Tunnels: Design and Construction. Safety measures

1 Purpose and scope

The consultation draft for the forthcoming TSI SRT has been used as a basis. The difference between the old and the new TSI SRT is primarily the requirements for the fire durability of tunnel surfaces and the requirements for rescue stations. The forthcoming revision of the TSI SRT is not restricted to tunnels greater than 20 km in length.

The requirements for safety measures have been harmonised with requirements in the new TSI on safety in railway tunnels, the TSI on rolling stock and the TSI on operation and traffic management.

The requirements for subsystems infrastructure and energy have been included in their entirety.

The requirements are to ensure that provision is made to allow passengers and crew to self-evacuate, should an incident occur in a tunnel. The safety measures also cover the risk to people in the neighbourhood of a tunnel where a collapse of the structure could have catastrophic consequences.

The safety measures can be regarded as a response to the following incident scenarios:

- Fire
- Explosion
- Emission of toxic gas
- Collision
- Derailment
- Spontaneous evacuation

It is a prerequisite that the rolling stock is equipped to be capable of driving out of a 20 km long tunnel with a fire on board, and equipped with fire barriers capable of withstanding a fully developed fire for a minimum of 15 minutes and ensuring continued operation for a corresponding length of time.

2 TSI requirements with supplementations

The table below reiterates the requirements of the TSI SRT that apply to subsystems infrastructure and energy and are of consequence to the design of a tunnel and its installations. The table also describes supplementary national requirements.

Requirement no in TSI	Requirement	Applicable to tunnel lengths (m)
	Subsystem infrastructure	
4.2.1.1 Prevent unauthorised access to emergency exits and technical rooms	a) Unauthorised personnel must be prevented from having access to technical rooms and technical installations secured in cabinets. b) Where emergency exits are locked for security purposes, it must always be possible to open these from the inside.	All
4.2.1.2	a) In the event of fire, the strength of the structure must be maintained for a period of time sufficient to permit the self-rescue and evacuation of passengers and crew and the	All

	intervention of the emergency services. This will have been achieved if it can be demonstrated that the structure has maintained its integrity at a temperature of 450°C at ceiling level for the same period of time. This must be in accordance with the evacuation scenario described in the emergency response plan.	
Fire protection of structures	Supplementary requirements: The following functional requirements must be satisfied: • Structures must not actively contribute to a train fire, spread such a fire or continue to burn after the train fire has ceased. • Structures must not contribute to extra smoke development while the fire is ongoing, and must not develop toxic gases.	
4.2.1.3 Fire safety requirements for building material	a) Building material and installations in tunnels must be of low flammability, be non-flammable or be protected from the effects of fire. b) Material for supporting structures must comply with the requirements in classification A2 in EN 13501-1:2002. Non-structural panels and other equipment must comply with the requirements in classification A2 in EN 13501-1:2002.	All
4.2.1.4 Fire detection in technical rooms	a) Technical rooms are closed rooms with doors for access/egress inside or outside the tunnel, with safety installations that are necessary for the following functions: • Self-rescue and evacuation • Emergency communication • Rescue and firefighting operations • Signalling and communication equipment • Traction power supply b) Technical rooms must be fitted with detectors that alert the infrastructure manager in the event of fire.	> 1000 m
4.2.1.5.1 Safe area	a) A safe area must permit evacuation from trains using the tunnel, and can be located adjacent to the tunnel. The area must have a capacity equivalent to the maximum capacity of the trains planned to operate on the line on which the tunnel is located. b) The safe area must provide conditions in which unprotected persons can survive during the time needed to evacuate the safe area (away from the accident scene, e.g. to the surface).	> 1000 m

4.2.1.5.2 Access to the safe area	c) For cases where the safe area is underground or under the sea, the provisions must permit people to move from the safe area to the surface without having to enter the affected tunnel bore. The requirements apply to all tunnels greater than 1000 m in length. a) Safe areas must be accessible for people who commence self-evacuation from the train, as well as for the emergency services. b) One of the following solutions must be selected for access points from a train to safe areas: 1. Lateral and/or vertical emergency exits to the surface, where the surface is a safe area. 2. Cross-passages to an adjacent tunnel bore or other safe area. c) Access to a safe area must be available at least every 1000 m for a double-track tunnel, and at least every 500 m for a single-track tunnel. d) For points (b) and (c) above, alternative measures with an equivalent level of safety are permitted. These must be verified using the Common Safety Method. e) Doors that provide access to safe areas must be a minimum of 1.40 m wide and 2.0 m high. f) The dimensions of lateral and/or vertical emergency exits to the surface must be at least 1.5 m wide and 2.3 m high. g) The emergency response plan must describe how the emergency services can access the safe areas.	> 1000 m
4.2.1.5.3 Means of communications in safe areas	a) Communication must be possible either by mobile telephone or by fixed connection from safe areas underground to the control centre of the infrastructure manager. For specific requirements regarding communication, refer to Kommunikasjonssystemer.	> 1000 m
4.2.1.5.4 Emergency lighting	a) There must be emergency lighting to guide passengers and staff to a safe area in the event of an emergency situation. b) The lighting must satisfy the following requirements: 1. Single-track tunnel: On at least one side (the same side as the walkway)	> 500 m

	2. Double-track tunnel: On both sides 3. Position of lights: Above the walkway, as low as possible, but not so low as to interfere with the free passage of people. Lights can be built into handrails. 4. The illuminance must be at least 1 lux on the horizontal plane at walkway level. c) Autonomy and reliability: An alternative power supply must be available for a given period after a power supply failure. The time required must be consistent with evacuation scenarios described in the emergency response plan. d) If the emergency lighting is switched off under normal operating conditions, it must be possible to switch it on using both of the following methods: • Manually inside the tunnel at intervals of 250 m. • By the tunnel operator using remote control. For the design of electric emergency lighting, refer to Lavspenning/Prosjektering/Belysning|Belysning. For the construction of electric emergency lighting, refer to Lavspenning/Bygging/Belysning|Belysning.	
4.2.1.5.5 Emergency signage	a) Markings must indicate the emergency exits, including the distance and direction to a safe area. b) All markings must be designed in accordance with the requirements of Directive 92/58/EF of 24 June 1992 regarding minimum requirements for health and/or safety signage at worksites and with ISO 3864-1. c) Emergency exit signs must be mounted on the side walls. d) The distance between emergency exit signs must be no greater than 50 m. e) If emergency equipment is available, there must be signs in the tunnel that show the location of this emergency equipment. f) All doors leading to emergency exits or cross-passages must be marked.	All
4.2.1.6 Escape walkways	a) In a single-track tunnel, walkways must be constructed on at least one side of the track. In a double-track tunnel, the walkway must be constructed on both sides of the tunnel. In tunnels with more than two tracks, access to walkways must be possible from each track.	> 500 m

The following requirements apply to gangways:

1. The width of a walkway must be a minimum of 0.8 m.
2. The minimum vertical clearance above a walkway must be 2.3 m.
3. The walkway must be at least on a level with the track.
4. Local obstacles in the escape area must be avoided. Any obstacles must not reduce the minimum width to less than 0.7 m, and the length of such obstacles must not exceed 2 m.

b) Handrails must be installed between 0.8 m and 1.1 m above the walkway and provide access to a safe area.

1. Handrails must be positioned outside the walkway's minimum width.
2. Where handrails encounter an obstacle, they must be angled by between 30° and 40° to the longitudinal direction of the tunnel.

Supplementary requirements:

- Walkways must be located on the same side as emergency lighting and signs.
- Handrails must be made from non-conductive material.
- The width of a walkway must be a minimum of 1.2 m. For tunnels that are infrequently trafficked, the width requirement for walkways can be reduced to at least 0.8 m.
- Local obstacles in the escape area must be avoided. Any obstacles must not reduce the minimum width to less than 0.8 m, and the length of such obstacles must not exceed 2 m.

4.2.7 Designated stopping points for evacuation	The following requirements (4.2.1.7.1 Emergency response points and 4.2.1.7.2 Rescue stations) apply to tunnels that are evaluated on an individual basis. On lines with several successive tunnels, there must be designated stopping points that are accessible with a maximum distance of 5 km from each tunnel portal. A list of the designated stopping points must be provided in the emergency response plan.	
4.2.1.7.1 Emergency response points	a) Emergency response points must be provided outside both portals. b) The emergency response point must be equipped with a water supply (minimum 800 l/min for two hours) close to the train's intended stopping point. The method of supplying the	> 1000 m

	water must be described in the emergency response plan. c) The area around an emergency response point must be large enough to allow passengers to move to a safe location. d) The emergency response point must be accessible to the emergency services. The access routes must be described in the emergency response plan.	
4.2.1.7.2 Rescue station	a) A rescue station must be available at a maximum distance of 20 km from the tunnel portal and from other rescue stations. b) The intended stopping point of the affected train must be indicated to the train driver. This must not require specific on-board equipment (all TSI-compatible trains must be able to use the tunnel). c) A safe area must be accessible from the train's stopping point. The design of evacuation routes to a safe area must take evacuation time into account. d) A safe area associated with a rescue station must have standing room per person of at least 0.5 m^2. e) The rescue station must be equipped with a water supply (minimum 800 l/min for two hours) close to the train's intended stopping point. The method of supplying the water must be described in the emergency response plan. f) It must be possible to switch off the traction power supply and earth the electrical installations of rescue stations. g) Emergency services must have access to rescue stations. Access routes must be described in the emergency response plan (e.g. road access or rescue train). h) Emergency services must be able to gain access to the affected train without having to pass through the safe area. i) The design of rescue stations and their equipment must take into account the control of smoke, in particular to protect people using self-evacuation equipment to gain access to a safe area.	> 20 km
4.2.1.8 Emergency communication	a) There must be radio communication in the form of GSM-R between the train and the control centre in every tunnel. b) The radio coverage must be sufficient to allow the emergency services to communicate with on-site command posts. The system must permit the emergency services to use	> 1000 m

	their own communication equipment. For specific requirements regarding communication, refer to Kommunikasjonssystemer.	
	Subsystem energy	
4.2.2.1 Segmentation of overhead contact line or conductor rails	a) The system that supplies the train with traction power in tunnels must be divided into sections, none of which must exceed 5 km in length. This specification is only applicable if the signalling system permits more than one train to be on each track in the tunnel at the same time. b) The location of switches must be arranged so that there are as few switches in the tunnel as possible. c) Each 'switching section' must have remote control and switches. d) There must be means of communication and lighting at the switching location, so as to enable safe manual operation and maintenance of the switching equipment.	> 5000 m
4.2.2.2 Earthing of overhead contact line or conductor rail	a) There must be earthing devices at the tunnel's access points and, if earthing procedures permit a single section to be earthed, these must be close to the separation points between the sections. They must either be manually fitted or remotely controlled fixed installations. b) There must be lighting and means of communication necessary for earthing operations. c) Procedures and areas of responsibility for earthing must be defined between the infrastructure manager and the emergency services in the emergency response plan.	> 1000 m
4.2.2.3 Power supply	a) The distribution system for electric power in the tunnel must be suitable for the emergency services' equipment, in accordance with the emergency response plan for the rail tunnel.	> 1000 m
4.2.2.4 Requirements for electrical cables in tunnels	a) In the event of fire, exposed cables must have the characteristics of low flammability, low fire spread, low toxicity and low smoke density. These requirements will have been met if the cables comply with EN 50267-2-1 (1998), EN 50267-2-2 (1998) og EN 50268-2 (1999).	> 1000 m
4.2.2.5 Reliability of electrical installations	a) Electrical installations that are relevant to safety (fire detection, emergency lighting, emergency communication and other systems identified by the infrastructure manager or client as essential for the safety of passengers in the rail tunnel) must be protected against damage arising from mechanical impact,	> 1000 m

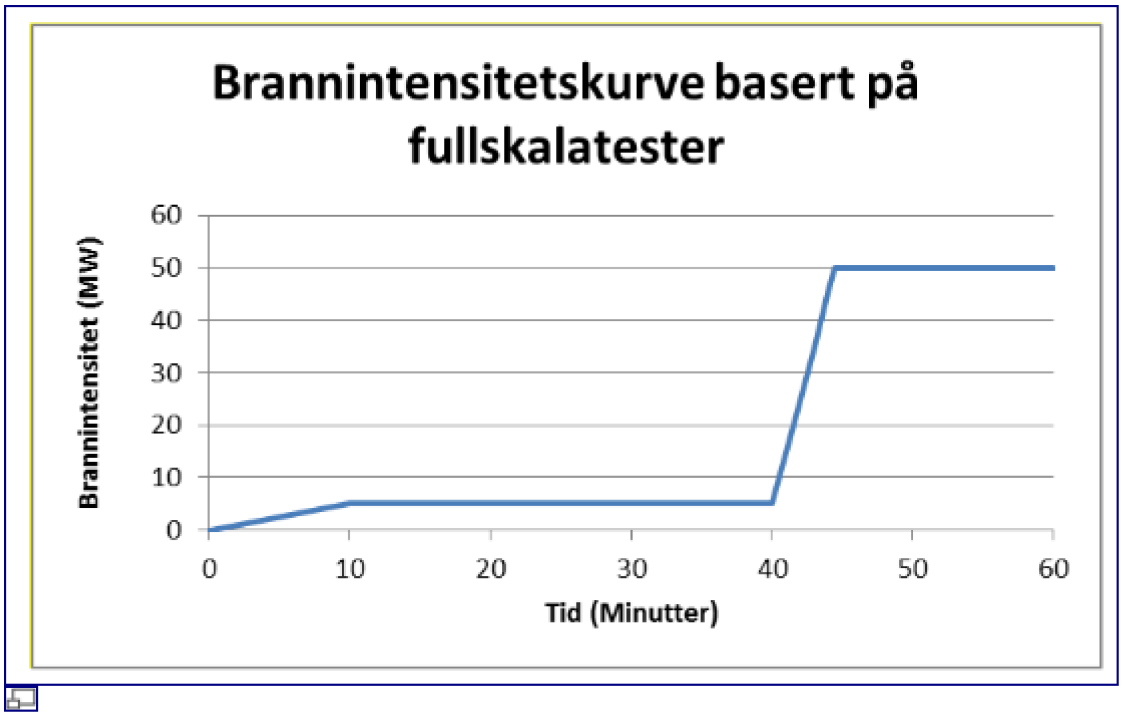
heat or fire.

b) The distribution system must be constructed in such a way that the system can tolerate damage that is unavoidable, by having (for example) an alternative power supply.

c) Autonomy and reliability: An alternative power supply must be available for a given period after a power supply failure. The time required must be consistent with evacuation scenarios described in the emergency response plan.

3 Design fire for evacuation

a) The following fire intensity curve must be used as a basis for designing fire scenarios for passenger rolling stock:



Figur 1: Fire intensity curve for passenger rolling stock with fire retardant properties

4 Ventilation

a) For sections on which diesel trains operate, tunnels longer than 2000 m must be assessed for air quality and ventilation, in order to avoid concentrations of CO and CO_2.

5 Information signs

The requirements apply to tunnels greater than 100 m in length.

a) Signs must be mounted at least every 50 m.

b) Information signs must show:

- Telephone number of traffic control centre

- Direction and distance of nearest tunnel opening/evacuation route
- Direction of tunnel gradient
- Direction designations, A and B.

The signs can continue to be illuminated in emergency situations.

6 Derailment indicators

The requirements apply to tunnels greater than 1000 m in length.

a) Derailment indicators must be fitted in the following cases:

1. Before all double-track tunnels or before sections with several double-track tunnels
2. Before tunnels with crossing tracks

b) Derailment indicators must be fitted to each track, close to the entry signal.

7 Hot box detection

a) Detectors or equipment to prevent hot boxes along the track must be installed at strategic positions on railway networks that include tunnels, so that there is a high probability that hot boxes will be detected before a train enters a tunnel, and will allow a defective train to be stopped before entering a tunnel(s).

The infrastructure manager must indicate hot box detectors and other detectors that prevent hot boxes, and the positions of these along the track, in the infrastructure register. The railway undertaking must include information about these in the description of a section.