient components.

16.5.6 Points

Requirements with reference to location of points and tunnel environments are specified in TS 05333 (series).

Catch points should not be placed near tunnel mouths to avoid derailment hazards.

Points shall not be located in tunnels, steep cuttings, or on or under bridges unless a safe place is available next to the points.

Concrete slab tracks may need cut-outs or recesses to enable installation of point machine rodding and locking systems.

16.6 Combined service routes

Combined services routes shall be constructed in accordance with the requirements set out in TS 05164 with respect to specific requirements regarding tunnel environments.

16.7 Emergency response planning

16.7.1 Tunnel emergency planning

New tunnels shall either be part of an existing emergency response plan or have their own plan.

The following legislation contains requirements that apply to emergency response planning:

- State Emergency and Rescue Management Act 1989
- Rail Safety National Law (NSW) 2012
- *Work Health and Safety Act 2011* (NSW) and *Work Health and Safety Regulation 2025* (NSW).

The emergency response plan applicable to rail tunnel construction, operation and maintenance shall:

- provide a coordinated response by all organisations participating in the operation of the tunnel and the agency responsible for controlling the response to any emergency in the tunnel, in the shortest possible time to minimise loss of life and property
- restore the tunnel to normal operations in an orderly manner in the shortest possible time.

The emergency response plan shall detail the arrangements for control and coordination of the response to, and recovery from, an emergency in the tunnel. The arrangements in the emergency response plan shall be designed to manage an emergency in the tunnel that requires a significant and coordinated response to the closure of tunnels, stations or the suspension of services.

The emergency response plan is a coordinated response to emergencies by all agencies having responsibilities and functions in emergencies. Designers shall integrate the relevant emergency response plan into their tunnel fire safety designs.

16.7.2 Integration with NSW emergency management arrangements

Tunnel emergency plans shall include a mechanism for regular engagement with the NSW emergency management arrangements and stakeholders.

Engagement should commence at development stage and continue throughout delivery and operation stages.

Engagement should include connection into the local and regional emergency management committees in the emergency management regions in which the tunnel will operate.

Where practicable, exercising of the tunnel's emergency plan should include all agencies and other organisations that may have a role to play in the event of an actual emergency.

16.8 Other rail tunnel requirements

In addition to Section 16, other rail specific requirements are provided in the following sections:

- fire life safety, see Section 19
- tunnel ventilation and mechanical, see Section 20

- electrical, see Section 21
- control and telecommunications systems, see Section 22
- rail tunnel signalling, see Section 23.

17 Specific requirements for road tunnels

17.1 Introduction

Section 17 contains road specific requirements that shall apply to all road tunnels in addition to the general civil, electrical, intelligent transport systems, mechanical and fire life safety requirements listed in this document.

17.2 Design criteria

17.2.1 General

Key road design measures for delivering efficient and safe tunnels shall:

- take into account driver behaviour especially in long tunnels or tunnels with long straight stretches
- minimise horizontal curves or curves with adverse cross fall where possible with as large a curve as practicable
- allow for the effect of vertical grades on traffic flow within the tunnel and at the entry and exit portals.

17.2.2 Design vehicles

Road tunnels in NSW shall be designed and constructed for one of the following design vehicles, as specified by the National Heavy Vehicle Regulator in *Common Heavy Freight Vehicle Configurations*:

- A-double (maximum length of 36.5 m)
- B-triple (maximum length of 35.4 m).

17.2.3 Cross-sections and clearances

Figure 1 and Figure 2 show the typical cross-sections and clearances for the tunnel respectively.

The terms and definitions are as follows:

- A: Upper pavement limit: Pavement limit comprising the actual constructed pavement and the pavement maintenance tolerance.

- B: Pavement maintenance tolerance: The allowance for possible future resurfacing of the pavement.
- C: Actual constructed pavement depth.
- D: Services kinematic tolerance: The allowance for increases in the kinematic envelope to cope with bumping movements.
- E: Equipment installation tolerance: The allowance for inaccuracy between the design location and installed position of equipment.
- F: Maximum allowable vehicle height: Height limitation of vehicles passing through the tunnel, to prevent structural damage. This height limit (see Figure 2) may vary depending on the project site.
- G: Maintained headroom: Vertical distance from the upper pavement limit to the equipment installation tolerance.
- H: Services envelope: The vertical distance from the maximum allowable vehicle height to the lowest point of any overhead obstruction (such as mechanical and electrical equipment, signage, lighting), which comprises the services kinematic tolerance and the equipment installation tolerance.
- Working width: The sum of the dynamic deflection of a barrier system and the vehicle roll allowance. This is the minimum width provided to prevent any part of a design vehicle from impacting an object or hazard behind the safety barrier system. In NSW, the working width is taken from the vehicle roll line at a fixed height above the pavement surface, as this is the assumed height for an impacting vehicle (shown on Figure 2).

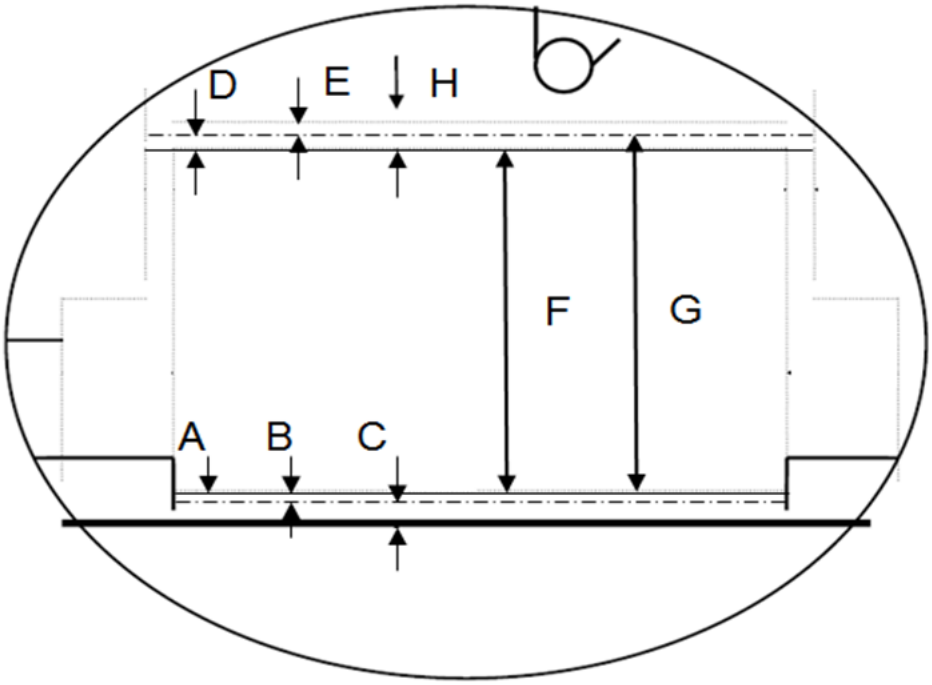

Figure 1 – Typical tunnel cross section definition of terms

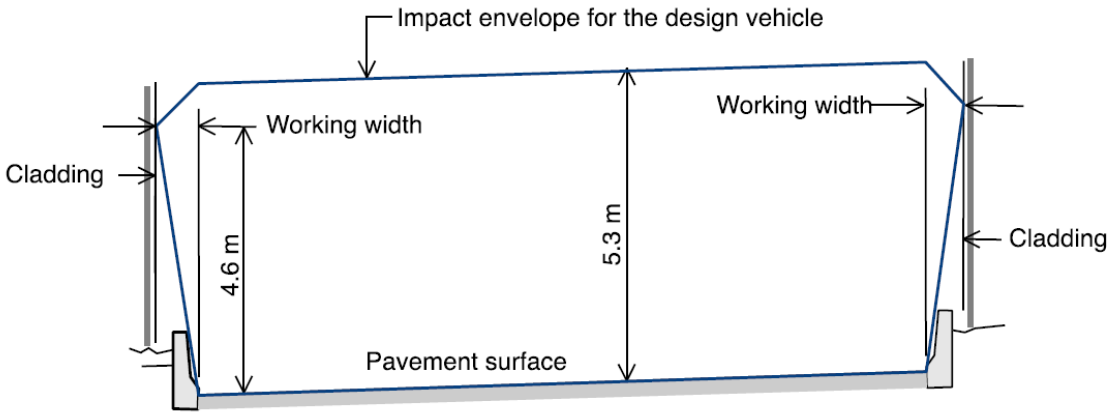

Figure 2 – Typical road tunnel vehicle envelope

17.2.4 Road geometry

17.2.4.1 General

Road design in tunnels shall comply with the following documents (in order of precedence):

- Austroads Guide to Road Tunnels – Part 1: Introduction to Road Tunnels and Guide to Road Tunnels – Part 2: Planning, Design and Commissioning
- Austroads *Guide to Road Design (all parts)* as well as TS 02642.

17.2.4.2 Cross-section

The design of cross-sectional elements in tunnels shall be in accordance with Austroads *Guide to Road Tunnels – Part 2: Planning, Design and Commissioning* and Austroads *Guide to Road Design – Part 3: Geometric Design*. Tunnels are constrained environments where further restrictions on geometric elements may be applicable. Human factors specific to tunnel environments shall be prioritised in the design.

The minimum height of the road tunnel vehicle envelope shall be 5.3 metres from the top of the road surface.

17.2.4.3 Traffic lane and shoulder widths

A standard traffic lane minimum width of 3.5 m shall be adopted.

The minimum shoulder width is 1.0 m. traffic lane and shoulder widths shall be increased to ensure sight lines and driver safety as required by the Austroads *Guide to Road Design – Part 3: Geometric Design* for the vehicle design speeds and horizontal radii.

Minimum lane and shoulder widths shall be:

- measured to the centre of the lane and edge lines
- increased to include allowances for curve and lane widening and sight widening
- for shoulder widths, of sufficient width to allow for drainage and electrical pits, to minimise the impact of traffic on pit durability.

17.2.4.4 Safety barriers

The design of all safety barrier systems shall be in accordance with Austroads *Guide to Road Design – Part 6: Roadside Design, Safety and Barriers* and the relevant section of TfNSW supplement TS 02642.

Rigid concrete safety barriers shall be adopted. Precast barriers shall not be used.

The following factors shall be allowed for in the tunnel safety barrier design:

- any construction joint to have a waterproof seal at the back of the barrier.
- the reduction in sight distances on horizontal curves due to the placement and arrangement of safety barriers
- modified barrier arrangements at cross passages and longitudinal egress passages to allow for movement in an emergency incident. The arrangement of safety barriers at openings to room doorways and emergency egress passages shall ensure that the leading side traffic barrier shields the trailing side traffic barrier end to prevent head on collision by errant vehicles (spearing). The front face of the trailing side traffic barrier end shall be:

- set back minimum 300 mm laterally behind the front face of the leading side traffic barrier
- angled in the plan view, with a maximum deviation of 15 degrees from the line of barriers

Note: ‘The terms ‘leading’ and ‘trailing’ indicate the direction of travel.

17.2.4.5 Working width

The working width of a barrier system is defined in Section 17.2.3 and shown in context to the vehicle impact envelope in Figure 2. All critical tunnel infrastructure and hazards shall be placed behind the working width to avoid impacting vehicles.

The adopted working width is based on the legal maximum vehicle height of the road network on which the tunnel is located, and in consideration of outcomes from the TfNSW concept of operations process. The allowable height limit is generally 4.3 m or 4.6 m with a permit. The height limits shall be approved by TfNSW prior to undertaking the design.

Designers shall adopt the safety barrier design containment level (MASH TL3 or TL4) in accordance with TS 00028 and Austroads *Guide to Road Design – Part 6: Roadside Design, Safety and Barriers*, alongside a project specific risk assessment taking into account the proportion of heavy vehicles anticipated in the road tunnel. The working width of the adopted barrier can be found in the relevant TfNSW safety barrier system acceptance conditions.

17.2.4.6 Horizontal alignment

The design of horizontal alignment in tunnels shall be in accordance with the requirements of Austroads *Guide to Road Tunnels – Part 2: Planning, Design and Commissioning* and Austroads *Guide to Road Design – Part 3: Geometric Design*.

Designers should avoid incorporating merges, diverges and tight curves in close proximity to tunnel portals to minimise driver decision-making and stress.

17.2.4.7 Vertical alignment

The design of vertical alignment in tunnels shall be in accordance with the requirements of Austroads *Guide to Road Tunnels – Part 2: Planning, Design and Commissioning* and Austroads *Guide to Road Design – Part 3: Geometric Design*.

Designers shall where practicable achieve the following vertical grades along the alignment:

- main carriageway: 4%
- ramps:
  - 6% upgrade
  - 8% downgrade.

The vertical grade shall generally be minimised within the tunnel to limit the speed differential between cars and heavy vehicles and maintain a consistent traffic flow. Where congestion risks are likely due to steep grades, overtaking lanes can be provided.

Flatter grades support efficient ventilation and less vehicle emissions and shall be provided where possible.

17.2.4.8 Sight distance

The sight distance in tunnels shall adhere to the principles described in Austroads *Guide to Road Tunnels – Part 2: Planning, Design and Commissioning* and Austroads *Guide to Road Design – Part 3: Geometric Design*.

17.2.4.9 Crossfall

Crossfall in tunnels shall be in accordance with the requirements of Austroads *Guide to Road Tunnels – Part 2: Planning, Design and Commissioning* and Austroads *Guide to Road Design – Part 3: Geometric Design*.

The standard crossfall of 2% shall generally be adopted within tunnels where practicable.

17.2.5 Signage

Tunnel signage shall be provided to ensure adequate management of traffic and alerts, to ensure safety and to convey information to drivers to allow wayfinding and decision-making.

Signs in the tunnel include the following types:

- static backlit signs
- variable message signs
- dynamic speed and lane allocation signs (see requirements on lane use management in Section 22.6.3.2)
- signs that are specified for in-tunnel use only through the TfNSW *Traffic Signs Register* – these include alternative arrangements for standard guide, warning and regulatory signs.

All signs shall be designed and positioned such that they are conspicuous and easy to read. An exclusion zone for mechanical and electrical equipment is required prior to tunnel signs to ensure clear driver sightlines to the sign legend. Tunnel niches may be required where the exclusion zone cannot be maintained.

17.2.6 Pavement and linemarking

The design of pavement in tunnels shall be in accordance with the requirements of Austroads *Guide to Road Tunnels – Part 2: Planning, Design and Commissioning*.

The pavement design for tunnels is dependent on the type of groundwater control system:

- for drained tunnels, rock floor with CRCP base layer
- for undrained tunnels, backfill with sub-base with CRCP base layer.

For undrained tunnels, granular sub-base material should be used on surface pavements in preference to lean mix.

The design of the CRCP base thickness shall take into account the following:

- thickness of concrete base – an increased thickness allows for future grinding that in turn helps extend the design life
- the enclosed nature of a tunnel environment that minimises exposure to the environmental stresses that cause deterioration on surface roads. Consequently, the magnitude of warping and curling is significantly reduced.

Asphalt as a wearing course in tunnels should not be used due to its flammable nature and the constructability issues associated with bitumen. Furthermore, asphalt surfaces are prone to having voids filled with debris in a tunnel environment and thus may not appropriately satisfy the texture requirements for a pavement wearing surface, which contribute to the safety and driveability of the road tunnel.

Pavement line marking shall comply with AS 1742.2.

17.2.7 Emergency and maintenance provisions

Provisions for emergency and maintenance services within the tunnel shall be subject to the operational concept definition process specified in TS 01472 and approved by TfNSW in the development stage on a project specific basis.

17.3 Road tunnel over height vehicle protection

Over height vehicle management system requirements are based on TS 06320 and shall comply with TS 06225.03.

The over height vehicle protection system shall be designed to accommodate the maximum allowable vehicle height and take into account the maintained headroom (see definitions provided in Section 17.2.3). This shall be coordinated with the signposting strategy for the project.

The over height vehicle protection strategy incorporates intelligent transport system infrastructure (see Section 22.6) as well as static signage to detect over height vehicles and direct them to alternative routes prior to the tunnel portal.

The tunnel over height protection system shall include the following provisions to protect the tunnel portal structures and in tunnel services from damage resulting from over height vehicles:

- advanced fixed warning signs indicating maximum clearance
- sufficient early warning to the drivers of vehicles higher than the maximum clearance that they are not permitted to enter the tunnels
- adequate signage advising of the alternative route definition onto an appropriate part of the local road network
- automatic over height vehicle detection by the primary and secondary over height vehicle detector system at maximum clearance and communication in accordance with TfNSW standard requirements
- appropriate signage at entry portals in accordance with AS 1742.2.

The over height detection system shall be integrated into the tunnel approaches in accordance with TfNSW warning signage requirements, ensuring adequate space for detection, warning and driver decision-making.

If other protection strategies are deemed insufficient to manage the risk, tunnel damage prevention devices such as portal beam structures shall be provided to protect the tunnel from damage caused by an over height vehicle entering the tunnel. Portal beams shall be designed in accordance with TS 01714.

Where required, the tunnel damage prevention devices shall provide a physical barrier capable of withstanding a force of 1000 kN and provide the maximum clearance (plus 50 mm / −0 mm) above the road surface. The tunnel damage prevention device shall be independent of the tunnel portal structure. These devices shall be able to be removed and replaced without damage to the permanent tunnel structure.

17.4 Road tunnel future proofing

To appropriately future proof road tunnel infrastructure, at the development stage, space proofing of the tunnel for the provision of future additional lanes and shoulder widths when determined by the traffic modelling and analysis using the ultimate traffic volumes at a specified project target date for the design life of the tunnel shall be taken into account. Ultimate traffic volumes may account for future roads or road tunnel projects (or both) or connected programs.

The following shall be assessed, with the future proofing strategy to be agreed in consultation with TfNSW:

- staging requirements, including line marking and barriers during the interim operational state
- additional environmental footprint and construction cost associated with a larger tunnel cross-section

- level of uncertainty regarding potential significant changes in vehicle fleet types (for example, autonomous vehicles) and the impact on road design parameters, including reduced vehicle gaps and reaction times.

17.5 Other road tunnel requirements

In addition to Section 17, other road specific requirements are provided in the following sections:

- fire life safety, see Section 19
- tunnel ventilation and mechanical, see Section 20
- electrical, see Section 21
- control and telecommunications systems, see Section 22.

18 Specific requirements for active transport tunnels

18.1 Civil requirements

Active Transport tunnel (also called shared or multi-user tunnel) shall be safe and practical, with the design supporting a comfortable and convenient user experience.

Design of active transport tunnels shall be undertaken in conjunction with an experienced pedestrian modeller to provide the required width and height clearance requirements for the given tunnel to meet the minimum level of service requirements.

For underpasses, the principles discussed in Austroads *Guide to Road Design – Part 6A: Paths for Walking and Cycling* shall be incorporated into design.

Designers shall prioritise human factors in the design of active transport tunnels, including maintaining user interest and engagement with their environment as well as taking into account potential claustrophobic tendencies in confined spaces.

The following operating spatial requirements for active transport tunnels and the access points shall apply:

- The design of active transport tunnels shall provide dry, light and comfortable tunnel conditions in accordance with human factors considerations that allow and encourage usage. The spatial arrangement shall satisfy a minimum level of service ‘C’ for the maximum pedestrian and cyclist volumes derived from the patronage assessment model applicable for the design life of the tunnel. For information on level of service, refer to Austroads *Level of Service Metrics (for Network Operations Planning).*

- The design of active transport tunnels shall be in accordance with the following reference documents:
    - relevant parts of AS 1428 (series)
    - TS 00169 *Pedestrian underpass design guideline – Design guideline to improve the safety and appearance of underpasses in NSW*
    - Austroads *Guide to Road Design – Part 6A: Paths for Walking and Cycling*
    - Austroads research report AP-R639-20 *Updating Austroads Pedestrian Planning and Design Guidance in line with International Best Practice.*

The design of active transport tunnels shall allow for mobility impaired persons, provision for wheelchair turning envelope and clearances between walls and other objects.

Other factors shall include:

- tunnel alignment be straight and orientated so that the line of sight is clear
- tunnel portals should open into well lit and open spaces.

18.2 Other requirements

Where relevant, other pedestrian and cycleway tunnel requirements are provided in the following sections of this document:

- fire life safety, see Section 19
- tunnel ventilation and mechanical, see Section 20
- electrical, see Section 21
- control and telecommunications systems, see Section 22.

19 Fire life safety

The fire life safety requirements for tunnels, including equipment and service rooms that are ancillary to the tunnels, shall be in accordance with TS 00008.3.

19.1 Fire engineering

19.1.1 Fire life safety objectives

Tunnels shall be designed, built, operated and maintained to:

- provide acceptable levels of fire safety for all tunnel users
- allow for the safety of people outside the tunnel or at connecting infrastructure and buildings

- minimise the impact of fire on the infrastructure, buildings or assets, and on the continuity of operations of the network the tunnel is part of.

Further fire life safety requirements are found in TS 00008 (all parts).

19.1.2 General design requirements

General design requirements for fire life safety systems shall be in accordance with TS 00008 (all parts). These standards set the fire life safety objectives and principles and their application on transport tunnel assets.

19.1.3 Modifications

For modifications or changes to tunnel construction, changes in how the tunnel is used (for example, frequency or type of vehicle, or both), modifications or changes to fire protection systems or equipment due to repair, refurbishments, upgrade or other means, shall be assessed in accordance with TS 00008 (all parts).

Where practicable, changes to tunnels shall improve fire life safety. All modifications or upgrades shall form part of a total, integrated fire engineering design.

19.1.4 Consultation and assurance

The requirement of TS 00008.1 to “communicate with the relevant stakeholders and agree to the asset fire life safety strategy and associated residual risks” shall be followed for all tunnels.

The emergency services, particularly FRNSW, shall be consulted through the concept design and design development process to assess and accommodate relevant operational procedures, specific detailed requirements and recent lessons learned from current TfNSW tunnel projects.

The proponent shall consult all key safety stakeholders, which include all relevant bodies, authorities and other stakeholders who have any input to safety, including TfNSW and the independent certifier, the Office of Transport Safety Investigations and emergency services, at each of the required stages of submission. The review comments, inputs and requirements of the key stakeholders shall be responded to and adequately addressed.

Proponents shall provide TfNSW with evidence of compliance with both general and specific performance requirements throughout the design, construction, commissioning and operation of tunnels. This shall include certification, validation and verification records, requirements and verification traceability matrices, evidence of consultation and that all key stakeholder requirements, inputs and review comments have been adequately addressed. These compliance and assurance records shall be provided to TfNSW with sufficient time allowance for final consideration, review and response by TfNSW.

19.1.5 Fire engineering process

The asset fire life safety strategy process and fire engineering process outlined in TS 00008.1 and TS 00008.3 shall be followed when developing, establishing, documenting and agreeing on the fire safety design for new tunnels or extensions to existing tunnels.

Fire life safety engineering documentation shall be in accordance with TS 00008.1 (all parts).

In the development stages of a tunnel project, the fire safety engineer shall ensure that the design of the tunnel complies with all the relevant requirements of this document.

The development of feasibility and concept design shall follow TS 00008 (all parts).

Development of the delivery stage design shall be in accordance with TS 00008 (all parts).

At appropriate stages of the construction process, various levels of testing and commissioning of the fire safety systems shall be undertaken in accordance with the requirements of design documentation. Testing of equipment shall be undertaken by the contractor in the presence of any relevant subcontractor and equipment supplier.

TfNSW and other stakeholders shall be invited to comment on, attend or witness tests, including hot smoke tests, fire main tests, and fire phone and alarm tests.

Appropriate policies, procedures and training regimes shall be developed and documented by the fire safety engineer in association with TfNSW to ensure that satisfactory ongoing fire safety management of the tunnels occurs within the broader TfNSW safety management system.

Maintenance plans shall be developed for fire safety equipment, documented in maintenance manuals and submitted to TfNSW on completion of commissioning.

19.2 Fire resistance

19.2.1 General

The identification and performance of the elements requiring fire resistance shall be in accordance with TS 00008.3.

19.2.2 Asset protection

A risk assessment shall be undertaken to determine the fire resistance requirements for the tunnel and rooms critical for the operation of the tunnel. As a minimum, the risk assessment shall take in account the value of the asset, criticality of tunnel operation and likely disruption due to fire. The level of protection required shall be approved by TfNSW.

For the fire resistance requirements of permanent tunnel structures and structural linings, see Section 13.8.

19.2.3 Life safety protection

For life safety protection during evacuation or firefighting, the fire separation between incident and non-incident areas shall be determined by the fire safety strategy, including egress and emergency service provisions, and be in accordance with TS 00008.1 and TS 00008.3.

19.3 Fire hydrant systems

Where a fire hydrant system is required to be installed, the fire mains and hydrants shall be a charged wet system and designed and installed in accordance with the requirements of TS 00008.3.

19.4 Detection

A fire detection system shall be installed providing full coverage to the main tunnels in accordance with the minimum requirements of TS 00008.3.

19.5 Rail tunnel fire life safety

Fire engineering shall be in accordance with TS 00008.1 and TS 00008.3.

At the development stage of a project, a decision whether single or twin track tunnels shall be provided and take into account all of the relevant fire life safety factors such as length of tunnel, type of rolling stock, walkways, egress provisions, access for emergency services, emergency and evacuation preparedness plans and other issues.

Tunnel designers shall take into account design fires in accordance with TS 00008.3. The design fire as a minimum shall consider peak HRR, rolling stock, interfaces with stations and operational characteristics of the railway system.

19.6 Road tunnel fire life safety

19.6.1 Emegency egress strategy

Implementation of the emergency egress strategy, including provision of emergency egress cross passages and their spacing along the tunnel alignment, shall be in accordance with TS 00008.3.

19.6.2 Suppression

Road tunnels shall have a suppression system to protect people and assets in accordance with TS 00008.3.

19.6.3 Fire suppression water supply

The deluge, hydrant and foam systems shall be provided with a reliable water supply in the form of water storage tanks provided as part of the tunnel project works in accordance with TS 00008.3.

19.6.4 Detection

Detection systems notify the operator and FRNSW of a fire emergency within the tunnel as well as other ancillary sites.

For more information and minimum requirements for the detection system, refer to relevant parts of TS 00008.3.

19.6.5 Fire detection and occupant warning system

Fire detection and occupant warning systems provide a communication option for the operator to the tunnel user during emergencies.

Refer to relevant parts of TS 00008.3 for more information and minimum requirements for emergency warning and communications systems.

19.6.6 Fire brigade emergency equipment points

FEEPs are locations within the tunnel that contain the necessary equipment FRNSW requires during an emergency, and shall be in accordance with TS 00008.3.

19.6.7 Motorist emergency equipment points

MEEPs provide a means for road tunnel users to communicate to tunnel control and access emergency equipment.

A MEEP shall be installed in the opposite tunnel wall directly across the main tunnel from each FEEP.

In addition, a MEEP shall be provided in the tunnel wall panel immediately beside each FEEP in main tunnels. MEEPs shall be identified to motorists by having suitable illuminated signage above.

Each MEEP shall include the following:

- motorist emergency telephone facilities that are suitable for use in the tunnel environment, refer to the requirements of relevant parts of TS 06225 (series)
- one 4.5 kg dry chemical type fire extinguisher complying with AS 2444.

19.6.8 Emergency equipment cabinets

Each FEEP and MEEP shall be positioned in an EEC.

All electric and electronic equipment within enclosures shall be rated IP65 to withstand the conditions in the tunnels during cleaning operations.

Where installed in wall panels, EECs shall be mounted flush with the tunnel wall panels.

The EECs shall be mounted to enable the EEC opening mechanism and all equipment to be accessible.

Cabinet doors shall be designed to not extend into the traffic envelope or endanger users or motorists in any way.

Cabinet doors shall be capable of being safely and securely latched open.

Each EEC shall be provided with a unique identification number clearly visible to the user.

Each EEC shall be clearly labelled with the contents of each cabinet.

All EEC cabinet doors, when opened, shall send a signal to the tunnel operations control centre such that the location of the FEEP or MEEP in use can be clearly identified by the tunnel operations control centre operators. The requirements for monitoring and alerting of cabinet doors are further detailed in the project documents.

EECs shall normally be held closed but not locked.

A risk assessment may be conducted to determine the minimum alternative requirements for MEEPs and to form part of the tunnel breakdown strategy.

19.6.9 Maintenance and breakdown bay emergency equipment

The following emergency equipment shall be provided at each maintenance bay and emergency breakdown bay:

- motorist emergency telephone facilities that are suitable for use in the tunnel environment and comply with the requirements of the project documents
- one 4.5 kg dry chemical type fire extinguisher complying with AS 2444
- one fire hose reel of 60 m in length.

The EECs shall be located so that the fire hose reel achieves full coverage of the maintenance or breakdown bay.

Breakdown and maintenance bays shall be equipped with vehicle detection systems that alert operators whenever vehicles enter the breakdown or maintenance bays. Operator CCTV displays shall automatically switch to the CCTV camera monitoring the bay (including any applicable camera pre-set control) whenever vehicles enter or leave the bay.

20 Tunnel ventilation

20.1 General

Tunnels shall continuously, reliably and efficiently provide a safe environment for tunnel users and external communities during all operational scenarios including normal operation and emergency operation.

Tunnels shall be ventilated to suit the specific needs of the asset under all operational scenarios.

Tunnels can be ventilated by natural or mechanical systems.

Ventilation systems and cooling systems shall be provided to suit the operational requirements of all ancillary spaces.

Refer to the relevant parts of TS 04955 (series) for more information and minimum requirements for technical spaces.

20.2 Rail tunnel ventilation

20.2.1 Tunnel ventilation

Refer to the relevant parts of TS 04955 (series) for more information and minimum requirements on the tunnel ventilation system.

20.2.2 Mechanical emergency ventilation system

If a mechanical emergency ventilation system is required, it shall be designed in accordance with the relevant parts of TS 04955 (series).

20.3 Road tunnel ventilation

The tunnel ventilation and mechanical equipment support the safe and efficient use of the tunnel during all operations.

Where tunnel ventilation systems are required for regular or continuous operation, the ventilation system configuration, equipment, and control sequences shall be aerodynamically and energy efficient.

Ventilation design and minimum requirements on the tunnel ventilation system shall be in accordance with relevant parts of TS 04955 (series).

20.3.1 Tunnel ventilation – normal operation

Normal operation is when the tunnel operates to maintain in-tunnel air quality (including temperature) under moving vehicle conditions to satisfy the requirements of Section 20 and the design.

During normal operations in the tunnel the ventilation system shall meet the ventilation requirements in accordance with the relevant parts of TS 04955 (series).

20.3.2 Tunnel ventilation – emergency operation

Emergency operation occurs when there is a fire in a tunnel.

In the event of a fire in the tunnel, the ventilation system shall satisfy the requirements of Section 19 and Section 20 as well as meet the fire life safety requirements specified in the project fire engineering brief.

Refer to the relevant parts of TS 04955 (series) for requirements for the ventilation system during emergency operations in the tunnel.

20.3.3 Axial fans

For road tunnels, axial fans shall be in accordance with the requirements of TS 02174.2.

20.3.4 Jet fans

For road tunnels, jet fans shall be in accordance with TS 02175.2.

20.3.5 Sensors

Sensors shall be provided to support the safe operations of the tunnel ventilation system and include, but are not limited to, sensors required for air quality, velocity, pressure, vibration, and temperature.

All sensors shall be in accordance with TS 04955.1. Road tunnels shall also be in accordance with TS 02176.2

20.3.6 Egress and access pressurisation

Egress and access pressurisation shall be provided to isolate compartments from smoke and to provide a clear path for evacuation and access to the fire site.

Pressurisation systems shall be in accordance with the minimum requirements of the relevant parts of TS 04955 (series).

21 Electrical

21.1 Electrical power system

21.1.1 General

The electrical system provides power to a range of mechanical and control equipment installed within tunnels to maintain the required level of safety for users, operational and maintenance personnel and emergency services personnel.

The equipment typically comprises high voltage and low voltage switchgear, transformers, distribution boards and uninterruptible power supply (UPS) systems. Substation and electrical switch room spacing is generally driven by electrical load distribution.

Electrical equipment installed within the tunnel shall be suitable to withstand the tunnel environment.

21.1.2 Rail tunnels

Electrical power supply for railway tunnels shall be both secure and designed to minimise the risk of fire ignition and to minimise combustible fire load.

Power supplies into rail stations shall have three sources of supply with sufficient independence and capacity that the loss of any two will still satisfy the rated load. Sectioning of high voltage feeders supplying station and tunnel services shall be remotely operable.

Low voltage distribution within rail stations and rail tunnels, including high voltage to low voltage transformers, shall be designed using N-1 redundancy design principles based on a firm continuous rating under the first level failure condition. Normal feeding conditions shall provide supply from at least two physically separated sources. As far as practicable low voltage loads should be evenly distributed between the two normal sources of supply.

High voltage electrical power, earthing and bonding for rail shall be in accordance with the relevant Transport standards.

Low voltage electrical power for rail shall be in accordance with TS 03954.

21.1.3 Road tunnels

High voltage and low voltage electrical power for road tunnels shall be in accordance with TS 06225.05.

21.2 Cable and cable containment

Cable and cable containment shall be low smoke, low toxicity, halogen free suitable for installation in a tunnel environment. Additionally, cable and cable containment shall be consistent with fire life safety requirements.

Cable containment systems shall provide a high degree of reliability to the power reticulation system and minimise the likelihood of adverse fire and mechanical damage. Cables shall be accessible for maintenance. In rail environments, where steel cable trays are used, they shall be installed in insulated sections to reduce the effects of electrolysis and stray currents.

High voltage and low voltage cable and cable containment associated with road tunnels shall be in accordance with TS 06225.05.

The segregation of wiring systems within rail tunnels shall give a high degree of reliability and security to the power reticulation system and minimise the likelihood of adverse interference by fire and mechanical damage. The following provisions shall apply:

- High voltage cables from one interlinking station shall be segregated from the other interlinking station. The high voltage feeders shall not be run in the same enclosure.
- High voltage cables shall be housed in conduits and draw pits or cable ducts concealed in the ground.
- High voltage and low voltage cables shall be segregated in accordance with TS 03750 and TS 03954 respectively.
- Cables for signalling, communications and other systems shall be segregated from each other in accordance with AS/CA S009 and AS/NZS 3000.
- High voltage or low voltage power circuits shall be segregated from circuits of fire smoke control equipment, lighting, emergency lighting and telephone systems.
- Where practicable, cables shall be kept at a low level to reduce the chance of being exposed to heat from a fire.

Low voltage cable and cable containment associated with rail shall be in accordance with TS 03954.

High voltage cable and cable containment associated with rail shall be in accordance with the relevant Transport standards.

21.3 Rail tunnel traction power and overhead wiring

21.3.1 Traction electrical supply

Power supplies into traction substations shall be designed using an N-1 design principle based on a firm continuous rating under the first level failure condition. Power supplies shall include AC feeders, rectifiers and transformers but do not include equipment downstream of the rectifiers. This design is in effect better than N-1, for the case of loss of DC supply from an adjacent substation, due to the overhead wiring connectivity between substations on the DC side. Under this circumstance it provides a reduced rating sufficient to move trains to a safe point of evacuation for passengers and crew.

Traction electrical supply systems shall be designed as specified in TS 03789 for light rail, or TS 03873 for heavy rail, or via an equivalent requirement approved by the RIM.

21.3.2 Overhead wiring

Overhead wiring systems, including other examples of traction supply, shall be designed as set out in TS 03802 and other relevant Transport standards, or via an equivalent requirement approved by the RIM.

Sectioning of the overhead wiring shall be designed to be consistent with the fire safety strategy. Additionally, the overhead wiring shall include the optimum placement of overlaps to the satisfaction of TfNSW.

The sectioning of overhead wiring shall be coordinated with:

- signal section boundaries
- ventilation section boundaries
- fire safety strategy
- other fire life safety systems.

There shall be at least one overhead wiring isolatable subsection for each ventilation section. However, more than one isolatable subsection may be required depending on the fire safety strategy adopted. Each overhead wiring subsection at the boundaries of the ventilation sections shall be capable of remote operation so that power can be removed from the minimum number of trains in the event of a fire or power fault.

Each electrical section shall include remotely operated rail and earth connection equipment at each end. Remote closure of rail connection switches shall only be permitted under emergency conditions involving threat to life. Rail connection switches may only be opened after having satisfied normal procedures used for the cancellation of access permits.

The specific requirements for the tunnel structure and surrounding environment shall be consistent with the requirements for the 25 kV ac traction system as specified in TS 00103 (all parts).

21.4 Rail tunnel lighting

21.4.1 Tunnel lighting

Lighting shall be provided to enable users to identify potential hazards and facilitate safe operation and infrastructure maintenance work.

Lighting design shall be in accordance with TS 04935 and the relevant parts of TS 04955 (series).

Lighting design shall be in accordance with TS 04935 and relevant parts of TS 04955 (series).

21.4.2 Emergency tunnel lighting

Tunnel emergency lighting shall be provided to enable safe egress from the tunnel, including but not limited to exit signage (directional or static), emergency lighting and strobe lights. This shall be achievable under mains failure conditions.

Lighting design shall be in accordance with AS/NZS 2293 (all parts), TS 04936 and the relevant parts of TS 04955 (series).

21.5 Road tunnel lighting

21.5.1 Tunnel lighting

Lighting shall be provided in tunnels to enable users to identify potential hazards and facilitate safe operation and infrastructure maintenance work.

Lighting design shall be in accordance with AS/NZS 1158 (all parts), TS 06225.09 and the relevant parts of TS 04955 (series).

21.5.2 Emergency tunnel lighting

Tunnel emergency lighting shall be provided to enable safe egress from the tunnel, including but not limited to exit signage (directional or static), emergency lighting and strobe lights. This shall be achievable under mains failure conditions.

Lighting design shall be in accordance with AS/NZ 2293 (all parts), TS 06225.09 and the relevant parts of TS 04955 (series).

22 Control and telecommunications systems

22.1 Introduction

A system architecture is required for telecommunications and control systems. The system architecture shall define the rules for data exchange, control, external interfaces, the required level of telecommunications architecture and the required level of interconnection and interoperability.

All low voltage electrical work for the control and telecommunications systems for road and rail shall comply with:

- AS/NZS 3000
- AS/NZS 3015
- AS 61386.1 and AS/NZS 61386 (all parts)
- AS/CA S009

- TS 06218
- TS 06220.

For further rail and road specific requirements, see Section 22.5 and Section 22.6 respectively.

22.2 Telecommunications systems

The following telecommunications systems shall be provided in the tunnel:

- Backbone and access cabling. Trunk cables shall be provided connecting main communications rooms outside the tunnel and to each adjacent station.
- Public Safety Network, formerly known as the NSW Government Radio Network. The Public Safety Network shall also be provided on platform and station concourse levels. This network is owned and managed by the NSW Telco Authority.
- Mobile phone network in all access passages. The mobile network shall be designed by the mobile service provider and comply with the distributed antenna system (DAS) codes and regulations in accordance with *MCF 2018 Design Specification for Distributed Antenna Systems*.

Telecommunications systems shall comply with the NSW Telco Authority *Digital Connectivity Principles*.

Refer to TS 00005 for guidance on the application of TfNSW telecommunications standards.

22.3 Control systems

This section is applicable to all control systems, excluding the Sydney Coordinated Adaptive Traffic System (SCATS) and rail signalling. Any exceptions are noted in the rail and road specific sections (Section 22.5 and Section 22.6 respectively).

There shall be operations management and control systems that monitor and control all mechanical, electrical, traffic, telecommunications and fire life safety systems for major road tunnels. These may be combined into one system.

22.4 Closed circuit television

CCTV in commuter rail and pedestrian tunnels shall be installed in accordance with TS 04989 and TS 00050. For use in tunnels other than rail and pedestrian a security risk assessment process shall be used to determine if CCTV is required.

For road tunnels, where a risk assessment determines that CCTV is required, it shall be provided in accordance with TS 00050.

22.5 Rail tunnel control and telecommunications system

22.5.1 Telecommunications systems

The following telecommunications systems shall be provided in the tunnel:

- emergency telephones shall be installed throughout a tunnel, in accordance with TS 06205. Emergency telephones shall also be installed at the end of station platforms adjacent to the portal of a tunnel, at cross passages and at emergency access portals.
- train radio network – operational radio networks, such as digital train radio systems, shall be installed throughout the tunnel. The designer shall provide designs subject to the approval of TfNSW, to confirm functional performance coverage. Coverage tests shall be conducted to confirm coverage within the tunnel complies with the design.

22.5.2 Control systems

Control systems shall be provided in the tunnel for electrical, mechanical, ventilation, lighting and safety (as specified in other sections of this document). Refer to the following standards for further requirements:

- TS 03863
- TS 03864
- TS 03866
- TS 03867
- TS 03865.

22.6 Road tunnel control and telecommunications systems

22.6.1 Introduction

Section 22.6 contains the requirements for control and telecommunications systems in road tunnels.

The TS 06225 series of motorway systems specifications shall be read as applicable to all tunnels for any road classification types.

22.6.2 Telecommunications systems

The network telecommunications system shall be in accordance with TS 06225.06, and TS 03389 for intelligent transport systems.

The voice communication and radio-retransmission systems shall be in accordance with TS 06225.03.

22.6.3 Control systems

22.6.3.1 General

An operations, management and control system shall support the safe, effective operations and management of the tunnel in accordance with TS 06225.00 and TS 06225.01.

Traffic management control systems shall be in accordance with TS 06225.03.

22.6.3.2 Lane use management

The lane use management shall be in accordance with TS 03647, TS 06339.1, and TS 06225.03.

22.6.4 Electronic toll collection system

An electronic toll collection system shall be a fully automated tolling system.

The electronic toll collection system shall comply with TS 06225.07.

23 Rail tunnel signalling

Signalling configuration shall be implemented in accordance with the requirements set out in the relevant parts of TS 05333 (series).

Key factors to be considered for implementation or modification of signalling configuration include the need to:

- ensure safe operation (including emergency evacuation) and maintenance
- maximise reliability of equipment.

These factors mean placements of signalling equipment should be avoided as much as possible within and in the vicinity of the tunnel where:

- visibility of the equipment itself is limited
- the issue of water build-up is present
- trains could be stopped at a location where egress is restricted.

23.1 Signal profile, mounting and assembly

Signals shall be designed and manufactured in accordance with TS 05300.

Signals shall be installed in accordance with TS 05165.

23.2 Emergency trackside telephones

In accordance with the relevant parts of TS 05333 (series), trackside telephone shall be provided where contact is required for access to tunnels. Refer to TS 05301 for details on performance requirements as well as details such as dimensions, spacing, and visibility for the telephone location lights.

23.3 Cables

All cabling shall be low smoke and zero halogen within the railway tunnel. Refer to TS 05268 for further details.

23.4 European train control system trackside equipment

Balise placements shall be in accordance with the relevant parts of TS 05333 (series).

Balises should not be placed in tunnels.

To facilitate safe and critical operation, installation of balises in tunnels shall make provision for safe maintenance to be performed.

Level transition borders shall not be placed in areas where a driver fails to acknowledge a transition that would result in the train stopping in a tunnel.

For installation of balises in tunnel areas where concrete derailment plinth is present, refer to TS 05373 for guidance.

23.5 Air systems

TS 05171 establishes the requirements for air systems in tunnel environments.

The brackets supporting the air mains in the tunnels shall be manufactured from Grade 316 (or better) stainless steel (not hot-dip galvanised steel).

23.6 Building and location cases

TS 05167 specifies the requirement that the signalling locations existing within a tunnel environment shall have fire protection consistent with the requirements of fire protection services.

23.7 Cable routes and civil works

Recesses shall be included for lineside cabling to cross the track. The requirements shall be for main route underline crossings and for feeding lineside equipment, such as signals, point machines, trainstops, axle counter heads, track circuits, impedance bonds, telephones and warning lights.

Recesses shall also be included for lineside signalling equipment components, such as point machine rodding and locking mechanisms, axle counter heads and Eurobalise.

Over the life of the tunnel there may be a need to relocate the equipment. Consequently, where applicable, a means to easily create new recesses without affecting the structural integrity of the slab should be considered.

Appendix A Design lives (normative)

The design lives of asset items and sub-items shall be as specified in Table 3

Table 3: Tunnels, underpass structures, underground support facilities and other underground buildings and structures

Asset type	Asset items	Asset sub-item	Design life (years)
All asset items and sub-items not listed in this table	-	-	120
Waterproof membranes, waterstops and seals	-	External waterproof membranes	120
Waterproof membranes, waterstops and seals	-	Water barriers, seals and waterstops	120
Joints	Seals	Gaskets	120
Drainage	Road drainage	Cast into pavement	120
Drainage	Road drainage	Accessible for maintenance and replacement without disruption of tunnel operation	50