CODE OF PRACTICE FOR FIRE PRECAUTIONS IN ROAD TUNNELS 2025

SINGAPORE CIVIL DEFENCE FORCE

Code of Practice for Fire Precautions in Road Tunnels (CPFPRT) 2025

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CHAPTER 1 GENERAL

1.1 SCOPE

1.1.1 General

The Code of Practice for Fire Precautions in Road Tunnels (CPFPRT), hereinafter called "the/ this Code", serves to establish the minimum requirements for fire safety provisions in all road tunnels. It takes into account the function, design, management, operation, and maintenance of road tunnels to secure the life safety of occupants and property safety in the event of a fire.

1.1.2 Road tunnel ventilation and facility buildings

a. Fire safety requirements for facility buildings, ventilation buildings and other non-road tunnels structures shall be in accordance with the Code of Practice for Fire Precautions in Buildings, except where herein modified in this Code.

b. The provision of this Code is not applicable to vehicle underpasses that are 90m or shorter in length.

c. Fire safety requirements implemented in the Fire Code shall be complied with for the design of road tunnels, unless modified or stated otherwise in the CPFPRT.

1.1.3 Energy Storage System (ESS)

Fire safety requirements for ESS shall be in accordance with the Code of Practice for Fire Precautions in Buildings, except where herein modified in this Code.

1.1.4 Solar Photo-Voltaic (PV) installation

Fire safety requirements for solar photo-voltaic (PV) installation shall be in accordance with the Code of Practice for Fire Precautions in Buildings, except where herein modified in this Code.

1.1.5 Fire Safety Report *(Appendix 1)*

Fire Safety Report for fire safety provisions specified by SCDF shall be submitted when making building plan submission.

1.1.6 Fire Safety Instruction Manual *(Appendix 2)*

a. Fire Safety Instruction Manual for fire safety provisions specified by SCDF shall be submitted when making application for Temporary Fire Permit (TFP) or Fire Safety Certificate (FSC).

b. The premises owner shall maintain and keep the Fire Safety Instruction Manual at all times and present to the Qualified Person (QP) upon request. Where any Addition & Alteration works are carried out to the road tunnels, the premises owner shall ensure that changes in the management of fire safety provisions are updated in the Fire Safety Instruction Manual by the QP. The updated Fire Safety Instruction Manual shall be submitted to SCDF for record.

1.2 CODES AND STANDARDS

1.2.1 Reference

This Code makes reference to numerous local and international codes of practice and standards. Only the latest version of the codes of practice and standards shall be used for the purpose of this Code. A list of such codes of practice and standards is shown in *Table 1.2A*.

1.2.2 Conflicting requirements

All codes of practice and standards which this Code referred to shall be read in conjunction with the relevant clauses in this Code. Where conflict exists between this Code and the referred codes of practice and/ or standards, the requirements stipulated in this Code shall take precedence.

1.2.3 Maintenance of fire protection systems

All fire protection systems installed/ provided in a road tunnel, shall be maintained in accordance with applicable codes or standards specified in *Table 1.2A*. The QP shall document down the maintenance details in the Fire Safety Instruction Manual and handover to the building owner for compliance at the completion of the road tunnel project.

For the purpose of this Code, “fire protection system” has the same meaning as in the Fire Safety Act 1993.

1.3 ABBREVIATIONS

The abbreviations used in this Code are listed in *Table 1.3A*.

1.4 DEFINITIONS

In this Code, unless the context otherwise requires, the following definitions will apply.

1.4.1 Ancillary area

"Ancillary area" refers to the non-public areas used to support the operation of road tunnels that are usually used to house or contain operating, maintenance, or support equipment and functions.

1.4.2 Approved

"Approved" refers to being approved by the SCDF.

1.4.3 Authority having jurisdiction

"Authority having jurisdiction" refers to non-SCDF local entities, which may include an organisation, office, or individual responsible for enforcing the requirement of a code or standard, or for approving equipment, materials, an installation, or a procedure.

1.4.4 Backlayering

"Backlayering" refers to the phenomenon in the reversal of movement of smoke and hot gases counter to the direction of the ventilation airflow. See *Diagram 1.4.4.*

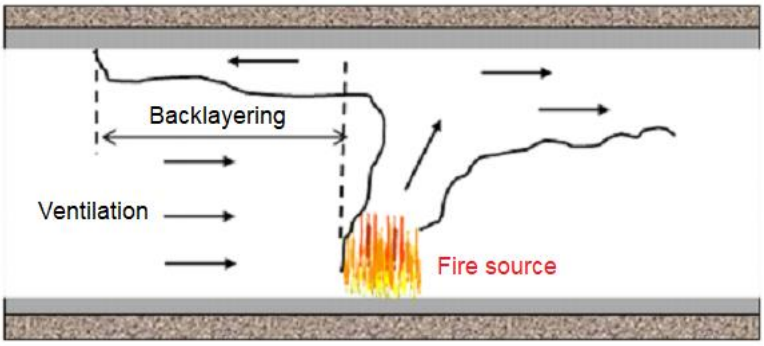


Diagram 1.4.4: Illustration of Backlayering

1.4.5 Basement storey

"Basement storey" refers to a storey of a building for which at least half the storey height is below the ground level, and which also adjoins its perimeter walls for at least half the length of such walls.

1.4.6 Classification of road tunnel

Road tunnels shall be classified based on the length of tunnel as defined in *Cl.1.4.47*. The requirements for each category shall refer to ***Table 1.4A***. The categories are listed below:

a. Category A - Where tunnel length exceeds 90m, and less than 300m.

b. Category B - Where tunnel length equals to or exceeds 300m and less than 1000m.

c. Category C - Where the tunnel length equals to or exceeds 1000m.

1.4.7 Code of Practice (CoP)

"Code of Practice" refers to the standard of practice acceptable to the authority having jurisdiction. The SCDF may adopt requirements stipulated in the stated year of publication of any referenced Code of Practice, or at its discretion adopt those specified in a later version.

1.4.8 Compartment wall and Compartment floor

"Compartment wall" and "Compartment floor" refers to walls or floors of fire-rated construction provided for the purpose of dividing a road tunnel into compartments.

1.4.9 Confinement velocity

"Confinement velocity" refers to the steady-state velocity of the longitudinal ventilation airflow moving toward a fire within a tunnel that controls the backlaying distance.

1.4.10 Corridor

"Corridor" refers to a passage providing means of access from rooms or spaces to an exit.

1.4.11 Critical velocity

"Critical velocity" refers to the minimum steady-state velocity of the ventilation airflow moving towards the fire, within a tunnel or passageway, that is required to control backlayering at the fire site.

1.4.12 Degraded modes of operation

"Degraded modes of operation" refer to any condition in which fire protection and life safety systems and other related systems are not operating at normal capacity.

1.4.13 Design fire scenario

"Design fire scenario" refers to a set of conditions that defines the fire development. Design fire scenario is selected for design inclusive of the conditions that define the fire development parameters, including the growth of fire, quantity of combustible materials, and fire load, that account for the effects of fire protection and life safety systems.

1.4.14 Emergency voice communications

"Emergency voice communications" refer to radio and telephone systems located throughout the facility dedicated to provide the ability for direct communications during an emergency.

1.4.15 Emergency lighting

"Emergency lighting" refers to lighting provided with a secondary source of power supply to illuminate the exits and spaces within a road tunnel.

1.4.16 Engineering analysis

"Engineering analysis" refers to an analysis that evaluates all factors that affect the fire safety of the system. A report of the analysis indicating the proposed method(s) providing a level of fire safety commensurate with this Code shall be submitted.

1.4.17 Engineering analysis report

"Engineering analysis report" refers to a report submitted by the project QP. The report shall contain factors to provide a holistic multidisciplinary engineering analysis of the fire protection and life safety requirements for the tunnel covered below:

a. New or alteration works of a tunnel

b. Transportation modes of tunnel

c. Anticipated traffic mix and volume

d. Restricted vehicle access and egress

e. Potential fire emergencies including but not limited to one location inside or on the facility

f. Exposure of emergency systems and structures to elevated temperature

g. Traffic congestion and control requirements during emergencies

h. Fire protection features, including:

(1) Fire alarm and detection system;

(2) Fire hydrant system;

(3) Fixed water-based fire-fighting system;

(4) Ventilation system; and

(5) Emergency voice communication system.

i. Protection of structure elements

j. Tunnel components, including emergency systems

k. Evacuation and rescue requirements

l. Emergency response time

m. Emergency vehicle access points

n. Emergency communication to appropriate agencies

o. Physical dimensions, number of traffic lanes, and road-way geometry

p. Natural factors, including prevailing wind and pressure conditions

q. Anticipated cargo

r. Impact to buildings or landmarks near the tunnel

s. Impact to tunnel from external condition and/ or incidents

t. Traffic operating mode (unidirectional, bidirectional, switchable, or reversible)

1.4.18 Exit

"Exit" refers to a means of egress from the interior of the road tunnel to an external space. An exit includes any of the following, either singly or in combination: doors, egress stairs, or egress corridors leading to a point of safety, such as cross-passages leading to an adjacent non-incident tunnel and portals.

1.4.19 Exit access door

"Exit access door" refers to a door which provides access to a room or space excluding a utility plant room, holding room and the like, or installed across the escape path leading to an exit.

1.4.20 Exit door

"Exit door" refers to a door provided at the doorway of an exit for the passage of people, forming part of the integrity of the exit, including the exterior door opening.

1.4.21 Exit lighting

"Exit lighting" refers to the part of emergency lighting that is provided to illuminate the exits.

1.4.22 Exit passageway

"Exit passageway" refers to the horizontal extension of a vertical exit via an exit staircase or passage leading from a habitable area to an external space.

1.4.23 Exit staircase

"Exit staircase" refers to a staircase constructed of non-combustible material and protected from fire (by fire-rated construction or located at the external space) for the purpose of enabling egress to the external space.

1.4.24 External space

"External space" refers to an open space abutting the perimeter of a building, which includes an air well and which is vertically open to the sky without any roof or trellis.

1.4.25 Facility building

"Facility building" refers to a structure, space, or area that supports the operation of road tunnels, that are usually used to house or contain operating, maintenance, or support equipment and functions.

1.4.26 Fire engine access road

"Fire engine access road" refers to a road designed for firefighting appliances to gain access to, and travel within a development for firefighting operations.

1.4.27 Fire engine accessway

"Fire engine accessway" refers to a metalled or paved road located along the perimeter of a building to allow a firefighting appliance to carry out firefighting operations. Compared to a fire engine access road, a fire engine accessway is designed to withstand a higher tonnage, and with a larger width, for the purpose of deploying firefighting appliances during an operation.

1.4.28 Fire resistance

"Fire resistance" refers to the minimum time period during which an element of structure or element of a road tunnel can be expected to function satisfactorily while subjected to a standard fire test.

1.4.29 Fire safety report

"Fire safety report" refers to a document that details the provision of fire protection systems, life safety features, and fire safety management for a road tunnel, plant, or installation.

1.4.30 Fire stop

"Fire stop" refers to a seal provided to close an imperfection of fit or any joint between elements, components or construction in a road tunnel, which serves to prevent/ limit the passage of smoke and flame through that imperfection or joint.

1.4.31 Fire suppression

"Fire suppression" refers to sharp reduction of the rate of heat release of a fire and the prevention of regrowth.

1.4.32 Fixed Water-Based Fire-Fighting System (FFFS)

"Fixed Water-Based Fire-Fighting System" refers to a system permanently attached to the tunnel that is able to spread a water-based fire extinguishing agent in all or part of the tunnel.

1.4.33 Heat Release Rate (HRR)

"Heat release rate" refers to energy evolved under a given fire scenario expressed as a function of time.

1.4.34 Length of tunnel

"Length of tunnel" refers to the length from face of portal or tunnel entrance to face of portal or tunnel exit that is measured using the centreline alignment along the tunnel roadway.

1.4.35 Load bearing wall

"Load bearing wall" refers to a wall that supports any load in addition to its own weight.

1.4.36 Masonry

"Masonry" refers to brick or concrete construction.

1.4.37 Mechanical ventilation

"Mechanical ventilation" refers to any system that uses mechanical means such as ventilation fan, to introduce outdoor air to a space when natural ventilation mode cannot be achieved during normal and fire emergency situations. This includes supply ventilation, exhaust ventilation, pressurisation, smoke purging, mechanical engineered smoke control systems, balanced systems that consist of both supply and exhaust ventilations, etc.

1.4.38 Non-combustible material

"Non-combustible material" refers to any material which neither burns nor gives off flammable vapour in sufficient quantity to ignite when subjected to the test for combustibility prescribed in *BS 476 Part 4*, and includes materials of limited combustibility, such as:

a. any material of density 300kg/m^3 or more, which when tested in accordance with *BS 476: Part 11*, does not flame, and the rise in temperature on the furnace thermocouple is not more than 20°C;

b. any material with a non-combustible core at least 8mm thick having combustible facings (on one or both sides) not more than 0.5mm thick; and

c. any material of density less than 300kg/m^3, which when tested in accordance with *BS 476: Part 11*,

   (1) does not flame for more than 10 sec;

   (2) the rise in temperature on the centre (specimen) thermocouple is not more than 35°C; and

   (3) the rise in temperature on the furnace thermocouple is not more than 25°C.

1.4.39 Operations Control Centre (OCC)

"Operations Control Centre (OCC)" refers to a dedicated location that controls and coordinates the specified road tunnel's traffic and emergency response operations and from which communication is maintained with the agency's supervisory and operating personnel and with participating agencies where required.

1.4.40 Partially enclosed roadway

"Partially enclosed roadway" refers to a roadway or portion of a roadway that is not fully enclosed on its' side, or above, or any combination thereof. For such cases, the SCDF shall be consulted.

1.4.41 Point of safety

"Point of safety" refers to an enclosed fire exit that leads to a safe location outside the structure, an at grade point beyond any enclosing structure, or another area that affords adequate protection for motorist.

1.4.42 Portal

"Portal" refers to the interface between a tunnel and the atmosphere through which motor vehicles pass, a connection point to an adjacent structure.

1.4.43 Pressurisation

"Pressurisation" refers to a mechanical ventilation system that introduce positive differential pressure to a space/ room to prevent smoke ingress during a fire emergency.

1.4.44 Protected shaft

"Protected shaft" refers to an exit staircase, exit passageway, duct, or other shaft which enables persons, things, or air to pass from one compartment to another.

1.4.45 Protecting structure

"Protecting structure" refers to a wall, floor, or other part of the tunnel which encloses a protected shaft.

1.4.46 Roadway

"Roadway" refers to the volume of space that is located above the pavement surface which motor vehicles travel.

1.4.47 Road tunnel

"Road tunnel" refers to an enclosed roadway that exceed 90m for motor vehicle traffic with vehicle access that is limited to portals.

1.4.48 Singapore Civil Defence Force (SCDF)

"Singapore Civil Defence Force (SCDF)" refers to the Commissioner of Singapore Civil Defence Force and includes officers authorised by him generally or specifically to exercise the powers, functions and duties conferred by the Fire Safety Act.

TABLE 1.2A: CODES & STANDARDS		
Name	**Description**	**Remarks**
SINGAPORE STANDARDS		
SS CP 52	CoP for Automatic Fire Sprinkler System	
SS 299	Fire Resistant Cables	
SS 332	Speciation for Fire Door	
SS 489	Speciation for Fire Shutters	
SS 508	Graphical Symbols - Safety Colours & Safety Signs	Formerly SS 217 & SS 364
Pt 1	Design Principles for Safety Signs & Safety Markings	
Pt 2	Design Principles for Product Safety Labels	
SS 535	CoP for Installation, Operation, Maintenance, Performance and Constructional Requirements of Mains Failure Standby Generating Systems	Formerly CP 31
SS 550	CoP for Installation, Operation and Maintenance of Electric Passenger and Goods Lifts	Formerly CP 2
SS 563	CoP for the Design, Installation and Maintenance of Emergency Lighting and Power Supply Systems in Buildings	
SS 575	CoP for Fire Hydrant, Rising Mains and Hose Reel System	Formerly CP 29
SS 578	CoP for the Use and Maintenance of Portable Fire Extinguishers	Formerly CP 55
SS 608	CoP for Gas Installation	Formerly CP 51
SS 638	CoP for Electrical Installations	Formerly CP 5
SS 645	CoP for Installation and Servicing of Electrical Fire Alarm System	Formerly CP 10
SS EN 3	Portable Fire Extinguishers	Replaces SS 232 Pt 1 to 6
Pt 7	Characteristics, performance requirements and test methods	
SS EN 1992-1-2	Design of concrete structures Part 1-2 General rules - Structural fire design	
BRITISH STANDARDS		
BS 476	Fire Tests on Building Materials and Structures	
Pt 6	Method of Test for Fire Propagation for Products	
Pt 11	Method for Assessing the Heat Emission from Building Materials	
Pt 20	Method for Determination of the Fire Resistance of Elements of Construction (General Principles)	
Pt 21	Methods for Determination of the Fire Resistance of Load-Bearing Elements of Construction	
Pt 22	Method for Determination of the Fire Resistance of Non-Load-Bearing Elements of Construction	
Pt 23	Methods for Determination of the Contribution of Components to the Fire Resistance of a Structure	
BS 1230	Specification for Plasterboard Excluding Materials Submitted to Secondary Operations	Replaced by BS EN 520
Pt 1		
BS 5234	Partitions (including matching linings) -	
Pt 2	Specification for Performance Requirements for Strength and Robustness including Methods of Test	
BS 8491	Method for assessment of fire integrity of large diameter power cables for use as components for smoke and heat control systems and certain other active fire safety systems	
BS EN 50200	Method of test for resistance to fire of unprotected small cables for use in emergency circuits	

TABLE 1.2A: CODES & STANDARDS		
Name	**Description**	**Remarks**
EUROPEAN STANDARDS		
EN 694	Fire-Fighting Hoses - Semi-rigid hoses for fixed systems	
IEC STANDARDS		
IEC 60331	Tests for Electric Cables Under Fire Conditions – Circuit Integrity	
Pt 25	Procedures and Requirements – Optical Fibre Cables	
IEC 60332	Tests on Electric and Optical Fibre Cables Under Fire Conditions – All Parts	
Pt 1	Test for Vertical Flame Propagation for a Single Insulated Wire or Cable - Apparatus	
Pt 3	Test for Vertical Flame Spread of Vertically-Mounted Bunched Wires or Cable - Apparatus	
IEC 60570	Electrical supply track systems for luminaires	
IEC 60754	Test on gases Evolved during Combustion of Materials from Cables	
Pt 1	Determination of the Halogen Acid Gas Content	
IEC 61386	Conduit systems for cable management	
IEC 61034	Measurement of smoke density of cables burning under defined conditions	
IEC 61084	Cable trunking systems and cable ducting systems for electrical installations	
IEC 61439	Low-voltage switchgear and control gear assemblies	
Pt 6	Busbar trunking systems (busways)	
IEC 61534	Powertrack systems	
IEC 61537	Cable management - Cable tray systems and cable ladder systems	
AMERICAN STANDARDS		
NFPA 11	Standard for Low-, Medium-, and High-Expansion Foam	
NFPA 15	Standard for Water Spray Fixed Systems for Fire Protection	
NFPA 16	Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems	
NFPA 502	Standard for Road Tunnels, Bridges, and Other Limited Access Highways	
NFPA 750	Standard on Water Mist Fire Protection Systems	
AUSTRALIAN STANDARDS		
Specification C1.8	Structural tests for lightweight construction	
CIE STANDARDS		
CIE 88	Guide for the lighting of road tunnels and underpasses	
ISO STANDARDS		
ISO 834	Fire resistance tests — Elements of building construction	

Note:

- The standard titles stated above are non-exhaustive

- SCDF shall not be held responsible for the accuracy of the standard titles shown in this Table

TABLE 1.3A: ABBREVIATIONS	
Abbreviation	**Definition**
AHJ	Authority Having Jurisdiction
BS	British Standard
CCTV	Closed-Circuit Television
Cl.	Clause
CoP/ CP	Code of Practice
Fire Code	Code of Practice for Fire Precautions in Buildings
CPFPRT	Code of Practice for Fire Precautions in Road Tunnels
E & M	Electrical & Mechanical
ETS	Emergency Telephone System
ESS	Energy Storage System
EVC	Emergency Voice Communication
FCC	Fire Command Centre
FFFS	Fixed Water-Based Fire-Fighting System
FM	Frequency Modulation
FSC	Fire Safety Certificate
FSM	Fire Safety Manager
HRR	Heat Release Rate
HR	Hour
LCX	Leaky coaxial cables
OCC	Operations Control Centre
Pt	Part
PV	Photo-Voltaic
QP	Qualified Person
RBBI	Radio Re-Broadcast and Break-In
RI	Registered Inspector
SCDF	Singapore Civil Defence Force
SS	Singapore Standard
TFP	Temporary Fire Permit

TABLE 1.4A: MINIMUM ROAD TUNNEL FIRE SAFETY PROVISIONS

Fire Safety Provisions	Clause/ Chapter	Road Tunnel Categories		
		Category A **90m < L < 300m**	**Category B** **300m ≤ L < 1000m**	**Category C** **L ≥ 1000m**
Engineering Analysis	Cl.1.4.17	MR	MR	MR
Structural Fire Precautions [a]	Chapter 3	MR	MR	MR
Electrical Fire Alarm System - Detection, identification, and location of fire in tunnel - CCTV systems [b]	Chapter 6	 CMR CMR	 MR CMR	 MR CMR
Emergency Voice Communications Systems [c]	Chapter 8	CMR	CMR	CMR
Fire Protection - Fire hydrant - Water supply - Hose connections - Fire hydrant pumps - Portable fire extinguishers - Fixed water-based fire-fighting system - Emergency ventilation systems - Tunnel drainage system - Hydrocarbon detection - Flammable and combustible environmental hazards	Chapter 4, 6, 7	 MR MR MR CMR CMR CMR CMR CMR CMR CMR	 MR MR MR CMR MR CMR CMR MR MR CMR	 MR MR MR CMR MR CMR MR MR MR CMR
Means of Egress - Emergency egress - Exit identification - Tenable environment - Walking surface - Emergency exit doors - Emergency exits (includes cross-passages)	Chapter 2	 CMR CMR CMR CMR CMR CMR	 MR MR MR MR MR MR	 MR MR MR MR MR MR
Electrical Systems - General - Emergency power - Emergency lighting - Exit signs	Chapter 5	 CMR CMR CMR CMR	 MR MR MR MR	 MR MR MR MR

Note:

MR - Mandatory Requirement
CMR - Conditionally Mandatory Requirement
[a] - Determination of requirement in accordance with *Chapter 3* of this Code
[b] - Refer to *Cl.6.5.1c.* of this Code
[c] - Refer to *Cl.8.2* of this Code

CHAPTER 2 MEANS OF ESCAPE

2.1 GENERAL

The provisions of this Chapter shall serve to express the intentions for determining the design, construction, protection, location, arrangement and maintenance of exit facilities to provide safe means of escape for occupants from all road tunnels hereafter erected or altered.

2.2 DETERMINATION OF EXIT REQUIREMENTS

2.2.1 General

The means of egress requirements for all road tunnels shall be in accordance with this Code. Exits such as exit staircase, cross-passageway, etc., shall be provided throughout the tunnel. Every occupant shall have direct access to the required exit or exits without the need to pass through other spaces or rooms.

2.2.2 Tenable environment for egress

A tenable environment shall be provided in the means of egress during the evacuation phase in accordance with the emergency response plan for a specific incident.

2.3 MEANS OF ESCAPE REQUIREMENTS

2.3.1 General

a. The flooring for the surface of steps, ramps, exit staircase, cross passageways, and road shoulders/ walkways shall be non-slip finishes/ materials.

b. Stair identification sign

Staircases shall be provided with a sign with dimensions of at least 300mm x 300mm within the stairwell at each storey landing. The sign as seen in *Diagram 2.3.1b.* shall contain the following information in the order as follows:

(1) The storey number, at least 125mm in height;

(2) An identification of the staircase in alphabet and/ or number, at least 25mm in height;

(3) The sign shall be located such that it is visible when the door is in the open position and also visible to any person moving up or down the staircase; and

(4) The letters and numbers on the sign can be of any colour that shall contrast with the background colour.

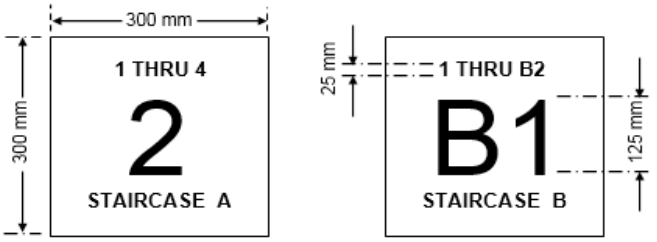


Diagram 2.3.1b.: Stair Identification Sign

2.3.2 Exit doors and exit access doors

Exit doors and exit access doors shall provide protection against fire and prevent ingress of smoke. They shall comply with all of the following:

a. Door swing

Exit doors and exit access doors shall open in the direction of exit travel in the following situations:

(1) when leading to exit, exit passageway, exit staircase, or

(2) when used in an exit enclosure, or

(3) when serving cross-passageways.

b. Fire resistance

Exit doors and exit access doors which are required to have fire resistance rating shall comply with the relevant provisions for the fire resisting doors under *Cl.3.6.2.*

c. Exit door/ exit access door opening

(1) Opening force

The maximum exit doors and exit access doors opening force when applied to the latch side shall not exceed 220N. This opening force shall not be exceeded under the worst-case ventilation differential pressure.

(2) Self-closing device

All fire doors shall be fitted with automatic self-closing device. The exit doors and exit access doors shall not be of a powered self-closing system.

d. Minimum width of exit door/ exit access door

The minimum clear width of exit door/ exit access door opening shall not be less than 1m.

e. Vision panel

The fire door to an exit staircase shall be constructed to incorporate a vision panel. The vision panel shall have a clear view size of 100mm width by 600mm height. The vision panel shall have the requisite fire resistance rating and shall not turn opaque when subject to heat. The bottom edge of the vision panel shall be located at 900mm above the finished floor level.

f. Revolving door

Revolving doors shall not be used as exit/ exit access doors for required exits.

g. Exit door/ exit access door

Where exit/ exit access doors in a means of escape are used in pairs,

(1) approved automatic flush bolts shall be provided; and

(2) the unlatching of any leaf shall not require more than one operation.

h. Horizontal sliding doors

(1) Horizontal sliding doors shall have a sign identifying them as horizontal sliding doors and indicating the direction to open.

(2) Horizontal sliding doors are permitted at cross-passageway provided the opening force shall not exceed 180N and shall have fire resistance rating of at least 2-hr.

2.3.3 Escape via cross-passageways

a. Cross-passageway doors shall be at most 300m apart.

b. Where cross-passageways are used as an emergency exit, traffic operation in the adjacent tunnel shall be stopped to allow occupants in the affected tunnel to seek refuge by cross-over to the adjacent tunnel.

c. The minimum clear width of cross-passageway door shall not be less than 1m for each bound of the door, see *Diagram 2.3.3c*.

d. Pictogram exit signage for passenger cross-passageways

(1) Pictogram exit signage shall be positioned adjacent and on both sides of the cross-passageway door and prominently displayed.

(2) The dimensions of the signage shall be at least 760mm x 1040mm.

(3) The signage colour shall be green, see *Diagram 2.3.3d*.

2.3.4 Egress pathway

a. The tunnel roadway surface, when supported by a traffic management system, shall be considered as a part of the egress pathway.

b. Road shoulder forming part of the egress pathway on either or both sides of the carriageway shall have a minimum clear width of 1.2m, leads directly to an exit (cross-passage, exit staircase or at-grade level), and be protected from traffic. The gradient of the egress pathway shall not exceed 1: 12. See *Diagram 2.3.4b. - 1 and Diagram 2.3.4b. - 2.*

2.3.5 Escape via tunnel portals

Where portals are used as part of escape path to at grade level, the road shoulder next to the slow lane of the slip tunnel shall be used as the egress pathway. See *Diagram 2.3.4b. - 2.*

2.3.6 Exit staircase

An exit staircase can be used as a required exit in lieu of cross-passage door provided it complies with the requirements of exit staircase:

a. The exit staircase shall be enclosed and its enclosure walls shall have at least 4-hr fire resistance rating and fire-rated door of at least 2-hr fire-resistance rating, and be fitted with an automatic self-closing device, except for final discharge door leading to aboveground shall have fire resistance of at least ½ hour with self-closing device.

b. The enclosure walls shall have not more than 2 exit doors excluding the final discharge door and exit staircase door opening into the exit staircase or exit passageway.

c. Where the exit staircase which connects to the internal exit passageway is pressurised, the internal passageway shall also be pressurised to comply with the requirements in *Chapter 7*.

d. The exit staircase shall be ventilated in accordance with *Chapter 7*.

e. Its final discharge leads directly to an external space.

2.3.7 Use of exit enclosure

Where fire-separated exit staircases are provided,

a. there shall be no enclosed useable space within the exit enclosure, including space under stairs; and
b. the exit enclosure shall not be used for any purpose that has the potential to interfere with egress.

c. Ventilation

All exit staircases shall be ventilated by fixed openings in the external walls. Such openings shall be of area at least 10% of the floor area per floor of the staircase, or mechanically ventilated to comply with the requirements in *Chapter 7*. Exit staircase and occupancy area shall not share the same air well or void for ventilation.

d. Landings

The exit staircase landing shall be at least 1.5m in clear width. The minimum clear width and length of a landing, where there is a change in direction shall not be less than the clear width of the exit staircase.

e. Risers and treads

The height of riser for any exit staircase shall not be more than 175mm and depth of tread shall not be less than 275mm.

f. Headroom

The clear headroom shall be at least 2m measured from the pitch line of the exit staircase or finished floor level of the landing to the underside of any obstruction.

g. Handrails

Every exit staircase shall have handrails on both sides. For exit staircases with only 1.25m or less in width, handrail can be provided at one side i.e., the opposite side shall be either wall, parapet, or grilles;

Exception: Handrails are not required for any staircase having not more than five risers.

(1) Where staircases exceed 2m in width, handrails shall be used to divide the staircase into sections between 1m to 2m of width;

(2) Handrail ends shall be returned to the wall or floor or shall terminate at newel posts; and

(3) Handrails that are not continuous between flights shall extend horizontally, at the required height, at least 300mm beyond the top riser and continue to slope for a depth of one tread beyond the bottom riser.

h. Exit staircase width

The exit staircase shall not be less than 1.5m in clear width. The exit staircase clear width shall be measured between:

(1) the finished surfaces of the walls, if the staircase is enclosed on both sides by walls only, or

(2) the finished surface of the wall and the inner side of the balustrade, if the staircase has a wall on one side and a balustrade on the other side, or

(3) the inner sides of the balustrades if the staircase has balustrades on both sides.

(4) The projection of handrail into the clear width of a staircase shall not exceed 80mm on each side of the staircase. If the projection exceeds 80mm, the clear width of the staircase shall be measured from the inner sides of the handrails.

2.3.8 Cross-passage for vehicles

For main tunnel, cross-passage for vehicles shall be provided at maximum intervals of 1500m with a minimum clear width of 6m and a minimum height of 4.5m, see *Diagram 2.3.8*.

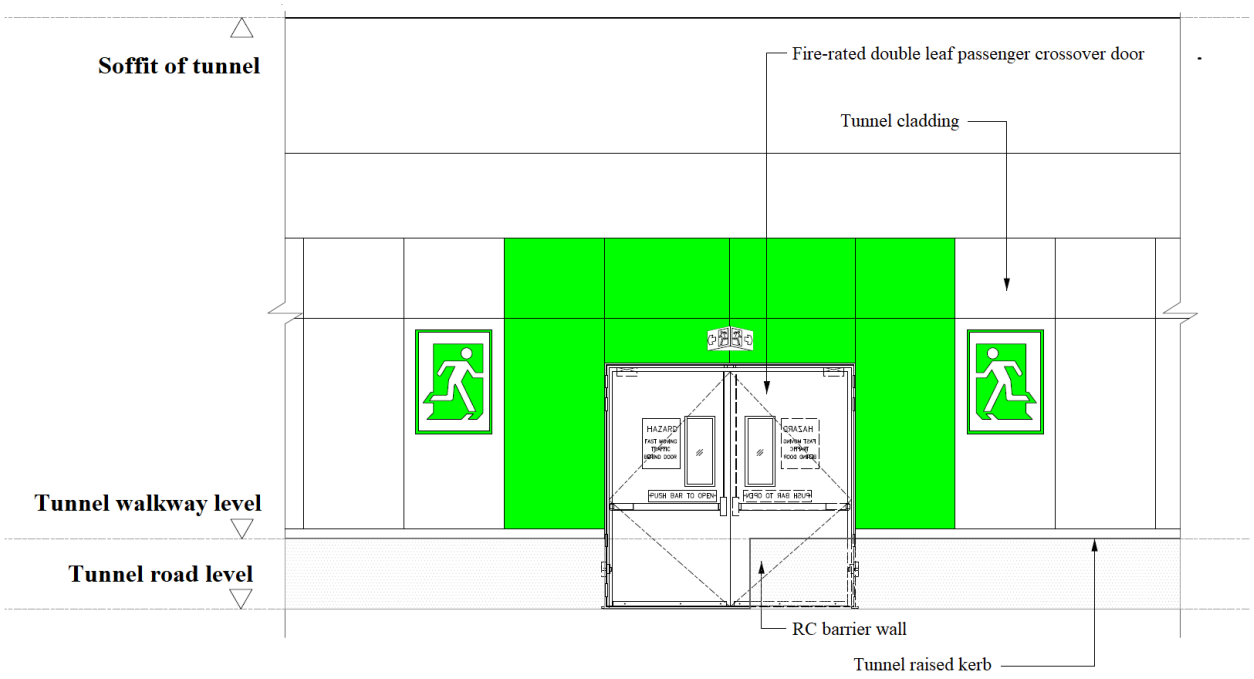


Diagram 2.3.3: Passenger Cross-passageway

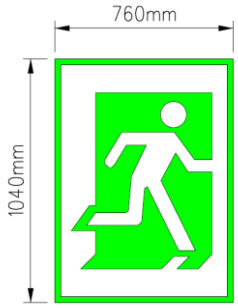
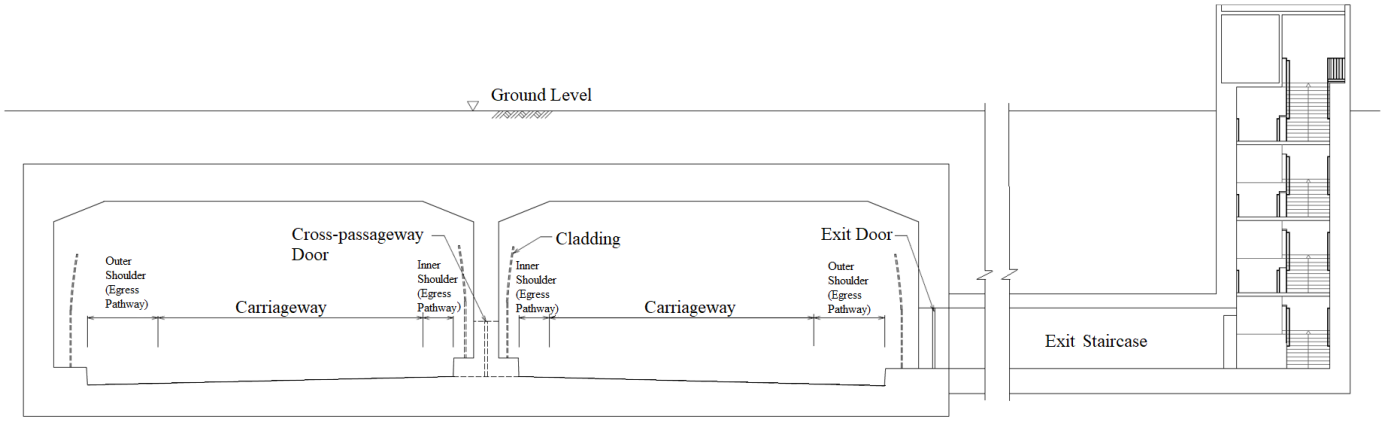
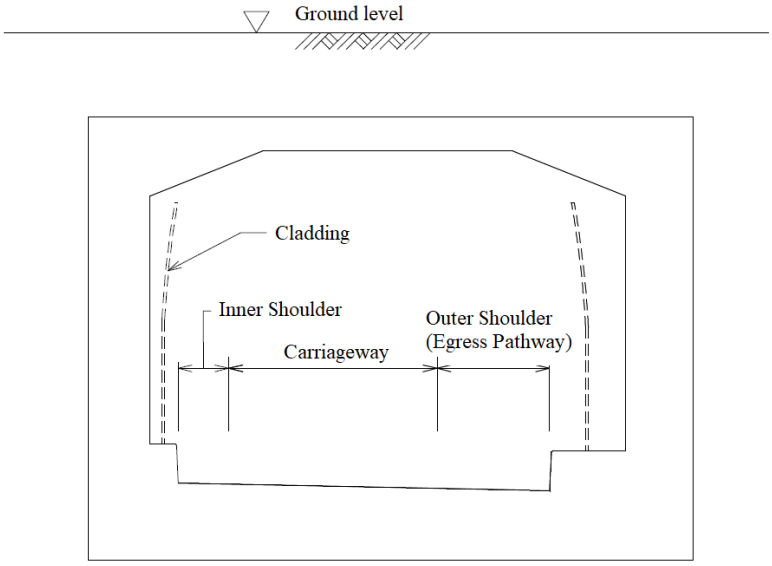


Diagram 2.3.3d.: Pictogram Exit Signage for Passenger Cross-passageway



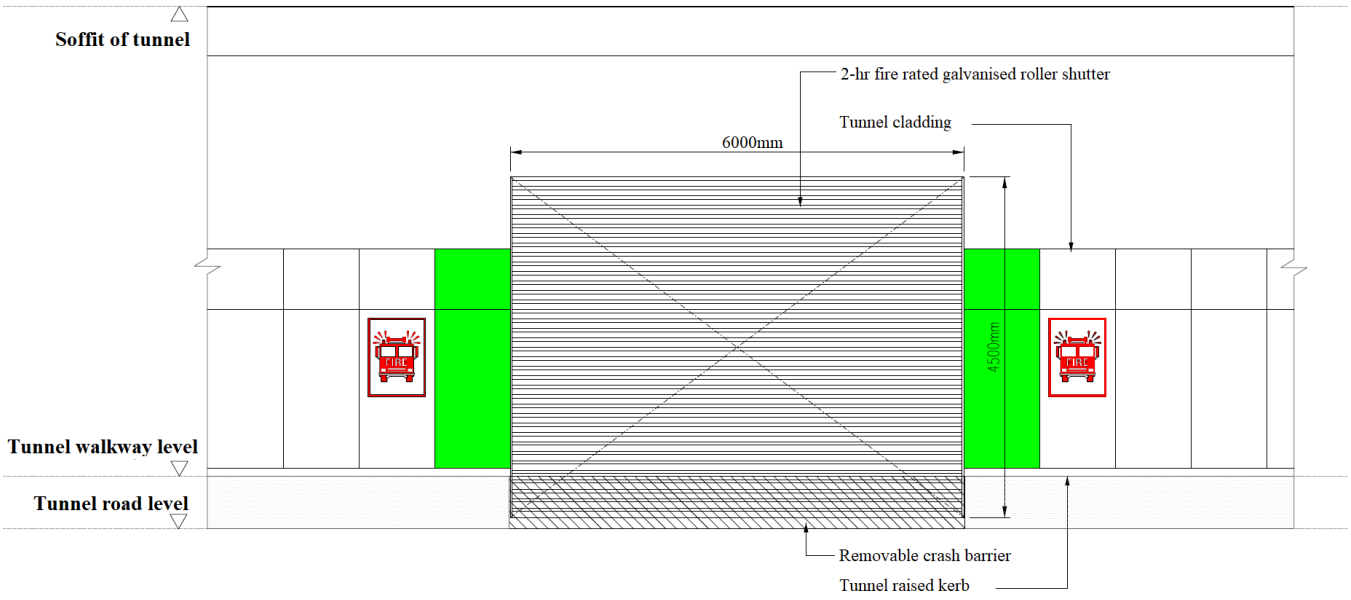
Sectional Elevation

Diagram 2.3.4b. - 1: Cross-section of Side-by-Side Tunnel

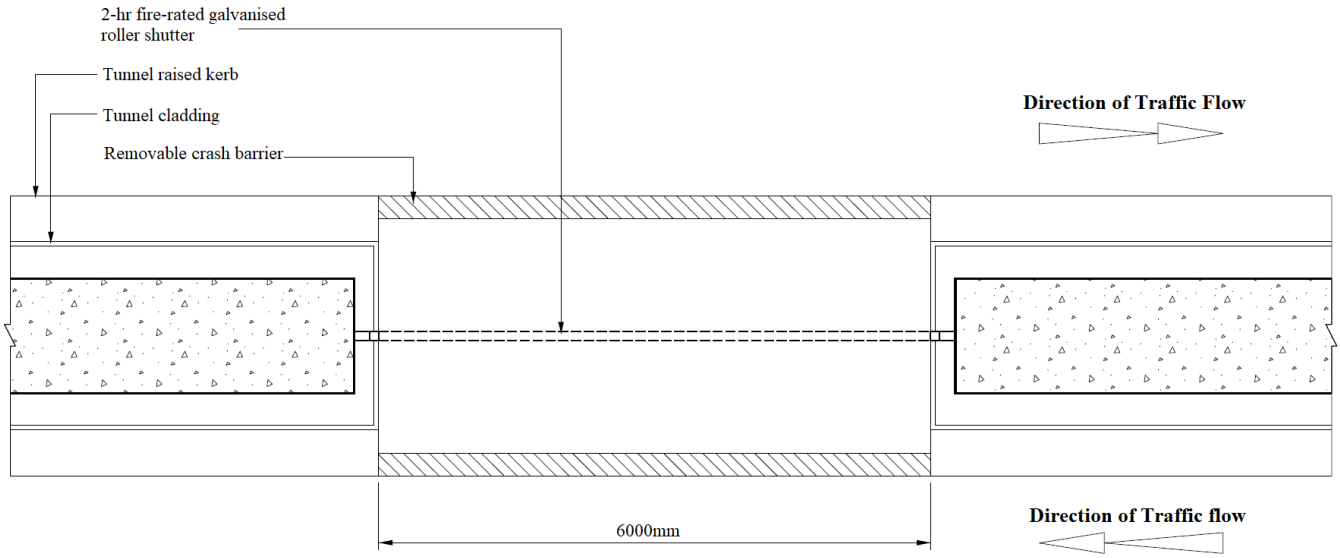


Sectional Elevation

Diagram 2.3.4b. - 2: Cross-section of Slip Road



Elevation



Plan

Diagram 2.3.8: Cross-passage for Vehicles

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CHAPTER 3 STRUCTURAL FIRE PRECAUTIONS

3.1 GENERAL

This Chapter provides minimum fire protection and life safety requirements for road tunnels.

3.2 FIRE RESISTANCE OF ELEMENTS OF STRUCTURE

3.2.1 Minimum periods of fire resistance

Subject to any expressed provision to the contrary, any element of structure shall be constructed of non-combustible materials and is required to have fire resistance for at least the relevant period specified as follows:

a. The road tunnels, escape staircases and all other underground structures shall be capable of withstanding the temperature exposure represented by standard fire curve in compliance with *ISO 834* or other recognised standard time-temperature curve that is acceptable to SCDF.

b. The fire resistance of elements of structure for road tunnels, slip roads, escape staircases & other underground structures that support tunnel operations shall be 4-hr, for the following:

(1) Structure members forming part of the structural frame of a road tunnel.

3.2.2 Criteria under fire exposure condition

The elements of structures shall satisfy the following criteria under fire exposure condition:

a. Any irreversible damage and deformation leading to progressive structural collapse shall be prevented.

b. The elements of road tunnel structure shall be designed and detailed such that fire-induced concrete spalling which leads to progressive structural collapse shall be prevented.

3.2.3 Design for structural fire resistance

The tunnel structures shall be designed in accordance with *SS EN 1992-1-2* and the associated Singapore National Annexes or other equivalent code of practice acceptable to SCDF.

3.2.4 Structural fire protection material

Structural fire protection material, where provided, shall satisfy all of the following performance criteria:

a. Tunnel structural elements shall be protected to achieve the following for concrete:

(1) The concrete is protected such that the fire-induced spalling is prevented.

(2) The temperature of the concrete surface does not exceed 380ºC.

(3) The temperature of the steel reinforcement within the concrete (assuming a minimum cover of 25mm) does not exceed 250°C.

b. The material shall be non-combustible.

3.2.5 Fasteners and other intermediate support elements

All fasteners, intermediate support elements, and anchors that attach equipment and devices not otherwise addressed in other codes and standards to the structure above roadway and maintenance walkways shall be capable of maintaining support during exposure to a minimum temperature of 450°C for at least 2-hr.

3.3 TEST OF STRUCTURAL FIRE RESISTANCE

3.3.1 Fire resistance

Performance for the fire resistance of elements of structure, doors and other forms of construction shall be determined by reference to the methods specified in *BS 476: Part 20 to 23*, or any other standard approved by SCDF, which specify tests for stability, integrity and insulation.

Specific requirements for each element in terms of the three performance criteria of stability, integrity and insulation are given in *Table 3.3A*.

3.3.2 "Deem to satisfy" provisions

An element of structure, door or other part of a road tunnel shall be deemed to have the requisite fire resistance if:

a. it is constructed to the same specification as that of a specimen exposed to test by fire in accordance with the method and procedure under *BS 476: Part 20 to 23*, and satisfied the requirements of that test for the three performance criteria of stability, integrity and insulation for not less than the specified period, or

b. in the case of structural concrete, it is constructed to comply with *SS EN 1992 Part 1 and 2.*

3.4 COMPARTMENT WALLS OR COMPARTMENT FLOORS

3.4.1 General

Every compartment wall shall be required to:

a. form a complete barrier to fire between the compartments it separates;

b. have the appropriate fire resistance to comply with the requirements of *Cl.3.2*; and

c. be constructed of non-combustible materials (together with any beam or column which forms part of the wall or floor and any structure which it carries).

3.4.2 Openings in compartment walls or compartment floors

A compartment wall or compartment floor shall have no openings in it, except for:

a. a door of at least 2-hr fire resistance rating is required to facilitate means of escape in the event of a fire as the compartment wall and complies with the relevant requirements of *Cl.3.3*, unless permitted by other provisions of the Code, or

b. a protected shaft which complies with the requirements of *Cl.3.5*; and

c. the passage of a pipe or ventilation duct or a conduit for E&M services.

Such openings in the compartment wall or compartment floor shall be protected to comply with the relevant provisions of *Cl.3.6*.

3.4.3 Openings at junction with other structures

Where a compartment wall or compartment floor forms a junction with any structure comprising any other compartment wall, or any external wall, separating wall or structure enclosing a protected shaft, such structures shall be bonded together at the junction, or the junctions shall be fire-stopped to comply with the requirements of *Cl.3.8*.

3.4.4 Prohibition of combustible materials

No combustible material shall be built into, carried through or carried across the ends of any compartment wall or carried over the top of any compartment wall in such a manner as to render ineffective the resistance of such wall to the effects of the spread of fire.

3.4.5 Non-combustibility of compartment walls

Every compartment wall shall be constructed of non-combustible materials, unless permitted by the SCDF.

3.4.6 Use of fire shutter

a. General

A fire shutter is only permitted to be used as compartment wall for vehicular cross-passage in tunnel.

b. Fire resistance

The fire shutter for vehicular cross passage, which is used to protect openings in compartment wall, shall have at least 2-hr fire resistance including thermal insulation of the compartment wall.

c. Operation

The commonly used vertical fire shutters for vehicular cross-passage shall comply with *SS 489*.

d. Mode of activation

The mode of activation for fire shutters between two road tunnels shall be as follows:

(1) The fire shutter shall remain closed at all times except for emergency, or for maintenance purposes.

(2) The fire shutter for the vehicular cross-passage is permitted to be operated remotely at the OCC or manually on site.

3.5 PROTECTED SHAFT

3.5.1 Purpose of protected shaft

A protected shaft shall not be used for any purpose additional to those given as defined under *Cl.1.4.34*. All services such as, pipe/ duct installation shall not be located inside an exit staircase, unless otherwise permitted in *Cl.3.5.7*.

3.5.2 Requirements of protected shaft

Every protected shaft shall be required to:

a. form a complete barrier to fire between the different compartments which the shaft connects;

b. have the appropriate fire resistance to comply with the requirements of *Cl.3.2*; and

c. be constructed of non-combustible material (together with any beam or column which forms part of the enclosure and any structure which carries it).

3.5.3 Openings in protected shaft

a. A protected shaft shall have no openings in its enclosure, except:

(1) In the case of any part of the enclosure which is formed by a compartment wall, any opening which complies with the requirements of *Cl.3.4* for compartment wall, or

(2) In the case of any part of the enclosure which is formed by the protecting structure:

(a) a door which has the appropriate fire resistance to comply with the requirements of *Cl.3.3* for test of fire resistance, or otherwise permitted by provision of *Cl.3.5.6,* or

(b) the passage of a pipe/ conduit, or

(c) inlets to and outlets from and opening for the duct, if the shaft contains or serves as a ventilation duct.

b. Such openings in the protected shaft shall be protected to comply with the relevant provisions of *Cl.3.6* for protection of openings.

3.5.4 Non-combustibility of protected shaft

Protected shaft shall be constructed wholly of non-combustible materials except that floor, wall and ceiling finishes which do not contribute to the fire resistance of such protecting structure are not required to comply with the requirements for non-combustibility

3.5.5 Ventilation of protected shaft

A protected shaft used for the passage of people, such as exit staircases, shall be ventilated to comply with the relevant provisions of the Code.

3.5.6 Doors in protected shaft

a. Any door fitted to an opening in protected shaft shall have fire resistance for not less than 2-hr the period required by other provisions of the Code for the protected shaft surrounding the opening.

b. Rising mains and hose reel doors shall not be fitted with self-closing device and shall comply with the stipulated corridor width when the door is in its fully opened position. Areas within the swing paths of the rising mains and hose reel doors shall be clear of any obstruction/ storage at all times.

c. Exception

(1) Any door fitted to an opening in protecting structure of a shaft containing services such as electrical cables, pipes (including gas pipe in separate shaft), ducts, etc., is not required to have the fire resistance rating if the door is located along the wall facing the external corridor.

3.5.7 Protected shaft containing exit staircase

A protected shaft which contains an exit staircase shall comply with the following:

a. It shall not contain any pipe conveying gas or combustible liquid.

b. It shall not be used as access to any plant room.

c. It shall not contain any services that are not solely serving the same exit staircase except for:

(1) Sprinkler pipe, rising mains, hose reel pipe, fire alarm system cable in metal conduit, metal water supply pipe not exceeding 50mm in nominal diameter and water tap;

(2) UPVC or cast-iron rainwater down-pipes serving the roof directly above the exit staircase, and not routed through anywhere outside the staircase; and

(3) Telecommunication cables, e.g., leaky coaxial cables (LCX) and emergency voice communication system cables.

d. Protected shaft shall be constructed of masonry or reinforced concrete or drywall. If drywall construction is used, all of the following conditions shall be complied with:

(1) The drywall shall be non-combustible.

(2) The drywall shall have the requisite fire resistance rating at least equal to that of elements of structure.

(3) The drywall shall, in terms of impact & deflection performance, meet the partition grade specified under *BS 9999* (Test for partitions) in accordance with *BS 5234-2*.

(4) The drywall shall meet the criteria, in terms of water absorption and bending strength performance, when subject to the test of *BS EN 520* or *ISO 1896*.

(5) The road tunnel shall have at least two independent exit staircase shafts (scissors exit staircases are considered single shaft).

3.5.8 Protected shaft containing other services installations

A protected shaft used for the enclosure of services shall comply with the following:

a. The protecting structure for protected shaft containing mechanical ventilation ducts serving exit staircases, exit passageways, which pass through one or more floors shall be constructed of masonry or drywall. Such shaft shall be completely compartmented from the rest of the shaft space containing other ducts or any other services installations. A protected shaft containing ducts serving other areas which pass through floor slabs can be constructed of drywall. If the protected shaft is of drywall construction, the conditions stipulated in *Cl.3.5.7d.* shall be complied with.

b. Fire resistant cables, flame retardant cables and extra low voltage telecommunication cables need not be housed in protected shafts.

3.6 PROTECTION OF OPENINGS

3.6.1 Application

The provisions of this Clause are made in connection with the protection of openings permitted in elements of structure or other forms of fire resisting construction required to act as a barrier to fire and smoke.

3.6.2 Fire doors

Fire doors for protection of openings shall comply with all of the following:

a. Fire doors shall have the appropriate fire resistance as required by relevant parts of the Code. A two-leaf door can be fitted in an opening if each door by itself is capable of closing the opening and the two doors together achieve the required level of fire resistance.

b. All fire doors shall be fitted with an automatic self-closing device which is capable of closing the door from any angle and against any latch fitted to the door.

c. Any fire door fitted in an opening which is provided as a means of escape:

(1) shall be capable of being opened manually, without the use of key, tool, special knowledge or effort for operation from the inside of the road tunnel; and

(2) shall open in the direction of exit travel in accordance with *Cl.2.3.2a*..

d. Any hinge on which a fire door is hung shall be of the approved type, complying with *SS 332*.

e. Fire doors, where required, shall be constructed and installed to comply with specifications stipulated under *SS 332*.

3.6.3 Pipes

Pipes passing through a separating wall, compartment wall shall be fire stopped around the pipe.

3.6.4 Ventilation ducts

Ventilation duct which passes directly through a compartment wall shall comply with the following:

a. Where the ventilation duct does not form a protected shaft or is not contained within a protecting structure,

(1) the duct shall be fitted with a fire damper where it passes through the compartment wall, and

(2) the opening for the duct shall be kept as small as practicable and any gap around the fire damper shall be fire-stopped.

b. Where the ventilation duct forms a protected shaft or is contained within a protecting structure, the duct shall be:

(1) fitted with fire dampers at the inlets to the shaft and outlets from it; and

(2) constructed and lined with materials in accordance with the requirements in *Chapter 6*.

c. The installation of ventilation ducts and fire dampers shall comply with the requirements in *Chapter 6*.

3.7 EXIT STAIRCASES

3.7.1 Non-combustibility of structure

Every exit staircase, including the treads/ risers and landing slabs shall be constructed of non-combustible materials, which shall have fire resistance for not less than the period required by *Cl.3.2* for Elements of Structure.

3.7.2 Structure separating exit staircase

The exit staircase shall be separated from other parts of the road tunnel by a masonry structure or dry wall complying with *Cl.3.5.7d*. which shall have fire resistance for not less than the period required by *Cl.3.2* for Elements of Structure.

3.7.3 Finishes

Finishes to the ceilings/ walls and floors of exit staircase shall be of non-combustible materials.

3.8 FIRE STOPPING

3.8.1 General provision

Openings for pipes, ducts, conduits or cables which pass through any part of an element of structure (except for a part which does not serve as a fire resisting barrier) or cavity barrier, shall be:

a. kept as few in number as possible;

b. kept as small as practicable; and

c. all gaps shall be filled with fire-stopping materials.

3.8.2 Fire-stopping

Fire-stopping shall be of material having the necessary fire resistance when tested to *BS 476: Part 20* or other acceptable standards.

3.8.3 Materials for fire-stopping

Suitable fire-stopping materials include:

a. Proprietary fire-stopping and sealing systems (including those designed for service penetrations) which have been shown under test conditions to maintain the fire resistance of the wall or other element, shall be in accordance with the Code of Practice for Fire Precautions in Buildings, except where herein modified in this Code.

b. Other fire-stopping materials include:

(1) cement mortar;

(2) gypsum based plaster;

(3) cement or gypsum based vermiculite/ perlite mixes;

(4) glass fibre, crushed rock, blast furnace slag or ceramic based products (with or without resin binders); and

(5) intumescent mastics.

The method of fire-stopping and choice of materials should be appropriate to the situation and its application.

TABLE 3.3A: SPECIFIC PROVISIONS OF TEST FOR FIRE RESISTANCE OF ELEMENTS OF STRUCTURE					
Part of Road Tunnel		**Minimum provisions when tested to BS 476: Part 20-23 (mins)**			**Method of exposure**
		Stability	**Integrity**	**Insulation**	
1.	Structural frame, beam, or column	*	no requirement	no requirement	exposed faces
2.	Loadbearing wall, which is not also compartment wall or protecting structure (See 4 or 5)	*	no requirement	no requirement	each side separately
3.	Floors (e.g. fan room in exit staircase shaft)	*	*	*	from underside
4.	Compartment wall	*	*	*	each side separately
5.	Protecting structure any part	*	*	*	each side separately
6.	Doors				
	(a) in a separating wall	no provision	+	no provision	each side separately when fitted in its frame
	(b) in a compartment wall	no provision	+	no provision	
	(c) in a protecting structure	no provision	**	no provision	

Note:

* - Period of fire resistance as specified

** - Half the period of fire resistance for the wall or floor in which the door is situated

\+ - Period of fire resistance for the wall or floor in which the door is situated

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CHAPTER 4 SITE PLANNING & FIREFIGHTING PROVISION

4.1 GENERAL

The purpose of this Chapter is to make provision for space within road tunnels to enable effective firefighting operations.

4.2 FIRE HYDRANT

4.2.1 Provision of private fire hydrant

a. General

Every part of a road tunnel shall be within an unobstructed distance of 50m from a fire hydrant. See *Diagram 4.2.1a.*

b. Fire hydrants installation

Fire hydrants shall be provided at each niche housing fire protection equipment along the road tunnel. Adequate clearance shall be provided for hose connections.

c. Ringed fire hydrant pipes

(1) With the exception of tunnels under Category A and B, fire hydrant pipe shall be constructed in a ring mains system. Isolation valves shall be provided on the fire hydrant ring such that on any section of ring can be isolated when required for maintenance without affecting the water supply (both designed pressure and flow) to the other fire hydrants on opposite bound served by the ring. See *Diagram 4.2.1c.(1).*

(2) As an alternative to the ringed fire hydrant pipes, more than one water supply can be provided to the fire hydrant. See *Diagram 4.2.1c.(2).*

d. Valve locking device

A locking device shall be provided to lock the valves in open position during normal operation. Underground valves shall be kept in an open position at all times.

e. An automatic air release valve shall be provided at the highest point on the system to permit air in the pipe to be discharged directly to external space.

f. Protection of fire hydrant mains

(1) The hydrant main pipes installation within the tunnel need not be fire-rated. The hydrant main pipes shall be located within a concrete trench in the tunnel where possible as shown in *Diagram 4.2.1f.*, except where the pipes are required to cross to the adjacent bound and/ or slip roads, or where the main pipes are coming from outside of the tunnel.

(2) Any part of fire hydrant pipes that is serving or located within a road tunnel shall be adequately protected from any mechanical or vehicular damage.

4.2.2 Water supply and storage requirement

Any fire hydrant that is required by this Code shall comply with the following requirements:

a. Direct supply from public mains

The running pressure/ flow at the hydraulically most unfavourable fire hydrant from the public water mains shall comply with the following:

(1) Running pressure >= 0.9 x (running pressure of the nearest public fire hydrant – pressure drop across the bulk water metre);

(2) Flow rate >= 0.9 x water flow of the nearest public fire hydrant provided the running pressure at the most remote fire hydrant is greater than 2 bars; and

(3) The pressure drop across bulk water metre shall not be more than 1 bar.

b. Pump supply

The running pressure and flow at the most hydraulically disadvantaged landing valve shall meet the requirement shown in *Table 4.2.2*. The water supply shall be capable of supplying the system demand for a minimum of 45 minutes. Fire pumps for the private fire hydrant shall comply with requirements stipulated in *SS 575*.

TABLE 4.2.2: WATER SUPPLY & STORAGE REQUIREMENT FOR PRIVATE FIRE HYDRANT

Minimum running pressure	2 bars	
Minium duration	45 mins	
Minimum flow rate	Fire Zone Area* (m^2)	Minimum flow rate
	$\leq 1000m^2$	38 L/s
	$> 1000m^2$ and $\leq 5000m^2$ (57 L/s if suppression system provided)	57 L/s
	$> 5000m^2$	76 L/s

Note: * - Fire Zone Area (FZA) = 50m x largest width of the incident tunnel (Refer to *Diagram 4.2.1a.*)

4.2.3 Fire hydrant landing valve

The design of the fire hydrant landing valve shall comply with the following:

a. Landing valves shall be kept free of physical obstruction.

b. Each hydrant shall have 2 oblique landing valves with an instantaneous female coupling for connecting to the 63.5mm diameter standard hose as shown in *Diagram 4.2.3.*

c. Landing valves shall be equipped with caps to protect the coupling.

4.2.4 Identification signs

a. Identification signage for each fire hydrant shall be provided.

b. The signage shall be conspicuous and shall be affixed to the fire niche door where the fire hydrant is located.

c. Graphic signage of the fire hydrant landing valve as shown in *Diagram 4.2.4.*

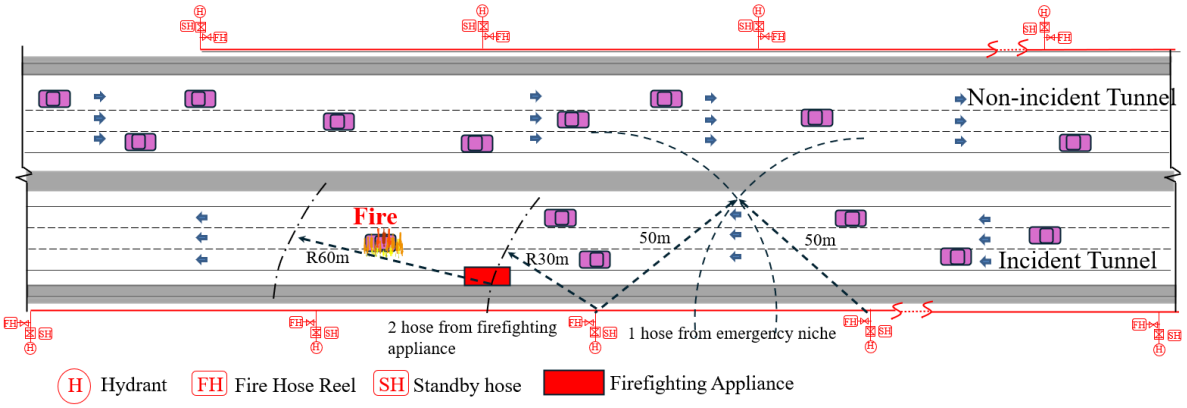

Diagram 4.2.1a. Provision of fire hydrant

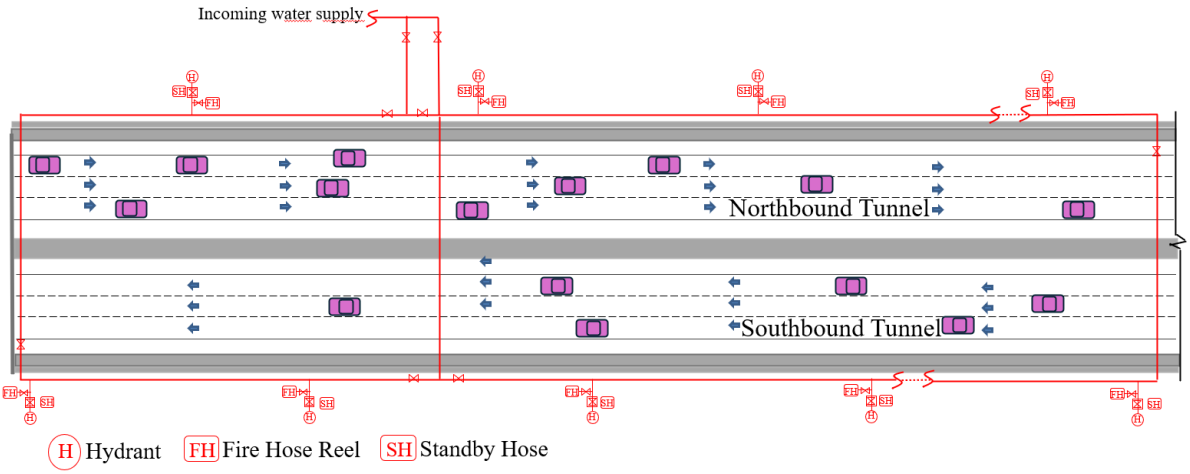

Diagram 4.2.1c.(1) Ringed fire hydrant schematic

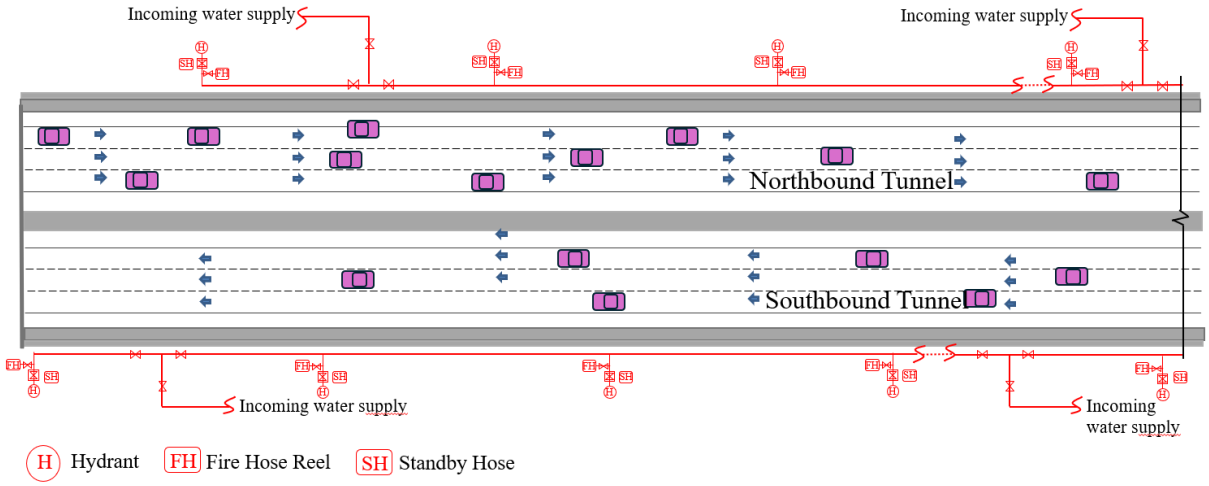

Diagram 4.2.1c.(2) Alternative to ringed fire hydrant schematic

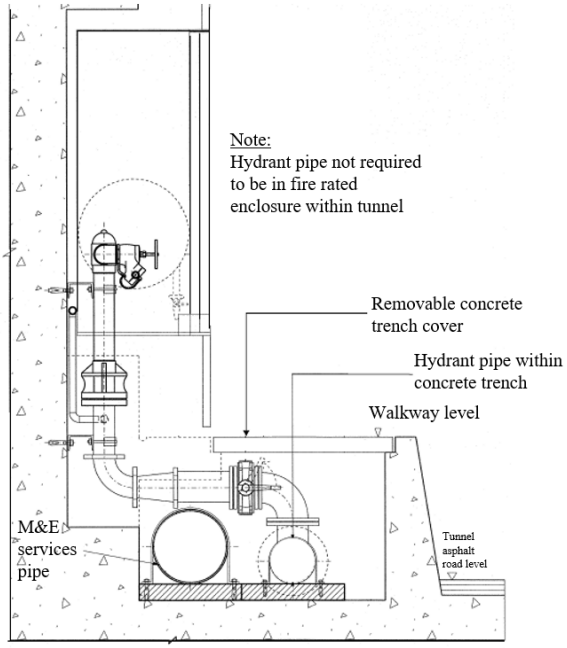

Diagram 4.2.1f. Typical section of hydrant mains within concrete trench

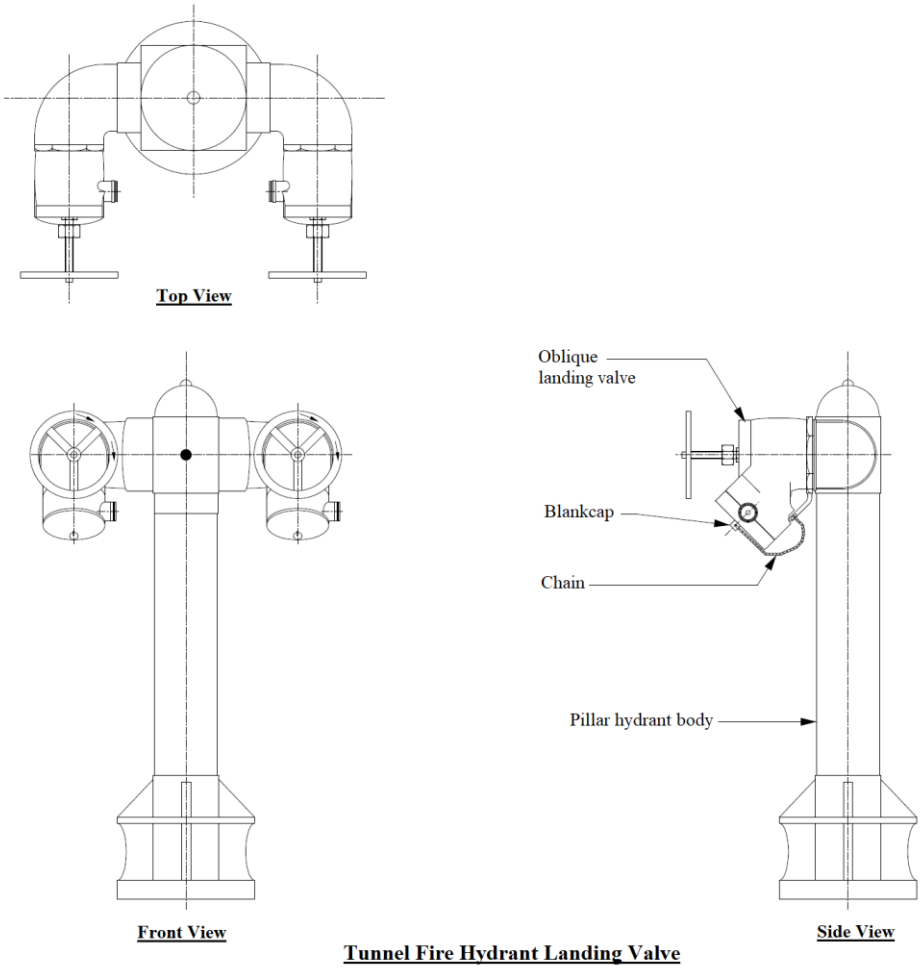

Diagram 4.2.3 Fire hydrant landing valve

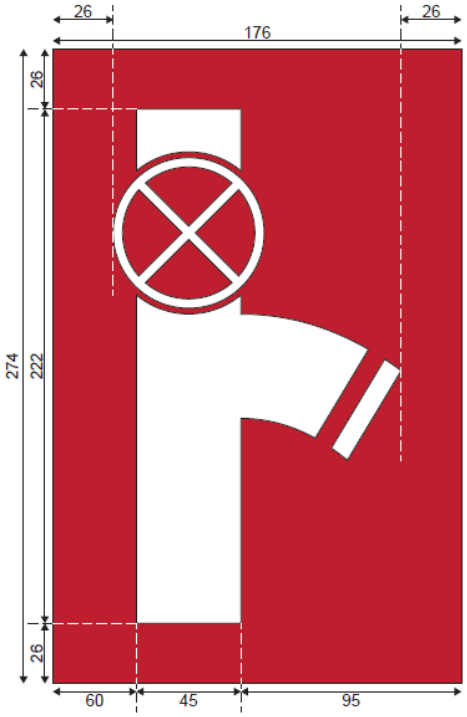

Diagram 4.2.4 Graphic signage of the fire hydrant landing valve

CHAPTER 5 ELECTRICAL POWER SUPPLIES

5.1 GENERAL

The electrical systems shall support life safety operations, fire emergency operations, and normal operations.

5.2 ELECTRICAL SYSTEM

5.2.1 Scope

The electrical systems shall maintain ventilation, lighting, communications, drainage, a fixed water-based fire-fighting system (FFFS), fire alarm and fire detection, exit signs, traffic control, and others for areas of refuge, exits, and exit routes, under all normal and emergency modes associated with the facility.

5.2.2 Emergency circuits

Emergency circuits installed in a road tunnel and ancillary areas shall remain functional for a period of not less than 1-hr for the anticipated fire condition by one of the following methods:

a. Fire-resistant cables shall comply with *SS 299*, *IEC 60331*, *BS EN 50200* or *BS 8491* or any other approved recognised standards

b. Circuits shall be protected by a 2-hr fire-rated enclosure complying with *BS 476*. The cables or conductors shall maintain functionality at the operating temperature within the fire barrier system.

c. Circuits shall remain functional by the routing of the cable system external to the roadway

d. Circuits shall remain functional by using diversity in system routing as approved, such as separate redundant or multiple circuits separated by a 2-hr fire-rated enclosure, so that a single fire or emergency event will not lead to a failure of the system.

Exception:

(1) The requirement of *Cl.5.2.2* shall not apply to bi-directional antennas used for emergency communication system circuits.

5.3 INSTALLATION AND WIRING METHOD

5.3.1 General

All wiring materials and installations shall conform to *SS 638*.

5.3.2 Fire resistant cables

Fire resistant cables shall comply with *SS 299* and fire-resistant fibre optic cable shall comply with *IEC 60331*.

5.3.3 Flame retardant cables

Flame retardant cables shall comply with *IEC 60332 Part 1 & 3* tested on both single and bunched cables under fire conditions.

5.3.4 Low-smoke and halogen-free cables

All cables used in road tunnels shall be of the low-smoke and halogen-free type and shall comply with the following requirements:

a. *IEC 61034*.

b. When a sample of cable is subjected to the combustion test to determine amount of halogen acid gases (other than hydrofluoric acid) set out in *IEC 60754 - Part 1*, and the amount of halogen acid evolved is less than 0.5%, the cable shall be regarded as halogen free.

5.3.5 Other cables

Cables for fire safety equipment/ systems that are required to operate during a fire emergency shall be of fire-resistant type, with the exception of internal cables within control panels/ equipment, light fittings and leaky coaxial cables (LCX).

5.3.6 Cables for non-essential equipment/ systems

Cables for non-essential equipment/ systems shall be minimally of flame retardant type.

5.3.7 Air plenum

Fire resistant/ flame retardant, low smoke zero halogen (LSOH) type cables are permitted to be run exposed in air plenum, provided that:

a. The air plenum shall be protected by fire detection system.

b. FCU or AHU using plenum for air return and serving more than one room shall be provided with smoke detector(s) at the return air plenum or return air duct to shut down the FCU/ AHU upon detection of smoke.

5.4 PRIMARY AND SECONDARY POWER SUPPLIES

5.4.1 Secondary power supply

Road tunnels complying with Categories B and C in *Cl.1.4.6* shall be provided with secondary power supply. To meet this requirement, either or combination of the following electrical sources shall be considered:

a. Uninterruptible power supply

Uninterruptible power supply (UPS) consisting of centralised batteries can be considered as a secondary source of power supply.

b. Emergency generator

Where emergency generators are provided as a secondary source of supply, they shall comply with *SS 535*.

c. Dual electric feeder

Notwithstanding the above, dual feeder power supply are deemed to have been provided with primary and secondary source of power supplies. The primary feeder (primary supply) shall be the normal power supply while the secondary feeder (secondary supply) shall be the emergency power supply as shown in *Diagram 5.5.1c. - 1 & Diagram 5.5.1c. - 2.*

5.4.2 Essential fire protection systems

The following systems shall be connected to the secondary power system:

a. Emergency lighting

b. Exit signs

c. Emergency voice emergency communication

d. Emergency ventilation

e. Fire alarm and detection

f. Closed-circuit television or video

g. Firefighting

h. Tunnel closure and traffic control

5.5 RELIABILITY

5.5.1 Redundancy

The electrical systems of tunnels in excess of 1000m in length shall have redundant facilities for the purpose of monitoring and control.

5.5.2 Maintenance

The electrical systems shall be designed to allow for routine maintenance without disruption of traffic operation.

Block diagram of Typical Road Tunnel Dual Feeder LV Power Supply Scheme

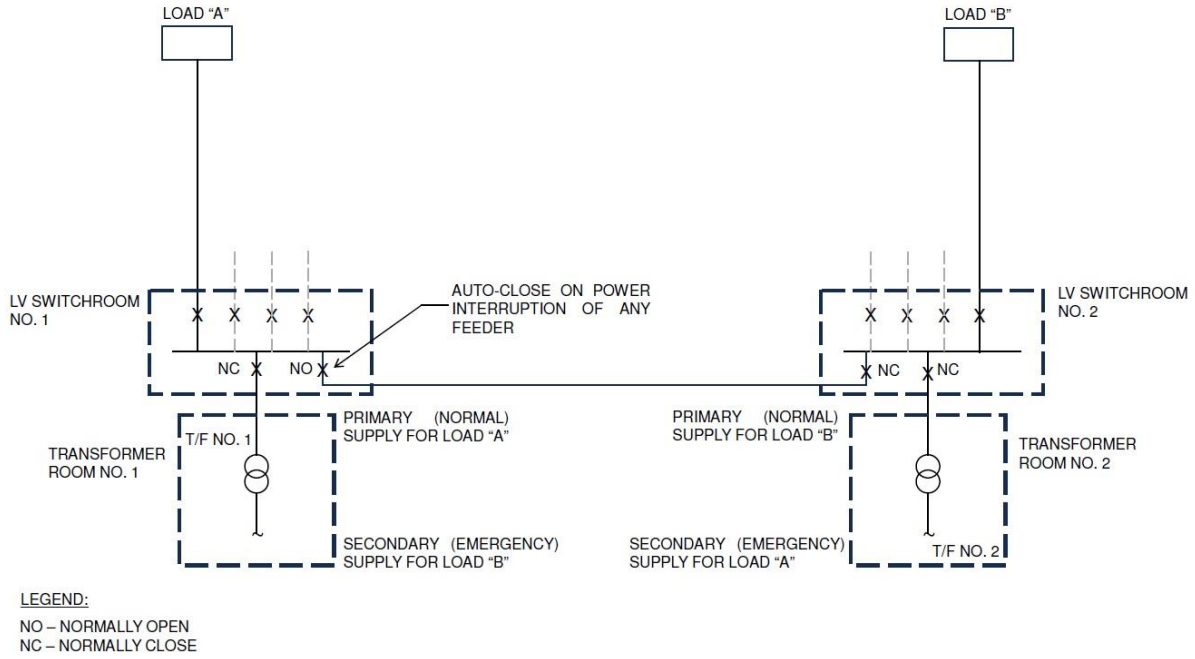

Diagram 5.5.1c. - 1

Block diagram of Typical Long Road Tunnel Dual Feeder HT Power Supply Scheme

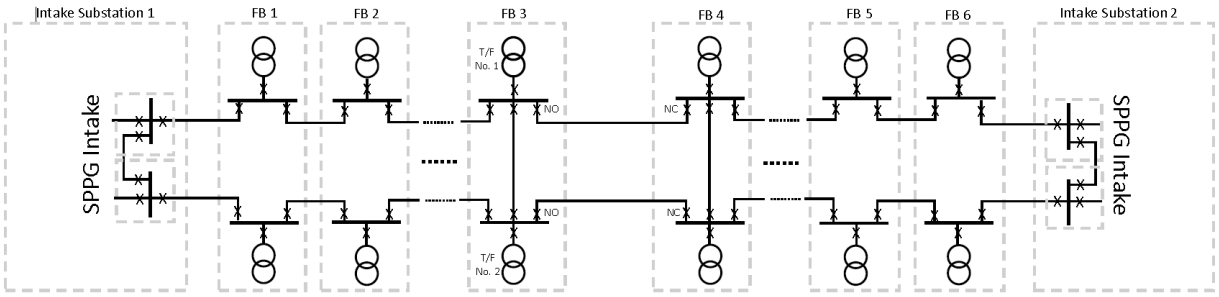

Diagram 5.5.1c. - 2

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CHAPTER 6 FIREFIGHTING SYSTEMS

6.1 GENERAL

Fixed water-based fire-fighting systems, namely foam, water mist or deluge systems, shall be provided in road tunnels as part of an integrated approach to the management of fire protection and fire life safety risks.

6.2 PORTABLE EXTINGUISHERS

6.2.1 General

a. Portable fire extinguishers, where required, shall be constructed in accordance with *SS EN 3*.

b. All portable fire extinguishers, where required to be provided, shall be selected, charged, tested, installed, maintained and properly tagged in accordance with *SS 578*.

6.2.2 Provision

a. The classification of portable fire extinguishers provided shall be selected in accordance with *SS 578* such that the contents within the tunnel concerned can be effectively protected. The size and quantity of these portable fire extinguishers shall comply with the requirements in *SS 578*.

b. Portable fire extinguishers shall be located along the roadway in approved wall cabinets at an interval of not more than 90m.

c. To facilitate safe use by motorists, the maximum weight of each extinguisher shall be 9kg.

6.3 HOSE REEL SYSTEMS

6.3.1 Hose reels

a. Provision

(1) Hose reel(s) shall be provided where the fire hydrant landing valves are located and ensure sufficient coverage within the tunnel complying with the requirements in *SS 575*.

(2) Hose reel(s) shall also be provided to cover the ancillary rooms/ spaces within the tunnel, with the exception of stormwater/ wastewater sumps located under the carriageway.

b. Size and type

The hose shall be of 20mm or 25mm in nominal diameter and conform to *EN 694*, shall not exceed 30m in length and terminate in "shut-off" branches with 4mm or 6mm nozzles.

c. Water supply

(1) Water supply for hose reels shall be taken from the fire hydrant main pipe.

(2) Flow rate and minimum running pressure of the hose reel(s) shall comply with the requirements of *SS 575*.

6.4 FIXED WATER-BASED FIRE-FIGHTING SYSTEM (FFFS)

6.4.1 General

a. The goal of a fixed water-based fire-fighting system (FFFS) is to slow, stop, or reverse the rate of fire growth or otherwise mitigate the impact of fire to improve tenability for tunnel occupants during a fire condition. At the same time, it is to enhance the ability of first responders to aid in evacuation and engage in firefighting activities, and/ or protect the major structural elements of a tunnel.

b. The performance objective of a fire suppression system is to limit the size of a fire by distribution of extinguishing agent to decrease the heat release rate and pre-wet adjacent combustibles while controlling gas temperatures to avoid structural damage.

c. When a FFFS is installed in road tunnels, it shall be installed, inspected, and maintained in accordance with *NFPA 11*, *NFPA 750*, *SS CP 52*, *SS 575* or other equivalent international standard.

6.4.2 Performance evaluation

a. Fire test protocols

In the case of water-mist system the fire test protocols shall be designed:

(1) in accordance with *Cl.6.4.1b.* and the tunnel parameters stated in *Cl.6.4.3; and*

(2) to replicate and evaluate the range of the application parameters associated with road tunnels.

b. Product approval

System components shall be listed (UL, FM, etc.) or as approved by the SCDF.

c. Impact on other fire safety provision

(1) For the sizing of the emergency ventilation system in accordance with *Chapter 7*, the effect of the FFFS shall be taken into account.

(2) For protection of structural elements, the applicable provisions of *Chapter 3* shall apply unless evidence of the performance of the required structural fire protection by a FFFS is provided and approved by the SCDF.

d. Layout parameters

To achieve the design objectives in accordance with *Cl.6.4.1a.* discharge device coverage, spacing, positioning, spray characteristics, working pressure, and flow rates shall be determined by use of applicable codes, standards, or accepted practices, or where necessary, by an engineering analysis considering relevant available data resulting from full-scale tunnel fixed water-based fire-fighting tests of the type of FFFS being used.

6.4.3 Tunnel parameters

a. General

Tunnel parameters shall be the features of the tunnel that affect the design of a fixed water-based fire-fighting system.

b. Tunnel geometry

The tunnel geometry (width, ceiling height, obstruction location) shall be considered when selecting such parameters as nozzle location and nozzle positioning.

c. Ventilation

Ventilation considerations shall include natural and fire-induced forced ventilation parameters.

d. Obstructions and shielding

The presence of obstructions and the potential for shielding of water-based fire-fighting system discharge shall be addressed to ensure that system performance is not affected.

6.4.4 System design and installation documentation

a. Design objectives and tunnel parameters

The system design and installation documentation shall identify the design objectives and tunnel parameters over which the system performance evaluation is valid.

b. Safety factors

System documentation shall clearly identify engineering safety factors incorporated into the overall system design. Safety factors of at least 2 (heat release rate) shall be required to ensure that installed system performance exceeds the performance of the system as tested in accordance with *Cl.6.4.1b.*.

6.4.5 Engineering design requirements

a. When a FFFS is included in the design of a road tunnel, the impact of this system on other measures that are part of the overall safety concept shall be evaluated. At a minimum, this evaluation shall address the following:

(1) Impact on tenability, including reduction in stratification and visibility upstream of the fire.

(2) Integration with other tunnel systems, including the following:

(a) Fire detection and alarm system

(b) Tunnel ventilation system

(c) Traffic control and monitoring systems

(d) Visible emergency alarm notification

(e) Protection of structure elements

(3) On-going system maintenance, periodic testing, and service requirements.

6.5 AUTOMATIC ELECTRICAL FIRE ALARM SYSTEM

6.5.1 Provision

a. Tunnels described in categories B and C as shown in *Table 1.4A* shall have at least two independent means of identifying and locating a fire.

b. Tunnels described in categories B and C shall have an automatic electrical fire alarm system in accordance with *Cl.6.4.2*. Ancillary rooms/ spaces within such tunnels (such as pump rooms) shall be supervised by automatic electrical fire alarm systems in accordance with *Cl.6.4.2*.

c. Closed-circuit television (CCTV) systems with traffic flow indication devices or surveillance cameras shall be permitted for use to identify and locate fires in tunnels with 24-hr supervision.

d. When an approved FFFS is installed in road tunnels, an automatic electrical fire alarm system shall be provided in accordance *Cl.6.4.2*.

e. Automatic electrical fire alarm systems within a tunnel shall be zoned to correspond with the tunnel ventilation zones and FFFS zones where either, or both, of these systems are provided.

6.5.2 Installation

The automatic electrical fire alarm system shall be installed in accordance with the requirements of the *SS 645* except as herein modified:

a. The main fire alarm panel serving the tunnel shall be located in the OCC within the tunnel facility building. If there is no OCC within the tunnel facility building, the panel shall be sited in a position clearly visible from the main entrance lobby.

b. Where there are more than one facility building serving the tunnel, the main fire alarm panel serving the tunnel shall be located in the OCC.

c. Automatic fire detection systems shall be able to provide detection in the early stages of a developing fire within the tunnel under anticipated air velocity.

d. Automatic electrical fire alarm systems shall be able to provide detection within the tunnel under anticipated air velocity.

6.5.3 Manual call points

a. Manual call points shall be provided at each niche, see *Diagram 6.5.4a.(1)* housing fire protection equipment and in ancillary rooms/ spaces within tunnels described in Categories B and C as shown in *Table 1.4A*.

b. Tunnel manual call points shall be located between 1m to 1.4m above the walkway level.

c. Wordings on manual call points shall comply with *SS 508*.

6.5.4 Alarm device

a. General

(1) Alarm devices within tunnels described in categories B and C as shown in *Table 1.4A* shall be provided at each niche housing fire protection equipment. See *Diagram 6.5.4a.(1)*.

(2) The alarm device, which should normally issue an audible or visible signal, unless specifically allowed or required otherwise by the SCDF, shall be actuated if the electrical fire alarm system is activated or operated. The type of the alarm device shall comply with the requirements in *SS 645*.

(3) All sounders and visual alarm signals devices in the tunnel shall be actuated simultaneously in the incident bound in the event of an activation. However, in cases permitted or required by the SCDF where the operation of alarm sounders is grouped or activated in stages, the arrangement shall comply with the requirements in *SS 645*.

(4) The height of tunnel visual alarms shall be between 1.5m and 2.1m above the walkway level.

b. Audio alarm

The fire alarm sounder shall provide the audio alarm which shall have a sound that is readily distinguishable from any other alarm systems.

c. Visual alarms

(1) Visual alarms shall be provided in addition to the audible alarms for tunnels protected by fire alarm systems.

(2) Visual alarms shall comply with all of the following requirements:

(a) They shall take the form of a flashing beacon or strobe light for use in conjunction with the conventional fire alarm system.

(b) They shall be clearly distinguishable from any other visual indicator used in the premises.

(c) They shall be labelled with the word "Fire" of at least 15mm in height and lettering colour shall contrast with the background.

(d) The flashing rate shall be within 30 to 130 flashes per minute.

(e) The visual alarm signal shall be in white or red.

(f) The flashing of all visual alarm signals within the tunnel shall be synchronised.

(g) The intensity of the light signal shall be sufficient to draw the attention of people in the vicinity.

6.5.5 Connection to OCC

The electrical fire alarm system shall be connected to the OCC.

6.6 FIXED AUTOMATIC FIRE EXTINGUISHING SYSTEMS

6.6.1 Installation

Installation of any fixed automatic fire extinguishing systems which are not deemed to be required by this Code shall not be accepted as substitute of any provision stipulated in this Code unless otherwise approved by the SCDF. Such systems will be considered additional protection for property safety and their installation shall not adversely affect the performance of the stipulated systems.

6.6.2 Design standard

The design and installation of such automatic fire extinguishing systems shall comply with corresponding codes of practice acceptable to the SCDF.

6.7 COLOUR SCHEME OF FIRE PROTECTION SYSTEMS

6.7.1 Equipment, fixtures, and fittings

The following equipment, fixtures, and fittings for the fire protection systems shall be painted in red. For those equipment, fixtures, and fittings not listed below, the colour scheme shall be in accordance with that specified in the relevant codes of practice.

a. Fire sprinkler system

(1) Fire pump & control panel

(2) Breeching inlet (excluding breeching inlet cabinet/ enclosure)

(3) Sprinkler control valve

(4) Sprinkler water proofing system/ device

b. Electrical fire alarm system

(1) Main fire alarm panel/ cabinet

(2) Sub fire alarm panel/ cabinet

(3) Manual alarm call point

(4) Visual alarm light housing

(Note: fire alarm bell sounder need not be in red)

c. Private fire hydrant

(1) Wet pillar hydrant (with yellow band in accordance with *SS 575*)

(2) Dry pillar hydrant (whole hydrant in yellow)

d. Dry rising mains

(1) Fire pump & control panel

(2) Breeching inlet (excluding breeching inlet cabinet/ enclosure)

(3) Dry riser breeching inlet in yellow

(4) Landing valve (except dry landing valve to be in yellow)

(5) Rising mains pipe

(6) Standby hose cabinet/ enclosure

e. Hose reel system

(1) Hose reel pump & control panel

(2) Hose reel drum (excluding cabinet/ enclosure)

f. Total flooding fire extinguishing system

Breathing apparatus cabinet/ enclosure

g. Emergency Voice Communication System

Two-way emergency voice communication system signage

h. Fire extinguisher

Housing cabinet/ enclosure

(Note: Alternatively, red graphic signage or red wordings “Fire Extinguisher” of minimum size 20mm shall be provided.)

6.7.2 Pipework, conduits, trunkings, and cable trays

For fire protection systems pipework/ conduits/ trunkings/ cable trays which are not required to be painted in red, red colour bands of width not less than 20mm and labelling shall be provided at an interval of not more than 6m apart.

6.7.3 Graphical symbols

Graphical symbols to depict fire safety equipment are allowed for use in stations provided the signs comply with *SS 508*. Either graphic or text format can be used for the design of the signage. *Table 6.7.3* shows the different sizes of the graphical symbol with respect to the viewing distance.

6.8 REDUNDANCY FOR FIRE PUMPING SYSTEM

The pumping system for hose reels, sprinklers and hydrants shall be provided with redundancy such that the system performance is not affected when one of the pumps and/ or the associated control system is out of operation due to routine maintenance or break-down.

TABLE 6.7.3: SIZES OF GRAPHICAL SYMBOLS				
Viewing Distance	0 to 6m	> 6 to 9m	> 9 to 12m	12m or more
Minimum height of symbol (Z=100)	60mm	90mm	120mm	150mm

Note:

The luminous factor (Z=100) from *SS 563* is used to determine the size of the sign. It essentially dictates the size of the sign that varies with distance. The graphical symbol for firefighting equipment shall be sized such that the height and width are same. The size of symbol is not inclusive of borders.

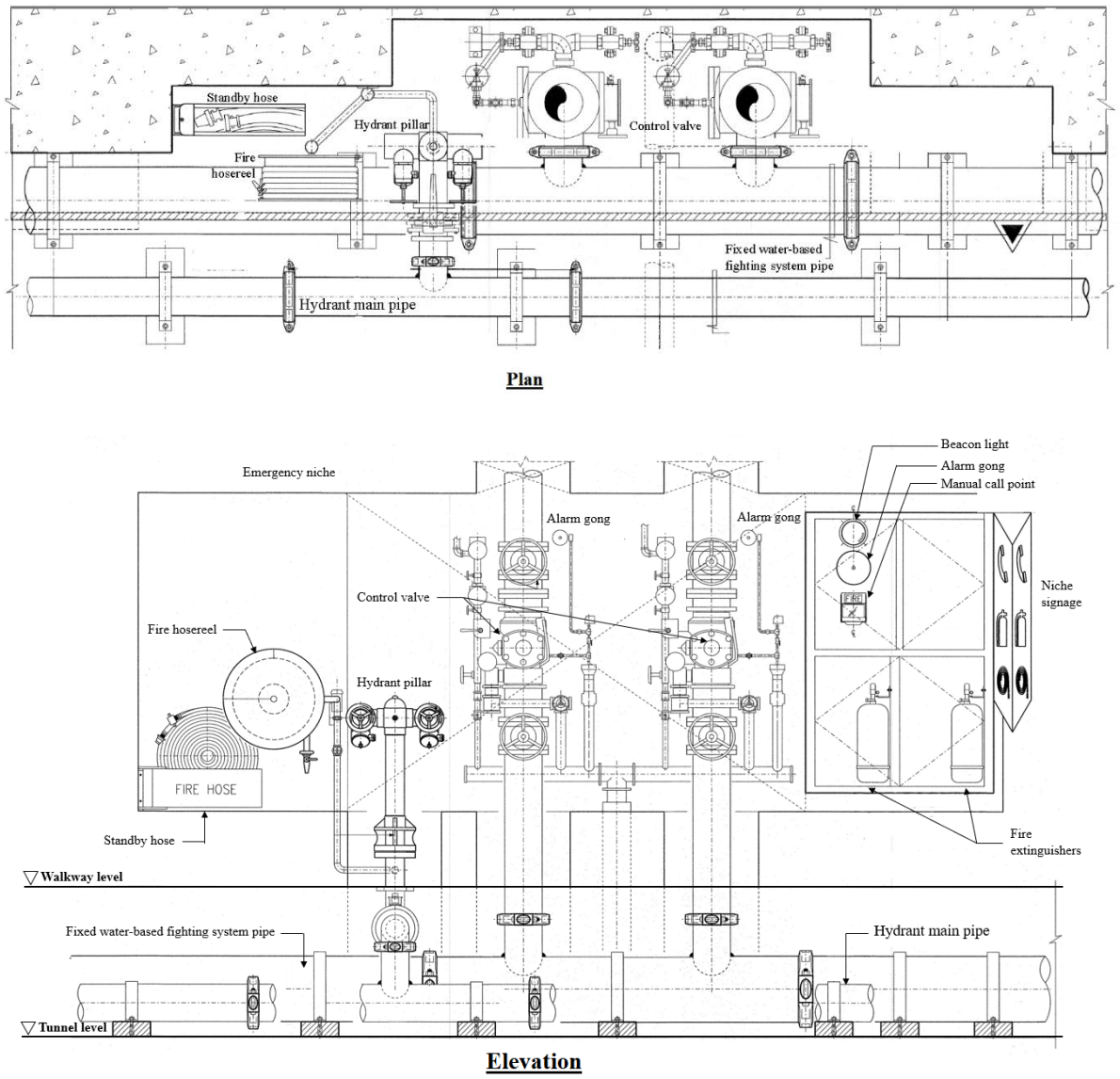

Diagram 6.5.4a.(1) Niche Housing for Fire Protection Equipment

CHAPTER 7 MECHANICAL VENTILATION & SMOKE CONTROL SYSTEMS

7.1 GENERAL

7.1.1 Road tunnel ventilation system

Emergency ventilation systems and tunnel operating procedures shall be developed to maximise the use of the road tunnel ventilation system for the removal and control of smoke and heated gases that result from fire emergencies within the tunnel.

7.1.2 Engineering analysis

For any engineering analysis performed to determine the requirement for tunnel emergency ventilation, potential fires immediately proximate to the tunnel portal, but outside the tunnel, that can have a negative impact on the tunnel environment shall be included in the engineering analysis.

7.1.3 Operational procedures

The emergency ventilation operational procedures shall be designed to assist in the evacuation or rescue, or both, of motorists from the tunnel.

7.2 SCOPE

7.2.1 Tunnels length

Emergency ventilation shall be provided in tunnels exceeding 1000m in length.

7.2.2 Alternative emergency ventilation

Emergency ventilation shall not be required in tunnels less than 1000m in length, where it can be shown by an engineering analysis, using the design parameters for a particular tunnel (length, cross-section, grade, prevailing wind, traffic direction, types of cargoes, design, fire size, etc.), that the level of safety provided by a mechanical ventilation system can be equaled or exceeded by enhancing the means of egress, the use of natural ventilation, or the use of smoke storage, and shall be permitted only where approved by the SCDF.

7.3 SMOKE CONTROL

7.3.1 General

The emergency ventilation system shall provide a means for controlling smoke. The desired goal is to provide an evacuation path for motorists who are exiting from the tunnel and to facilitate firefighting operations.

7.3.2 Bi-directional traffic

In tunnels with bi-directional traffic where motorists can be on both sides of the fire site, the following objectives shall be met:

a. Smoke stratification shall not be disturbed;

b. Longitudinal air velocity shall be kept at low magnitudes; and

c. Smoke extraction through ceiling openings or high openings along the tunnel wall(s) is effective and shall be considered.

7.3.3 Unidirectional traffic

In tunnels with unidirectional traffic where motorists are likely to be located upstream of the fire site, the following objectives shall be met:

a. Longitudinal systems

Control backlayering by producing a longitudinal air velocity that is calculated on the basis of critical velocity in the direction of traffic flow.

b. Transverse or semi-transverse systems

(1) Maximise the exhaust rate in the ventilation zone that contains the fire and minimise the amount of outside air that is introduced by a transverse system.

(2) Create a longitudinal airflow in the direction of traffic flow by operating the upstream ventilation zone(s) in maximum supply and the downstream ventilation zone(s) in maximum exhaust.

7.4 DESIGN

7.4.1 Objective

The design objectives of the emergency ventilation system shall be to control, to extract, or to control and extract smoke and heated gases as follows:

a. A stream of non-contaminated air is provided to motorists in path(s) of egress in accordance with the anticipated emergency response plan (see *Annex 7A*).

b. Longitudinal airflow rates are produced to control backlayering of smoke in a path of egress away from a fire (see *Annex 7B*).

7.4.2 Basis of design

The design of the emergency ventilation system shall be based on a fire scenario having defined heat release rates, and smoke release rates, all varying as a function of time. The selection of the fire scenario shall consider the operational risks that are associated with the types of vehicles expected to use the tunnel. The fire scenario shall consider fire at a location where the most stringent ventilation system performance requirement is anticipated by an engineering analysis.

a. The design fire size (heat release rate produced by a vehicle(s)) shall be used to design the emergency ventilation system.

b. The selection of the design fire size (heat release rate) shall consider the types of vehicles that are expected to use the tunnel and whether the tunnel is fitted with other fire-life safety systems including, but not limited to, FFFS, fire detection systems, and activation systems, and whether the other fire-life safety systems allow for mitigation of the design fire scenario.

7.5 VENTILATION FANS

7.5.1 Fire resistance rating

a. Emergency ventilation fans, their motors, and all components critical to the operation of the system during a fire emergency that can be exposed to elevated temperatures from the fire shall be designed to remain operational for a minimum of 2-hr at a temperature of 250°C.

Exception:

(1) The reduction of emergency ventilation fan rating to remain operational for 1-hr at a temperature of 250°C is allowed provided a FFFS is fitted in the tunnel to control the fire size.

b. Where design calculations carried out as required in *Cl.7.4.2* show that the equipment will be exposed to higher temperatures, those higher temperatures shall be used for the equipment selection.

7.5.2 Redundancy

Emergency ventilation system shall be sized such that in the event one of the fans fails or is taken out of service, the remaining fans shall be capable to meet the minimum ventilation requirements. Emergency ventilation fans, such as jet fans, that can be directly exposed to fire within the tunnel roadway shall be considered expendable. The design of emergency ventilation systems where fans can be directly exposed to a fire shall incorporate fan redundancy.

7.5.3 Design parameters

a. The emergency ventilation system shall be capable of reaching full operational mode within a maximum of 180 secs of activation.

b. Reversible fans shall be capable of completing full rotational reversal within 90 secs.

7.5.4 Discharge openings

a. Discharge and outlet openings for emergency fans shall be positioned away from any supply air intake openings to prevent recirculation.

b. Where separation is not possible, intake opening shall be protected by others approved means or devices to prevent smoke re-entering the system.

7.6 DAMPERS

7.6.1 Rating

a. All dampers, actuators, and accessories that are exposed to the elevated exhaust airstream temperature from the roadway fire shall be designed to remain fully operational in an airstream temperature of 250°C for at least 2-hr.

Exception:

(1) The reduction of dampers, actuators, and accessories rating to remain operational for 1-hr at a temperature of 250°C is allowed provided FFFS is fitted in the tunnel to control the fire size.

b. Where design calculations carried out as required in *Cl.7.4.2* show higher temperatures, those higher temperatures shall be used for equipment selection.

7.6.2 Design

a. All moving and other critical components of the damper shall be designed to allow for expansion and contraction throughout the maximum anticipated temperature range.

b. The bearings of multi-bladed dampers shall be located outside of the airstream.

c. The actuators and bearings shall be isolated from the heated airstream.

d. The requirements of *Cl.7.6.2b.* and *Cl.7.6.2c.* shall not apply where the application warrants a special type of bearing, or where it is impossible to locate the bearings in a position that is clear of the airstream.

e. All other dampers designed for use during a fire emergency shall be equipped with power actuators that are capable of being manually or automatically controlled.

7.7 SOUND ATTENUATORS

7.7.1 Rating

a. Sound attenuators that are located in the elevated airstream from the roadway, such as those used in semi transverse exhaust systems and fully transverse exhaust ducts, shall be capable of withstanding an airstream temperature of 250°C for at least 2-hr.

Exception:

(1) The reduction of sound attenuators rating to remain operational for 1-hr at a temperature of 250°C is allowed provided FFFS is installed in the tunnel to control the fire size.

b. Where design calculations carried out as required in *Cl.7.4.2* show higher temperatures, those higher temperatures shall be used for equipment selection.

7.7.2 Design

a. All components of the attenuator shall remain structurally intact and in place after the required 2-hr of operation.

b. The sound-absorbing fill material used in the baffles shall be non-combustible, non-toxic, and stable at the temperatures as stated in *Cl.7.7.1*.

7.8 CONTROLS

7.8.1 Local control

a. The fans shall be locally controllable in addition to any automatic or remote control so that the equipment can be manually operated. Where both the local and remote controls provide the capability to operate the fans in an emergency mode, local control shall be capable of overriding remote control.

b. Local control shall be the switching devices at the motor control.

7.8.2 Isolation of control devices

Control devices including motor starters, motor drives and motor disconnects shall be isolated from the fan airstream to the greatest extent practical.

7.9 FLAMMABLE AND COMBUSTIBLE LIQUIDS INTRUSION

7.9.1 General

Prevention of accidental intrusion of flammable and combustible liquids due to spills shall be provided in accordance with *Cl.7.9.2* and *Cl.7.9.3*.

7.9.2 Vehicle roadway terminations

Vent or fan shafts utilised for ventilation of tunnels shall not terminate at grade on any vehicle roadway.

7.9.3 Median and sidetable terminations

Vent and fan shafts shall be permitted to terminate in the centre median of divided highways, on sidetable designed to accept such shafts, or in open space areas, provided:

a. The grade level of the centre median, sidetable, or open space is at a higher elevation than the surrounding grade level.

b. The grade level of the centre median, sidetable, or open space is separated from the roadway by a concrete curb of at least 152.4mm in height.

ANNEX 7A

TEMPERATURE AND VELOCITY CRITERIA

A.1 GENERAL

This annex provides criteria for the protection of motorists and firefighters with regard to air temperature and velocity during emergency situations.

A.2 AIR TEMPERATURE CRITERIA

Motorists should not be exposed to maximum air temperatures that exceed 60°C during emergencies. It is anticipated that an air temperature of 60°C places a physiological burden on some motorists, but the exposure also is anticipated to be brief and to produce no lasting harmful effects.

A.3 AIR VELOCITY CRITERIA

The purpose of ventilation equipment in a tunnel emergency is to sweep out heated air and to remove the smoke caused by fire. Essentially all emergency cases, protection of the motorists is enhanced by prompt activation of emergency ventilation procedures as planned.

When ventilation air is needed in evacuation routes, it might be necessary to expose motorists to air velocities that are high. The only upper limit on the ventilation rate occurs when the air velocity is great enough to create a hazard to persons walking in such an airstream. According to the descriptions of the effects of various air velocities in the Beaufort scale, motorists under emergency conditions can tolerate velocities as great as 11m/sec.

The minimum air velocity within a tunnel section that is experiencing a fire emergency should be sufficient to control backlayering of smoke (i.e., the flow of smoke in the upper cross-section of the tunnel in the opposite direction of the forced ventilation air).

Increasing the airflow rate in the tunnel decreases the airborne concentration of potentially harmful chemical compounds (referred to by the general term smoke). The decrease in concentration is beneficial to people exposed to smoke. The effectiveness of an emergency ventilation system in providing a sufficient quantity of noncontaminated air and in minimizing the hazard of smoke backlayering in an evacuation pathway is a function of the fire load. The fire load in a tunnel result from the burning rate of a vehicle(s), which, in turn, is a function of the combustible load of the vehicle.

ANNEX 7B

SMOKE CONTROL

B1 GENERAL

This annex provides criteria for the protection of motorists, tunnel operational staffs, and firefighters with regard to air temperature and velocity during emergency situations.

B.1.2 DETERMINING VELOCITY CRITERIA

Longitudinal air velocity is an important design parameter for smoke control in road tunnels. The required longitudinal velocity typically establishes the longitudinal tunnel ventilation system's required capacity. Important definitions related to longitudinal velocity for smoke control include backlayering, critical velocity, or confinement velocity.

a. Backlayering is the movement of smoke and hot gases counter to the direction of the ventilation system's airflow, see *Diagram B.1.2a.*

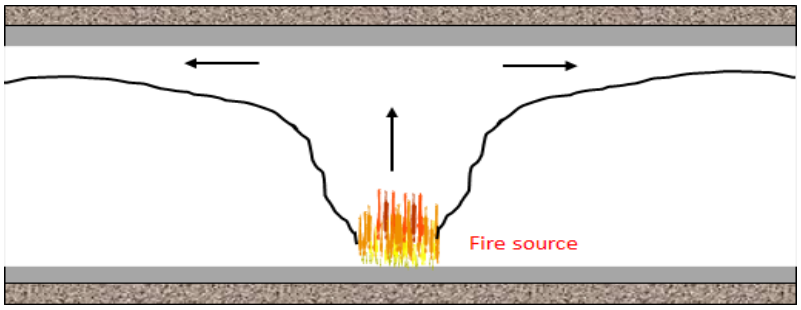

Diagram B.1.2a.: Smoke spread with insufficient ventilation or no ventilation

b. Critical velocity is the minimum steady-state velocity of the ventilation system's airflow moving toward a fire within a tunnel or passageway required to control backlayering at the fire site, see *Diagram B.1.2b.*

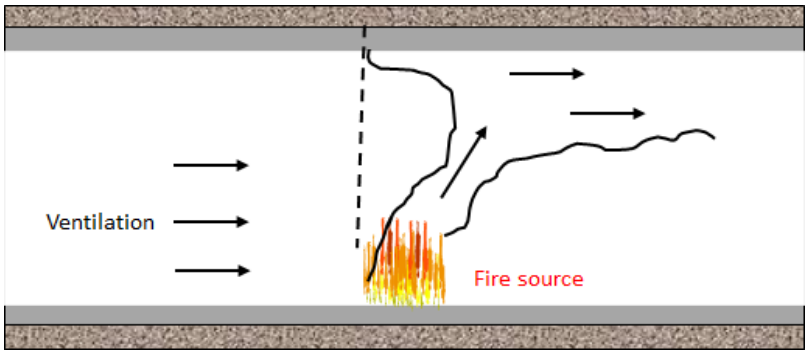

Diagram B.1.2b.: Ventilated tunnel fire with smoke backlayering prevented

c. Confinement velocity is the steady-state velocity of the longitudinal ventilation airflow moving toward a fire within a tunnel or passageway that controls the backlayering distance, see *Diagram B.1.2c.*

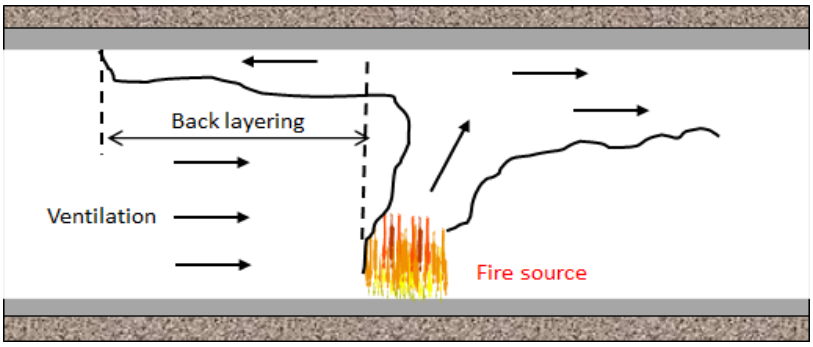

Diagram B.1.2c.: Ventilated tunnel fire with smoke backlayering distance confined

The tunnel ventilation capacity and control system should be designed to quickly establish the air velocity required to gain authority over fire-generated smoke, thereby enabling tunnel occupants to safely egress and firefighters to conduct firefighting and rescue operation.

The operational priority of the ventilation system is the rapid achievement of authority over smoke propagation to establish and maintain a tenable environment in the areas where motorists might be stopped due to the fire, in anticipated motorist evacuation paths, and in planned access routes for emergency responders. This operational priority can be met by confining smoke backlayering to the vicinity of a fire.

The confinement velocity can be found using *C.3.2 Zone of tenability* of this standard.

For example, for a fire with a high fire heat release rate (HRR) (on the order of 100MW), a confinement velocity capable of limiting the backlayering distance to within 30m of the fire location can be considered acceptable, while for a fire with a low HRR (on the order of 20MW), the goal can be to control backlayering.

B2 METHODS FOR DETERMINING CRITICAL AND/ OR CONFINEMENT VELOCITY

The methods for determining the critical/ confinement velocity vary in sophistication and shall include equation-based calculations or numerical modelling [such as three-dimensional (3D) computational fluid dynamics (CFD)].

B.2.1 Equation-based Calculation

The simultaneous solution of the following equations, by iteration, determines the critical velocity. The critical velocity, V_c, is the minimum steady state velocity of the ventilation air moving toward a fire that is necessary to control backlayering.

$$V_c = K_1 K_g \left(\frac{gHQ}{\rho C_p A T_f} \right)^{\frac{1}{3}}$$ -------- (1)

$$T_f = \left(\frac{Q}{\rho C_p A V_c} \right) + T$$ ---------- (2)

$$K_g = \begin{cases} 1 + 0.0374(G)^{0.8}, & G < 0 \\ 1, & G \geq 0 \end{cases}$$ -------(3)

V_c = Critical velocity (m/s)

A = Annulus area (not including the area of blockages, such as vehicles) perpendicular to the flow (m^2)

C_p = Specific heat of air (kJ/kg/K)

g = Acceleration due to gravity (m/s^2)

G = Absolute value of tunnel grade as a percent

K_g = Grade factor

H = Height from base of fire to the tunnel ceiling at the fire site, not tunnel height (m)

K_1 = Froude number factor with a constant value of 0.606 Refer to *Table B1*

ρ = Average density of the approach (upstream) air (kg/m^3)

Q = Convective heat the fire adds directly to air at the fire site (kW)

T = Temperature of the approach air (K)

T_f = Average temperature of the fire site gases (K)

Table B1 A range of K_1 values that apply for various HRRs

Table B1: A RANGE OF K_2 VALUES THAT APPLY FOR VARIOUS HRRs	
Q (MW)	**K_1**
> 100	0.606
90	0.62
70	0.64
50	0.68
30	0.74
< 10	0.87

B.2.2 CFD Numerical Simulation

CFD modelling has been widely used by engineers for tunnel fire safety design. It is particularly useful in complex scenarios (e.g., areas with wide tunnels, fixed firefighting systems, blockages, distinct fuel types and confinement velocity) where equations like those presented herein might not be as accurate. The emergency ventilation system shall provide a tenable environment *(Annex 7C)* along the paths of egress in the incident and non-incident tunnel.

ANNEX 7C

TENABLE ENVIRONMENT

C.1 GENERAL

The purpose of this appendix is to provide fire safety requirements for the details of the tenable environment.

C.2 ENVIRONMENTAL CONSIDERATION

Some factors that shall be considered in maintaining a tenable environment for periods of short duration are defined as follows:

C.2.1 Heat effects

Exposure to heat can lead to life threat three basic ways:

a. Hyperthermia

b. Body surface burns

c. Respiratory tract burns

For use in the modelling of life threat due to heat exposure in fires, it is necessary to consider only two criteria – the threshold of burning of the skin and the exposure at which hyperthermia is sufficient to cause mental deterioration and thereby threaten survival.

Note that thermal burns to the respiratory tract from inhalation of air containing less than 10% by volume of water vapor do not occur in the absence of burns to the skin or the face; thus, tenability limits with regard to skin burns normally are lower than for burns to the respiratory tract. However, thermal burns to the respiratory tract can occur upon inhalation of air above 60°C that is saturated with water vapor.

The tenability limit for exposure of skin to radiant heat is approximately 2.5 kW/m^2. Below this incident heat flux level, exposure can be tolerated for 30 minutes or longer without significantly affecting the time available for escape. Above this threshold value, the time to burning of skin due to radiant heat decreases rapidly according to equation (1).

(1) $$t_{Irad} = 4q^{-1.35}$$

where: t_{Irad} = time in minutes
q = radiant heat flux in kW/m^2

As with toxic gases, an exposed occupant can be considered to accumulate a dose of radiant heat over a period of time. The fraction equivalent dose (FED) of radiant heat accumulated per minute is the reciprocal of t_{Irad}.

Radiant heat tends to be directional, producing localised heating of particular areas of skin even though the air temperature in contact with other parts of the body might be relatively low. Skin temperature depends on the balance between the rate of heat applied to the skin surface and the removal of heat subcutaneously by the blood. Thus, there is a threshold radiant flux below which significant heating of the skin is prevented but above which rapid heating occurs.

Based on the preceding information, it is estimated that the uncertainty associated with the use of equation (1) is ±25%. Moreover, an irradiance of 2.5 kW/m^2 would correspond to a source surface temperature of approximately 200°C, which is most likely to be exceeded near the fire, where conditions are changing rapidly.

Calculation of the time to incapacitation under conditions of exposure to convected heat from air containing less than 10 percent by volume of water vapor can be made using either equation (2) or equation (3).

As with toxic gases, an exposed occupant can be considered to accumulate a dose of convected heat over a period of time. The FED of convected heat accumulated per minute is the reciprocal of t_{Iconv}.

Convected heat accumulated per minute depends on the extent to which an exposed occupant is clothed and the nature of the clothing. For fully clothed subjects, equation (2) is suggested:

$$t_{Iconv} = (4.1 \times 10^{8})T^{-3.61} \quad (2)$$

where: t_{Iconv} = time in minutes
T = temperature in °C

For unclothed or lightly clothed subjects, it might be more appropriate to use equation

$$t_{Iconv} = (5 \times 10^{7})T^{-3.4} \quad (3)$$

where: t_{Iconv} = time in minutes
T = temperature in °C

Equations (2) and (3) are empirical fits to human data. It is estimated that the uncertainty is 25%.

Thermal tolerance data for unprotected human skin suggest a limit of about 120°C for convected heat, above which there is, within minutes, onset of considerable pain along with the production of burns. Depending on the length of exposure, convective heat below this temperature can also cause hyperthermia.

The body of an exposed occupant can be regarded as acquiring a “dose” of heat over a period of time. A short exposure to a high radiant heat flux or temperature generally is less tolerable than a longer exposure to a lower temperature or heat flux. A methodology based on additive FEDs similar to that used with toxic gases can be applied. Providing that the temperature in the fire is stable or increasing, the total fractional effective dose of heat acquired during an exposure can be calculated using equation (4):

$$FED = \sum_{t_1}^{t_2} (1/ t_{Irad} + 1/ t_{Iconv})\Delta t$$

Note 1: In areas within an occupancy where the radiant flux to the skin is under 2.5 kW/m^2, the first term in equation (4) is to be set at zero.

Note 2: The uncertainty associated with the use of this last equation would be dependent on the uncertainties with the use of the three earlier equations.

The time at which the FED accumulated sum exceeds an incapacitating threshold value of 0.3 represents the time available for escape for the chosen radiant and convective heat exposures.

C.2.2 Air carbon monoxide content

Maximum of 2000ppm (parts per million) for a few seconds, averaging 1500ppm or less for the first 6 mins of the exposure, averaging 800ppm or less for the first 15 mins of the exposure, averaging 50ppm or less for the remainder of the exposure.

C.2.3 Smoke obscuration levels

Smoke obscuration levels shall be continuously maintained below the point at which a sign internally illuminated at 80 lux is discernible at 30m and doors and walls are discernible at 10m. This is equivalent to a light attenuation coefficient of 0.267 per metre.

C.2.4 Air velocities

Air velocities in the enclosed road tunnel shall be greater than or equal to 0.76m/s and less than or equal to 11.18m/s.

C.2.5 Noise levels

Maximum of 115dBA for a few secs, maximum of 92dBA for the remainder of the exposure.

C.3 GEOMETRIC CONSIDERATION

Some factors that shall be considered in establishing a tenable environment in tunnels are as follows:

C.3.1 Smoke layer height

The evacuation path requires a height clear of smoke of at least 2m. The current precision of modelling methods is within 25%. Therefore, in modelling methods a height of at least 2.5m shall be maintained above any point along the surface of the evacuation pathway.

C.3.2 Zone of tenability

The application of tenability criteria at the perimeter of a fire is impractical. The zone of tenability shall be defined to apply outside a boundary away from the perimeter of the fire. This distance will be dependent on the fire heat release rate and could be as much as 30m.

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CHAPTER 8 EMERGENCY LIGHTING & VOICE COMMUNICATION SYSTEMS

8.1 EXIT LIGHTING AND EXIT SIGN

8.1.1 Exit lighting

a. Exits of road tunnels shall be provided with artificial lighting facilities to the satisfaction of the requirements under this Code.

b. The minimum illuminance to be provided for all exits and the spacing for luminaires shall be in accordance with the requirements in *SS 563*.

c. The delay between the failure of the electrical supply to normal lighting and the energisation of the exit lighting shall not exceed 0.5 sec.

8.1.2 Emergency lighting

a. Emergency lighting shall be provided within the road tunnel, corridors, lobbies, exits and maintained in accordance with *SS 563*, *CIE 88* and *BS 5489 Pt 2*.

b. Emergency lights, exit lights, and essential signs shall be included in the emergency lighting system and shall be powered by an emergency power supply.

c. Emergency luminaires, exit lights, and signs shall be wired from emergency distribution panels in separate cable containment.

d. Emergency lighting levels for roadways and walkways shall be maintained in those portions of the tunnel that are not involved in an emergency.

e. The delay between the failure of the electrical supply to normal lighting and the energisation of the emergency lighting shall not exceed 0.5 sec.

f. The emergency illumination level to be provided for roadway and walkway surfaces shall be a minimum average maintained value of 10 lux and, at any point, not less than 1 lux, measured at the roadway and walkway surface.

g. A maximum-to-minimum illumination uniformity ratio of 40 to 1 shall not be exceeded.

h. Fire alarm panels, fire alarm call points and firefighting equipment shall be adequately illuminated at all times so that they can be readily located.

8.1.3 Secondary source of power supply

a. The delay or interruption for energization of the lighting levels shall not be greater than 0.5 sec.

b. Emergency lights, exit lights, and essential signs shall be included in the emergency lighting system and shall be powered by an emergency power supply.

c. Emergency luminaires, exit lights, and signs shall be wired from emergency distribution panels in separate raceways.

8.1.4 Exit sign

a. Externally illuminated exit signs shall be illuminated by not less than 54 lux and employ a contrast ratio of not less than 0.5.

b. Internally illuminated exit signs shall produce a minimum luminance of 8.6 cd/m^2 (2.5 fl).

8.2 EMERGENCY VOICE COMMUNICATION SYSTEM(S)

8.2.1 System components

The emergency voice communication system for a road tunnel shall be provided for road tunnels longer than 300m and shall comprise the following:

a. Two-way emergency voice communication system

b. Radio communication system

c. Frequency Modulation (FM) Radio Re-Broadcast and Break-In (RBBI) System

8.2.2 Two-way emergency voice communication system

a. The two-way emergency voice communication system is to provide two-way voice communication between the remote handsets and the master handset during emergency operations. The use of an Emergency Telephone System (ETS) is permitted to be used as a two-way emergency voice communication system.

b. The ETS shall be in the form of a network of telephone handsets located at designated areas in road tunnels and shall be connected to the master handset at the road tunnel's Operations Control Centre (OCC).

c. The system shall be continuously monitored for equipment and line failures. There shall be visual indicators and an audio alarm when any failure is detected. A fault in any of the remote handsets shall not affect the communication of the master handset with other remote handsets.

d. The ETS system shall have a master handset in OCC and remote handsets located in the designated areas in the road tunnels.

e. Master handset can be in the form of a workstation and shall have the following:

(1) Handset selector switches (or icons) for individual remote handsets selection, de-selection or put the remote handset for private-line connection.

(2) “Call-in”, “On-hold” and “On-line” visual indicators for each remote handset and a common distinct “Call-in” audible signal for all handsets;

(3) Individual audio and visual fault indicator for each remote handset; and

(4) A common audio and visual fault indicator.

f. Remote handsets shall be:

(1) installed at every 100m in the road tunnels.

(2) housed in an enclosure with front panel marked with the word “SOS phone” and the word shall be in red lettering on contrasting background of at least 200 mm in height. The word “SOS” in white lettering on red background is also acceptable. The enclosure shall have an ingress protection of at least IP65.

(3) accompanied with a visible identification number plate and an instruction for use by motorists and emergency personnel.

g. ETS operational requirements, the ETS:

(1) shall not allow communication between or among remote handsets without the master handset.

(2) calls initiated by remote handsets to the master handset shall be as follows:

(a) The raising of any remote handset from its cradle at any location shall activate a distinct audible signal and visual indication at the master handset, indicating an incoming call from the remote handset that initiated the call.

(b) There shall be a reassurance tone in that remote handset to indicate that the system is functioning. Until such time that the master handset at the OCC is raised from its cradle then shall the tone disappear, and communication be enabled.

(c) The raising of the master handset at the OCC shall silence the audible signal and put the call on queue with a message played at the remote handset when the operators are engaged.

(d) Since a remote handset could be accidentally left off-hook, particularly in an emergency, this shall not jeopardise the correct operation of the remaining handsets of the ETS system.

Note:

Private-line: A built-in facility in the ETS whereby private conversation between the master handset at the OCC and any one remote handset can be affected through the selector switches.

Indicators: All indicators shall be by means of separate light-emitting indicators and/ or an alphanumeric/ graphic display. No filament lamps shall be used for visible indication. Fault indicators shall be in yellow, while the other status indicator shall be either red or green. The indicator on alphanumeric/ graphic display do not require the use of different colours.

8.2.3 Voice recording system

a. The voice recording system of not less than 120 min of continuous recording duration shall be provided at the OCC to record simultaneously and separately all voice traffic over the ETS.

b. The recording system shall automatically start recording upon the activation of the ETS. The recording shall continue to operate until it is manually reset.

c. The recording system shall only be made accessible to authorised persons.

8.2.4 Radio communication system

Road tunnels shall be provided with radio (voice and data) communication facilities capable of operating in the frequency band as allocated to SCDF and approved by the authority having jurisdiction.

8.2.5 Frequency Modulation (FM) Radio Re-Broadcast and Break-In (RBBI) System

a. The FM radio RBBI system shall be provided to facilitate the re-broadcast and break-in of local FM stations in tunnel, to give motorists information regarding the nature of the emergency and the actions the motorists should take.

b. The FM radio RBBI system shall be provided with facilities to enable real-time override of FM station broadcast in tunnel.

c. The FM radio RBBI system can also feature a selection of pre-recorded voice messages for broadcasting into the tunnels.

8.2.6 Cables

a. All cable conductions sized to comply with the requirements of the Singapore Standards determined by the authority having jurisdiction

b. Fire-resistant cable shall comply with *SS 299*, except for leaky co-axial (LCX) cable which are required to be flame retardant. Where fire resistance fibre optic cables are to be used, it shall conform to the requirements of *IEC 60331*.

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CHAPTER 9 ADDITIONAL REQUIREMENTS

9.1 GENERAL

This Chapter specifies the additional requirements applicable to road tunnels. These additional requirements shall be read in conjunction with other requirements relevant to *Chapter 1 to 8* of this Code. Where there are conflicting requirements between this chapter and the preceding chapters, the requirements stipulated in this chapter shall take precedence.

9.2 TUNNEL DRAINAGE SYSTEM

9.2.1 General

a. A drainage system shall be provided in tunnel to collect, store, or discharge effluent from the tunnel, or to perform a combination of these functions.

b. The drainage collection system shall be designed to capture spills or hazardous or flammable liquids so that they cannot spread or cause flame propagation such that the length of the road surface drain path from any potential spill point to the drain inlet(s) is minimised.

c. Components of the drainage conveyance and collection system, including the main lines, shall be non-combustible (e.g., steel, ductile iron, or concrete).

d. The drainage conveyance and collection system shall be constructed entirely of non-combustible materials.

e. The drainage conveyance and collection system shall have sufficient capacity to receive, as a minimum, the rate of flow from all design roadway sources without causing flooding of the roadway.

f. The minimum design flow rate shall include, where applicable, the design spill rate of fuel or other hazardous liquids, the fire hydrant system discharge rate, any fixed water-based fire-fighting system discharge rate, environmental sources (rain, etc.), tunnel washing, and any other catchments sharing the tunnel drainage system piping.

g. Where the tunnel roadway drainage system discharges by gravity or by pumped discharge, it shall be provided with a separator, drainage storage capacity, or combination sufficient for the design spill rate for the hazardous liquids.

h. Storage tanks and pump rooms shall be monitored for hydrocarbons.

i. Detection of hydrocarbon in the tunnel drainage effluent shall initiate both a local and a remote alarm.

9.3 OCC

9.3.1 Alternate location

Alternate location(s) shall be provided in the event the OCC is out of service for any reason and shall be equipped or have equipment readily available as required to duplicate the functions of the primary OCC.

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APPENDIX 1	FIRE SAFETY REPORT

1.0 GENERAL

a. Fire Safety Report is to document the provision of fire protection, life safety features and fire safety management in the road tunnel. This report serves as a useful reference to Fire Safety Managers (FSMs), premises owner, Registered Inspectors (RIs), the SCDF and Qualified Persons (QPs) who carry out any subsequent additions and alteration works. Where the nature of the additions and alteration works would require the updating of the Fire Safety Report, the QP shall be responsible to submit revised and updated report to the premises owner and the SCDF.

b. The premises owner shall be responsible to maintain and keep the Fire Safety Report at all times and present to the Qualified Person (QP) upon request. Where any Addition & Alteration works are carried out to the road tunnels, the premises owner shall ensure that changes in the management of fire safety provisions are updated in the Fire Safety Report by the QP. The updated report shall be submitted to SCDF for record.

c. The project QP shall submit the fire safety report when making building plan submission for projects such as:

   (1) Road tunnel length greater than 90m and in accordance with *Table 1.4A*.

   (2) Road tunnel using fire-rated board protection or intumescent paints for structural steel.

   (3) Road tunnel with structural steel members coated with intumescent paint (only item *a., b., d., e. & o*. of paragraph 2 need to be included in the Fire Safety Report).

d. Where there may be presence of corrosive atmosphere that may affect the effectiveness of intumescent paints for protection to structural steel members of road tunnel and fire-rated dry board, such proposal shall be subjected to evaluation of the SCDF.

2.0 CONTENTS OF THE REPORT

The write-up of the report on fire protection and life safety features shall include the following subjects. However, qualified person could expand or modify the report to suit his presentation:

a. project description;

b. fire safety design concept;

c. fire engine accessibility;

d. means of escape;

e. structural fire precautions;

f. control and exhaust of smoke and toxic fumes;

g. firefighting systems;

h. fire alarm system;

i. emergency power supply;

j. emergency evacuation lighting;

k. emergency voice communication system;

l. areas of fire risk;

m. fire scenario;

n. conclusion; and

o. attachments.

3.0 BRIEF EXPLANATORY NOTE FOR OUTLINE REPORT ON FIRE PROTECTION AND LIFE SAFETY FEATURES

a. Project description

A description of the project with brief outline of the facilities provided.

b. Fire safety design concept

This would include the safety design concept incorporated in the project such as the application of design and provision of cross-passages, exit staircases, additional compartment walls/ doors in sectionalising between the incident and non-incident tunnel, detection, suppression and smoke control system in the road tunnel, etc., and other added fire safety features provided over and above the intent of the Code.

c. Fire engine accessibility

This would briefly outline the driveways, emergency lay-by, emergency vehicle passage and emergency access point, to be provided.

d. Means of escape

This would include the description of the escape routes that would be taken by occupants in the tunnel in a fire scenario, besides the provision of the number, type and location of staircases, etc.

e. Structural fire precautions

This would outline the fire resistance rating and the type of structural protection to elements of structures, compartment walls/ floors, types and methods of fire-stoppings to ducts, cavity and curtain walling construction, and types and rating of all fire doors.

f. Control and exhaust of smoke and toxic fumes

This would include the description of the type of system to be provided to exit staircases and escape corridors, etc.

g. Firefighting system

This would include the active protection system such as portable fire extinguishers, hose reels, dry rising mains, suppression system, foam flooding system, fixed/ portable water monitors, fixed water spray, drenchers, etc.

h. Fire alarm system

This would include the provision of passive fire protection system such as automatic fire detection systems (smoke or heat type), "break the glass" fire alarm system. Besides naming the type of automatic system, the description shall also include where the detectors would be generally located in fire risk areas such as main tunnel, slip road and shafts, and how, when any of the systems is activated, the public in the tunnel, the people in the OCC or FCC are alerted.

i. Emergency power supply

This would include the description of how the emergency power system operates in times of loss of normal electric power supply to any part of the tunnel and the areas or systems that will be designed to receive emergency power.

j. Emergency evacuation lighting

This would include the description of the system designed in accordance with *SS 563*, and the location of exit signs etc. and the types of battery system, and designed time for the switchover to emergency lighting system from the time the normal power supply is cut-off.

k. Emergency voice communication system

This would describe the operation of the 2-way zoned and coded voice communication system, which is electrically supervised from the central control located in the OCC or FCC in the absence of which, the main alarm panel.

l. Areas of fire risk

This would briefly describe the areas of fire risk such as main tunnel, slip road, petrol interceptor, etc. and the type of fire protection/ detection system proposed.

m. Fire scenario

Under this subject, the qualified person would have to assume the outbreak of a fire in one of the critical areas and describe the sequence of operation of the fire protection and life safety design features.

n. Conclusion

This would include the summing up of the outline concepts and systems that have been designed for the project.

o. Attachments

(1) Location plans of steel structural members coated with intumescent paint.

(2) Location plans of fire risk areas.

(3) Any other attachments required for the report.

APPENDIX 2 FIRE SAFETY INSTRUCTION MANUAL

1.0 GENERAL

The Fire Safety Instruction Manual is a document prepared by the project QP to remind the premises owner of the management of fire safety provisions for the road tunnel. This includes maintenance regimes, evacuation procedures, and other relevant documents to be kept and maintained by the relevant parties. Any subsequent additions and alteration works shall be updated in the Fire Safety Instruction Manual by the QP carrying out the Addition & Alteration works.

The Fire Safety Instruction Manual, including any subsequent updates, shall be submitted by the project QP to the SCDF for records when making building plan submission. A copy shall be officially handed to the relevant parties for information and safekeeping before occupation of the building.

The QP can expand or modify the Fire Safety Instruction Manual to suit his presentation so as to convey the fire safety intents/ requirements to the relevant parties.

2.0 SCOPE

The QP shall prepare a Fire Safety Instruction Manual if the project involves any of the following:

a. Road tunnel using intumescent paint

b. Fire-rated dry construction

3.0 CONTENTS OF THE MANUAL

The Fire Safety Instruction Manual shall include the following subjects:

a. project description;

b. list of items under paragraph 2 present in this project; and

c. relevant information for each applicable item.

4.0 RELEVANT INFORMATION TO BE INCLUDED IN THE FIRE SAFETY INSTRUCTION MANUAL

4.1 Use of intumescent paints for protection to structural steel members of road tunnels

a. Inspection and maintenance

(1) The operator shall carry out annual inspection checks to ensure that the intumescent paint coatings are not damaged or tampered with. Records of inspections shall be properly kept.

(2) For road tunnels with Fire Certification, the annual renewal of the certificate shall include the inspection of the columns and beams coated with intumescent paint. The inspection shall be carried out by a QP.

b. Addition & alteration works

For addition & alteration works in a road tunnel where structural steel members are protected by intumescent paint, the following requirements shall be complied with:

(1) The premises owner, assisted by the FSM, shall engage a QP who shall submit building plans to the SCDF. The building plans shall be accompanied by the QP's declaration as to whether the existing columns and beams coated with intumescent paint are/ will be affected.

(2) An inspection certificate endorsed by a RI shall be required and kept by the operator.

c. There shall be no highly flammable/ combustible materials stored within the vicinity of any structural steel members protected by intumescent paint.

4.2 Fire-rated dry construction

The premises owner shall engage a QP for any subsequent Addition & Alteration works involving new or existing fire-rated dry construction.

HQ Singapore Civil Defence Force

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