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SIA 197/1:2004 Civil Engineering

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REGISTERED STANDARD OF THE SWISS STANDARDS ASSOCIATION

Replaces, together with the SIA 197 and SIA 197/2,
Sections 1 and 2 of the SIA 198, Edition 1993

Projet de tunnels – Tunnels ferroviaires
Progettazione di gallerie – Gallerie ferroviarie
Projektierung Tunnel – Bahntunnel

Design of Tunnels

Railway Tunnels

197/1

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CONTENTS

FOREWORD

The previous Standard SIA 198 *Underground Construction* (1993) mainly dealt with construction procedures; little consideration was given to design.

The present Standards:

- SIA 197 *Design of Tunnels – Basic Principles*
- SIA 197/1 *Design of Tunnels – Railway Tunnels*
- SIA 197/2 *Design of Tunnels – Highway Tunnels*

fill this gap. They are intended for design engineers. They will also be of interest to clients (owners and operators) and those involved in site supervision and construction work.

SIA 197 presents the basic principles to be taken into consideration in the design of traffic tunnels, irrespective of the actual purpose (railway or highway). This includes the various aspects of health and safety and environmental impact. It also includes the requirements for the design of a structure to be constructed underground according to the SIA Structural Standards. The special features that need be considered in the case of highway and rail tunnels are covered in the two specialist Standards SIA 197/1 and SIA 197/2.

In order to simplify application, the three Standards have the same structure up to the titles at the 3rd level. This does, however, frequently lead to the omission of text with only a cross-reference to the other Standard(s).

The requirements for the construction of underground structures are dealt with as before in SIA 198 *Underground Structures – Construction*.

Committee for SIA 197

0 SCOPE

0.1 Limitations

0.1.1 SIA 197/1 *Design of Tunnels – Railway Tunnels* lays down the specific rules for the design of railway tunnels (rail tunnels). These are valid in addition to the provisions of SIA 197.

SIA 197/1 applies to tunnels for standard and narrow gauge, cogwheel and funicular railways.

0.1.2 SIA 197 *Design of Tunnels – Basic Principles* lays down the basic principles for the design of transport tunnels. Operational aspects (use, operation and maintenance) are dealt with only insofar as they are of significance for the design.

0.1.3 The clauses relating to tunnel layout (infrastructure concept) in SIA 197 and 197/1 apply irrespective of whether the tunnel is constructed by a mined or cut-and-cover construction method.

0.1.4 SIA 198 *Underground Structures – Execution* contains the requirements for the construction materials and the principle regulations for construction (lining of underground structures).

0.1.5 SIA 197, 197/1 and 198 may be applied for changes to existing railway tunnels, where appropriate.

0.2 References

See SIA 197.

0.3 General contract conditions

See SIA 197.

0.4 Exceptions

See SIA 197.

1 TERMINOLOGY

1.1 SIA 197/1 uses the same technical terms as defined in SIA 197.

1.2 Technical terms not defined in SIA 197 are explained in SIA 197/1 at their first occurrence.

2 BASIC PRINCIPLES

See SIA 197.

3 GROUND

See SIA 197.

4 SAFETY

4.1 Basic principles

See SIA 197.

4.2 Hazards

See SIA 197.

4.3 Design procedure

See SIA 197.

4.4 Safety planning

4.4.1 General

4.4.1.1 Safety in railway tunnels depends on the following groups of influential factors:
- Railway traffic (train frequency, percentage of freight trains, train speeds, number of persons and percentage of seats filled in passenger trains, type of goods transported).
- Infrastructure (tunnel system, tunnel length, structures, operating and safety equipment, length of emergency escape routes).
- Tunnel operations (operation and servicing of the operating and safety equipment, the reaction of the emergency services when incidents occur).
- Condition of the vehicles (rolling stock, track condition monitoring plant and inspection of trains on the line and on the rolling stock).

4.4.1.2 An important principle in safety planning is to prevent accidents by the adoption of safety measures over the whole network.

4.4.1.3 Due to space restrictions in tunnels, the possibilities of escape (self-rescue) and outside help from emergency services (rescue by others) are restricted. Therefore structural and operational measures are needed with the following priorities:
- A train can leave the tunnel as quickly as possible,
- the persons involved can rescue themselves if the train cannot leave the tunnel.

4.4.1.4 The main measures to aid self-rescue are emergency escape routes and depending on the situation emergency exits into protected areas, ventilation, etc.

4.4.1.5 The emergency services shall be involved early in safety planning, since the use of these emergency services, depending on the rescue concept, may necessitate special infrastructure measures e.g., access to the portals, the profile-free earthing of the contact wire, emergency lighting, ventilation, drainage measures and fire-fighting plant.

4.4.1.6 The procedures set out in the Safety Planning Appendix H [2] and [4] shall also be taken into consideration.

4.4.2 Procedure, safety analysis and measures

See SIA 197, Sections 4.4.2 to 4.4.6.

5 ENVIRONMENT

See SIA 197.

6 MANAGEMENT

See SIA 197 and Appendix A.

7 STRUCTURAL DESIGN

7.1 Basic principles

See SIA 197.

7.2 Structural analysis

See SIA 197.

7.3 Dimensioning

See SIA 197.

7.4 Accidental actions and corrosion

7.4.1 Fire

7.4.1.1 The essential parts of the structure shall be designed for a specified fire rating. The temperature–time curve required for the design shall be specified in the Safety Plan and documented in the Safety Report.

Information for determining the temperature–time curve can be found in Appendix B.

Refer to the design procedures set out in SIA 261, Clause 15, and SIA 262, Clause 4.3.10.

7.4.1.2 Critical elements of the structure in connection with a fire incident are:

- the tunnel arch or the roof and walls, if there is considerable danger to persons and goods in the vicinity of the affected tunnel in the case of failure or due to heat transfer (above, next to or below the tunnel),
- the structural elements of adjacent service and rescue tunnels.

7.4.1.3 The structural elements and fastenings for plant in the tunnel shall be designed such that they do not fail in the initial phase of a fire. This initial phase is defined by a temperature of 450 °C over a period of thirty minutes (limiting case for protected persons, see also Appendix B, Clause B.3.1).

7.4.2 Explosion

7.4.2.1 The tunnel shall be assigned to Category 1 (see SIA 261, Clause 17).

7.4.2.2 Any assignment made to a higher category in consideration of a specific danger shall be recorded in the Required Duty Agreement.

7.4.2.3 The parameters used in design detailing shall be specified in the Safety Plan.

7.4.2.4 The required design checks shall be part of the Safety Plan. The results shall be described in the Safety Report.

7.4.2.5 Effective protective measures shall be taken if there is any permanent occurrence of natural gas.

7.4.3 **Earthquake**

See SIA 197.

7.4.4 **Corrosion**

7.4.4.1 Consideration shall be given to the corrosive atmosphere in tunnels in the design of structural elements and plant:

- High relative humidity and increased temperatures in long tunnels. (The critical relative humidity of 75% for the corrosion of metals is exceeded in most tunnels.)
- Effect of chlorides from groundwater or brought into the tunnel on sections where highway vehicles are loaded onto Roll-on Roll-off rail ferries. (It should be noted that even low relative humidity situations can be critical as railway tunnels are not generally regularly cleaned.)
- Effect of highly mineralised groundwater (e.g., deep groundwater).

7.4.4.2 The following points shall be taken into consideration to prevent corrosion affecting the structure:

- Appropriate design of surfaces and edges of tunnel furnishings (soft shaped construction), to avoid the accumulation of dirt and salt deposits.
- Avoidance of galvanic action (e.g., contact of fastenings with the reinforcement of the lining).
- Provision of additional coating for galvanised metal components (e.g., duplex method) and designed to be replaceable.
- Clarification of the suitability of light metal components on a case-by-case basis.
- Use of corrosion-resistant, high alloy steel for fastenings (e.g., Material No. 1.4529, X1NiCrMoCuN with 6% Mo according to EN 10088).

7.4.4.3 Special attention shall be taken with respect to the choice of the materials due to the possible diffusion of water, salts and heat through the lining and the accumulation of salt due to evaporation (internal damage to the concrete, spalling, detachment of coatings, etc.).

7.4.4.4 It may be necessary to use special materials (high alloy or coated steel) for the reinforcement in the case of high condensation (due to the flow of warm humid air over cold parts of the structure at the portals or the tops of shafts). Any consequences for the earthing concept shall be taken into consideration.

7.4.4.5 The design of the protection of the structure and of plant in contact with the soil shall be in accordance with the Guidelines of the SGK Corrosion Committee Appendix H [11] and [12].

7.5 Special construction works

See SIA 197.

7.6 Execution checks and monitoring

See SIA 197.

8 CONSTRUCTION WORKS

8.1 General

8.1.1 Basic Design Principles

8.1.1.1 The Basis of design and design specifications are:
- the specified superstructure characteristics,
- the Railway Operations Plan, in conjunction with the Maintenance Plan,
- the basic Safety Specifications,
- the track topology,
- the design speed,
- the kinematic envelope (see Appendix D),
- other service criteria.

These shall be specified in the Service Criteria Agreement (see SIA 260).

8.1.1.2 The design shall be in accordance with requirements for railway operations, health and safety planning and environmental impact for each project phase. A possible procedure is shown in Appendix G.

8.1.2 Choice of tunnel system

8.1.2.1 The following basic considerations and criteria shall be included in the choice of the tunnel system:
- the Railway Operations Plan, in conjunction with the Maintenance Plan
- the safety analysis and the state-of-the-art in safety technology
- the length of tunnel and the travel time of train in tunnel
- the ground conditions
- the longitudinal gradient and the construction concept
- the climate and the ventilation
- the environment
- economic aspects.

8.1.2.2 The following tunnel systems are possible:
- single-track tunnels,
- double and multiple track tunnels,
- system with two or more tunnels, single or multiple track,

with additional service, ventilation, rescue or access tunnels if deemed necessary.

8.2 Alignment

8.2.1 The track geometry shall be determined on the basis of the specified superstructure characteristics. The geometrical boundary conditions for the track geometry are specified in the Construction Requirements of the Railways Regulation (AB-EBV).

8.2.2 The design longitudinal profile of the track is usually fixed along the axis of the track.

8.2.3 The maximum permissible gradient in the tunnel depends on the Railway Operations Plan and the superstructure concept. The aerodynamic drag of the trains in the tunnel shall be taken into consideration.

8.2.4 The distance between parallel tunnels shall be determined taking the space requirements for any service, ventilation, rescue or access tunnels into consideration.

8.3 Tunnel cross-section

8.3.1 General

8.3.1.1 The Operating Provisions AB-EBV shall be taken into consideration in the design of the cross-section and the excavation profile of the tunnel.

8.3.1.2 An axis system comprising a vertical tunnel axis and a horizontal reference plane shall be specified for the tunnel lining. All tunnel lining dimensions shall refer to this axis system.

8.3.1.3 The geometrical reference to the alignment of the track or tracks shall be defined throughout. This shall relate to the design top of rail level (TOR, nominal position) and horizontal alignment.

8.3.1.4 The cross-section survey reference systems for the tunnel are specified in Appendix C.

8.3.2 Design cross-section

8.3.2.1 The elements comprising the tunnel's standard cross-section are specified in Appendix E. The design cross-section is determined by the space requirements of these elements.

8.3.2.2 The kinematic envelope including the space for the pantograph shall be defined in the Service Criteria Agreement (based on the requirements of AB-EBV). A heave clearance reserve shall be specified for future track maintenance for ballast track or with a possible track correction for a slab track system (see Appendix D).

8.3.2.3 All dimensional data shall refer to the design position of the top of rail level (TOR) and the design position of the track in the horizontal direction according to the route alignment and setting-out surveys.

8.3.2.4 The utilisable construction space *t* shall be fixed and documented in the Basis of Design. The size of *t* together with *a* (tolerance clearance) and *b* (construction clearance for future measures) shall be determined in general according to Appendix F.

8.3.2.5 Installations such as niches for plant, fixings for the contact line, etc. may protrude into the utilisable construction space *t*. However, the tolerance clearance *a* shall be kept free.

8.3.2.6 The space required beneath the running surface shall be determined by the construction space required for the superstructure, the drainage system, the cable routes and if deemed necessary by measures for vibration protection as well as construction requirements.

8.3.3 Deviations from design value (construction errors)

See SIA 197 and Appendix F.

8.3.4 Aerodynamics

8.3.4.1 The comfort of the passengers at high speeds (pressure fluctuations) and traction energy consumption in the case of long tunnels determines the aerodynamic cross-section area *A*. This shall be taken into consideration in the design of the tunnel cross-section.

8.3.4.2 The tunnel cross-section shall be designed in accordance with the pressure-comfort criteria according to the conditions laid down by the Union Internationale des Chemins de Fer (UIC). The comfort criteria shall be specified in the Service Criteria Agreement.

8.3.4.3 The aerodynamic cross-section area *A* shall be measured from the top of rail level (TOR) exclusive of the construction clearance for future measures *b*.

8.3.4.4 The aerodynamic cross-section area *A* for tunnels with operating speeds of 180 km/h and higher shall be determined in accordance with Appendix H [3].

8.3.4.5 The values for A given in [3] for v = 180 km/h can be determined approximately with the following formula:

$$\frac{A_1}{A_2} = \frac{v_1^{1.5}}{v_2^{1.5}} \quad \text{for lower operating speeds.} \qquad (1)$$

8.3.4.6 There are usually no restrictions on A for operating speeds less than 140 km/h.

8.3.4.7 A reduction of the aerodynamic cross-section area A according to Clauses 8.3.4.4 or 8.3.4.5 can be achieved through the use of pressure relief ducts or other measures to absorb the pressure fluctuations. Numerical simulations or equivalent verifications shall be carried out to optimise the aerodynamic cross-section. The assumptions for speeds, the relevant aerodynamic characteristics of the trains and the pressure insulation of the vehicles shall take future rolling stock into consideration.

8.3.4.8 The same effective aerodynamic cross-section shall be taken into consideration for sections of tunnel constructed by mined or cut-and-cover construction methods. The transition region shall in any case be designed such that the pressure fluctuations are not unreasonable with regard to user comfort.

8.3.4.9 The effects on the traction energy consumption and ventilation shall be checked for tunnels of several kilometres length or more, taking into consideration the surface roughness of the lining of the free cross-section area A of tunnels, shafts and cross-passages.

8.4 Lining

8.4.1 The surface properties of the lining shall meet the requirements of aerodynamics, maintenance and noise protection.

8.4.2 In frost-endangered sections of the tunnel, frost-resistant concrete shall be used. The length of the frost-endangered section measured from the portal shall be determined on a case-by-case basis and specified in the Basis of Design.

8.4.3 The possible occurrence of strongly mineralised and/or aggressive groundwater shall be clarified prior to specifying the material properties. Protective measures shall be implemented, e.g., impregnation or coating of segments or a double-shell lining with sealing, if deemed necessary.

8.4.4 The requirements with respect to chloride resistance (de-icing salt) shall be verified for sections of tunnel used for Roll-on Roll-off ferries, particularly in the vicinity of the vehicle loading points.

8.4.5 The dimensioning and constructional details of the tunnel lining shall take into consideration the requirements of the railway technical equipment and operating and safety equipment (e.g., transmission of forces from the contact line, methods of fixing the equipment).

8.5 Track, walkways and cable ducts

8.5.1 Track

8.5.1.1 General

8.5.1.1.1 The track (superstructure and substructure or supporting structure) shall be designed in accordance with the requirements of AB-EBV and Railways Regulations [6], [7], [8], [9] (see Appendix H), etc.

8.5.1.1.2 The superstructure and substructure shall be designed in general for loads according to AB-EBV.

8.5.1.1.3 The substructure shall be protected against wetting and uplift forces by a permanently effective drainage system.

8.5.1.1.4 The different stiffnesses of the substructure at the transition from open-air sections of the railway line to the tunnel shall be taken into consideration and compensated accordingly (as with bridges).

8.5.1.1.5 The choice of superstructure, whether ballast or ballastless track, is influenced by
- the length of tunnel,
- the type of lining and substructure (invert),
- the drainage system,
- the maintenance requirements.

8.5.1.1.6 The design of ballastless track shall be considered for tunnels greater than 1 km in length and where the invert is stable. More detailed investigations (structural analyses) shall be carried out if differential deformations cannot be excluded. The design of the superstructure shall be determined on the basis of value engineering, taking the design life into consideration.

8.5.1.1.7 The type of superstructure shall be determined on the basis of the expected deformations of the substructure during the design life.

8.5.1.1.8 The track cant (transverse gradient) shall be determined according to the following principles:
- the running surface of the track is generally rotated about the axes of each individual track.
- If, for a two-track or multiple-track tunnel, the possibility has to be held open for the future installation of a crossover, then a solution involving the rotation of the running surface about the double-track axis is required.
- The tunnel axis (construction axis) offset from the track axis or the double-track axis toward the inner side of the arch to optimise the tunnel cross-section (see Appendix C).

8.5.1.2 Ballast track bed

8.5.1.2.1 Standard gauge railways

The nominal values for constructional space requirements for superstructure are:
- height between the running surface top of rail level (TOR) and the underside of the sleepers (ties): 0.40 m.
- thickness of ballast bed between underside of sleepers and subgrade: to be specified in accordance with current regulations in Appendix H [9].
- width of ballast bed for a double-track tunnel: ≥ 1.75 m from track axis.
- width of ballast bed for a single-track tunnel: ≥ 3.90 m for total width.

8.5.1.2.2 Narrow gauge (1.00 m) railways

The nominal values for constructional space requirements for superstructure are:
- height between the running surface top of rail level (TOR) and the underside of the sleepers: for concrete sleepers 0.38 m, for timber sleepers 0.32 m.
- thickness of ballast bed between underside of sleepers and subgrade: in general ≥ 0.30 m.
- width of ballast bed for a double-track tunnel: ≥ 1.60 m from track axis.
- width of ballast bed for a single-track tunnel: ≥ 3.40 m for total width.

8.5.1.2.3 Other types of railways

The construction space requirements shall be determined analogously.

8.5.1.3 Ballastless track

8.5.1.3.1 The maintenance requirements (methods and time requirements) and the construction parameters (e.g., stipulations for resetting the track) are important in determining the type of construction.

8.5.1.3.2 The construction space requirements for ballastless track depend on choice of track construction and the properties of the track-supporting structure or invert.

8.5.1.3.3 Standard gauge railways

The following construction space requirements shall be kept free for the superstructure (nominal values for the common types of construction in Switzerland with sleeper blocks embedded in concrete):
- height between the reference level TOR and subgrade:
  - without track-bearing slab (e.g., solid foundation slab or possibly with stable rock): 0.50 to 0.55 m
  - with track-bearing slab (e.g., gravel invert fill): 0.50 to 0.55 m in addition the thickness of the track-bearing slab 0.20 to 0.35 m
- width of the track-bearing slab from the track axis: ≥ 1.65 m.

The height between the surface of the poured concrete and the running surface is normally 0.25 to 0.35 m for ballastless track with sleeper blocks embedded in concrete.

8.5.1.3.4 Other types of railways

The construction space requirements shall be determined analogously.

8.5.1.3.5 The construction space requirement for track includes the required space for the rails, the sleepers together with the surrounding concrete.

8.5.1.3.6 The following shall also be taken into consideration in the determination of the construction space requirement for track support:
- the space required for canting in the curves,
- the space for construction measures to resist noise and vibration,
- the space for construction measures in the transition region between the ballastless track and the ballast track bed,
- the space to accommodate production tolerances for the substructure, including any deformations before the construction of the track.

8.5.1.3.7 A concept for the track correction shall be prepared if geologically induced deformation cannot be ruled out. The space required for track correction shall be taken into consideration in the design cross-section.

8.5.1.3.8 The transitions between the ballastless track and the ballast bed are usually located 60 to 100 m inside the tunnel. The length shall be specified in the track specification.

8.5.2 **Kerbs, walkways**

8.5.2.1 The kerb serves as the lateral completion of the track structure and in general also houses cable ducts and drainage pipes.

8.5.2.2 The walkway usually lies on the kerb. It also serves as an access route for maintenance services and as an emergency escape route in case of an incident.

8.5.2.3 The width of the walkway from its edge to the wall of the tunnel (design cross-section) shall be at least 1.20 m. The utilisable construction space t may be reckoned part of the width. If the walkway is located at the same height as the ballast or the track-bearing slab, part of the track can be considered in the width.

8.5.2.4 The height of the walkway above the running surface shall be specified in the Service Criteria Agreement. The requirements of track maintenance (track maintenance plant) in the Railway Operating Plan (e.g., accessibility of the lower parts of the vehicles, reinstating derailed locomotives onto the rails) and rescue (emergency escape route) shall be taken into consideration.

8.5.2.5 The surface of the walkway shall be flat and free of obstacles.

8.5.2.6 The clearance above the walkway shall be at least 2.20 m.

8.5.2.7 Groundwater running down the sides of the tunnel wall shall be collected on the wall side of the walkway and drained away (narrow open drainage channels are normally sufficient for this purpose).

8.5.3 **Cable routes**

8.5.3.1 Cables required for railway operations are part of the railway technical equipment. They shall be installed in accordance with the Regulations for Railway Electrical Equipment (VEAB).

8.5.3.2 Cables, which do not serve railway operations (e.g., 50-Hz transit cables parallel or transverse to the railway tracks), shall be installed according to the Regulations for Transmission Lines (LeV).

8.5.3.3 The cable ducts running alongside the track are produced for continuous cable systems with standardised ducts. The installation of cable ducts shall be in accordance with Appendix H [10].

8.5.3.4 No re-inforcement or other electrically transmitting parts, which form a magnetic short circuit (ring), shall be placed around the cable ducts in the case of single-wire power cables.

8.5.3.5 Cables crossing under the track shall be arranged in the equipment niches and, if deemed necessary, regularly spaced between them. Additional cable crossings shall be provided at technical rooms and on both sides of crossover points.

8.5.3.6 The conditions for the power cables (HV and LV) and communication cables for safety and telecommunications plant shall be taken into consideration for the cable crossings. The laying of cable ducts for crossings of HV cables shall be in accordance with Appendix H [10].

8.5.3.7 The depth of the cable crossings shall be chosen such that the standard thickness of ballast is not reduced and there are no discontinuities in the substructure.

8.5.4 **Protection against vibration and structure-borne noise**

8.5.4.1 The construction measures for vibration protection and structure-borne noise protection (secondary airborne noise) shall be specified in the preliminary design.

8.5.4.2 The objective of the design shall be to reduce vibration and especially their propagation in the ground by decoupling the vibration of the track from the ground by installing intermediate elastic layers. Vibration insulators can only be installed in the following parts of the superstructure:
- where the rails are fixed (intermediate elastic layers and plates)
- under the sleepers (underside of sleepers)
- under a track support slab or the ballast (mats under the ballast)
- under a track trough or a track support slab (classical mass-spring system).

8.5.4.3 The effectiveness of the planned measures shall be verified using suitable prediction methods (experimental and numerical investigations).

8.5.4.4 The objective of the design shall be to provide a complete separation of the base of the superstructure from the adjacent tunnel lining to reduce the transmission of vibration to the surface, above all in the vicinity of adjacent surface structures.

8.6 Waterproofing

8.6.1 **Actions**

See SIA 197.

8.6.2 **Waterproofing requirements**

8.6.2.1 The following minimum Waterproofing Classes shall apply for railway tunnels and associated plant rooms (see SIA 197):

– Tunnel roof arch above the track, covering at least the width of the vehicles (reference line according to AB-EBV)	Waterproofing Class 2
– Portal vicinity (whole cross-section) and other frost-endangered zones	Waterproofing Class 2
– Niches and plant rooms	Waterproofing Class 1
– Other areas	Waterproofing Class 3.

8.6.2.2 Higher waterproofing requirements may be necessary to fulfil the required climatic conditions in long tunnels.

8.6.2.3 The waterproofing requirements for ventilation tunnels shall be decided on a case-by-case basis.

8.6.2.4 Tunnels situated within the groundwater shall be designed so that leaking water or water flowing from the portals cannot penetrate the ballast bed (ice formation with danger of instable track position).

8.6.3 Waterproofing concept, flexible and rigid waterproofing systems, additional measures

See SIA 197, Sections 8.6.3 to 8.6.6.

8.7 Drainage

8.7.1 General

8.7.1.1 Groundwater (clean water) and operational water (dirty water) shall be discharged either in separated or mixed drainage systems. The discharge system (separated or mixed drainage system) and the necessary drainage system outside the tunnel portals shall be specified according to the safety objectives and the relevant legal requirements.

8.7.1.2 The choice of the system depends on
- the amount of water present (groundwater and operational water),
- potential incidents,
- the possibilities of treatment and discharge of operations water as well as its retention in an emergency.

8.7.1.3 The drainage system shall be designed so that maintenance work (inspection, cleaning and maintenance) is possible within the periods of time planned in the Maintenance Plan. The basis for the given periods shall be the required availability of the tunnel for railway operations laid down in the Service Criteria Agreement.

8.7.1.4 The following safety aspects shall be observed with respect to track drainage:
Ballastless Track:
- smooth surface with a sufficiently large cross fall, allowing dangerous substances to drain away quickly,
- avoidance of non-draining surfaces, so that the vaporising period of fluids released during an accident is as short as possible.

Ballast track bed:
- enclosed, flat and impermeable subgrade (e.g., concrete, asphalt surfacing) with adequate fall.

8.7.2 Sintering

See SIA 197.

8.7.3 Collecting the water (drainage)

See SIA 197.

8.7.4 Discharge of water (separate drainage pipes to drain the side walls and groundwater)

8.7.4.1 Drain pipes intended for inspection by maintenance personnel shall have an minimum inside diameter of 600 mm.

8.7.4.2 The spacing between flushing manholes shall not exceed 100 m. The spacing between inspection manholes shall be specified in the Maintenance Plan, consistent with the means planned for maintenance.

8.7.4.3 The manholes for drainpipes for the side walls shall be located in the kerbs or in the entrances to the niches, near to the manholes for the groundwater drainpipes.

8.7.4.4 The manholes for the drainpipes in single-track tunnels shall be located at the side of the track or as a specific structure in the middle of the track, for double or multiple-track tunnels in general in the middle between two tracks.

8.7.4.5 The manholes shall be located such that inspection, cleaning and maintenance of the drainpipes are possible in a simple and economic way. The access openings of inspection manholes shall have a minimum diameter or a length and width of 600 mm.

8.7.4.6 The following minimum dimensions for manholes shall apply for seepage drainpipes (nominal values):
- length in direction of flow L $\geq$ 0.80 m
- width B $\geq$ 0.45 m

The depth of the sand trap beneath the collector pipe shall be at least 0.10 m. The potential use of a drainage channel instead of the sand and mud trap shall be considered where severe sintering is expected.

8.7.4.7 The following minimum dimensions for manholes of the drains shall apply (nominal values):
- length in direction of flow L $\geq$ 1.50 m
- width B $\geq$ 0.60 m

The depth of the sand trap beneath the collector pipe shall be determined on the basis of the amount of incoming water, the transported sand and the type of invert of the manhole. A sand trap can be dispensed with in favour of a drainage channel where the volume of water is large (e.g., > 40 l/s) or there is an adequate flow velocity. The manhole outlets shall be designed for turbulent-free discharge.

8.7.5 Discharge in front of the portal

See SIA 197.

8.7.6 Requirements for the discharge of operational water

8.7.6.1 The requirements for explosion protection shall be taken into consideration for the drainage of traffic space (operational water) in the case of tunnels through which hazardous goods are transported e.g.:
- siphon intakes, which prevent the return of explosive gases into the traffic space and ignition from the traffic space into the drainpipes,
- watertight, secured shaft covers, to avoid hazards (blowing away of covers), which could arise due to explosions in the drainage system.

8.7.6.2 The manholes for side wall seepage drainpipes and groundwater drainpipes shall be provided with a watertight cover when used in conjunction with a separated drainage system.

8.7.6.3 Aerodynamic actions due to railway operations shall be taken into consideration:
- danger of manhole covers lifting off,
- danger of siphons blowing out.

8.7.6.4 The permanent fittings, apparatus and manhole covers shall be made from corrosion-resistant materials.

8.8 Additional structural elements for safety

8.8.1 General

8.8.1.1 The most important additional structural elements for safety purposes include
- safety niches (safety of operations personnel in the tunnel),
- emergency escape routes within the railway tunnel, emergency exits, protected areas, access to the portals (safety in an emergency).

8.8.1.2 The safety niches for the protection of personnel shall in general be situated at regular intervals in all tunnels (see Railway Regulations, Art. 28).

8.8.1.3 No additional structural elements for safety in an emergency are required in the case of tunnels with a length of less than 1 km, in general. The walkway serves as an emergency escape route.

8.8.1.4 Additional structural elements for safety in an emergency shall be provided in tunnels with a length longer than 1 km.

8.8.1.5 The required measures shall be implemented over the whole length of consecutive tunnels unless the accessible area between the two consecutive tunnels is greater than the length of a train. The tunnels cannot be considered as separate and independent tunnels.

8.8.1.6 The planning of emergency-stopping places shall be considered if the emergency-running properties of the locomotives are inadequate to drive a train that is on fire out of the tunnel. This normally applies for standard gauge operating sectors of the railway line where tunnel length exceeds 20 km.

8.8.1.7 Deviations are permissible if
- the same safety is reached by other means and this is verified or
- the compliance with individual requirements would be disproportionate in particular cases.

8.8.1.8 The design shall also comply with requirements of the UIC Code 779-9 and UNECE Recommendations into consideration, see Appendix H [2] and [4].

8.8.2 Safety niches

8.8.2.1 Safety niches for personnel shall be provided to protect personnel working in the tunnel from the effects of railway traffic (AB-EBV, Art. 28, Section 1).

8.8.2.2 The niches shall, in general, be designed with the following minimum dimensions:
- in the standard case: 2.2 / 2.5 / 1.5 m (height / length / depth)
- alternatively: 2.2 / 1.5 / 2.0 m (height / length / depth), if a long niche is unfavourable for structural or geotechnical reasons.

(length = internal dimension of the niche in the direction of tunnel, depth = internal dimension of the niche perpendicular to the wall of the tunnel.)

8.8.2.3 Box niches in front of the tunnel wall are also possible instead of niches in the tunnel wall, provided there is sufficient space. The adequacy of the protective function shall to be verified.

8.8.2.4 A reduction in the entrance width to the niche shall be investigated for operating speeds in excess of 140 km/h. The minimum dimensions of the niche entrance shall be: width = 0.70 m, height = 2.00 m.

8.8.3 Emergency escape routes

8.8.3.1 Emergency escape route within a railway tunnel shall generally be provided by the walkway according to Section 8.5.2.

8.8.3.2 Single track tunnels shall be designed with at least one emergency escape route along one side of the tunnel, if possible on the outside of the curve, but without having to change sides.

8.8.3.3 Double and multi-track tunnels shall be designed with an emergency escape route on both sides.

8.8.3.4 The clearance of the emergency escape route shall be at least 1.00 m wide and 2.20 m high and free of obstacles.

8.8.3.5 The surface of the emergency escape route shall in general be above the running surface in order to simplify alighting from the train in an emergency. The requirements of track maintenance (e.g., possibility of use and access of machines for track maintenance) and ability to cope with emergencies shall be given due consideration in specifying the height and the spacing from the track axis (e.g., accessibility of the lower part of vehicles).

8.8.3.6 Emergency escape routes shall be provided with a handrail, lighting and signage for tunnels with a length in excess of 1 km (see Section 9.4).

8.8.4 **Emergency exits**

8.8.4.1 Emergency exits form the connection between the railway tunnel and a protected area. If deemed necessary, an airlock shall be provided at the transition between the emergency exit and the protected area.

8.8.4.2 Emergency exits leading into the open air shall be provided at least every 1,000 m.

8.8.4.3 Emergency exits through cross-passages into a parallel tunnel, service or rescue adit or another tunnel shall be provided at intervals of no more than 500 m.

8.8.4.4 Pedestrian cross-passages shall be at least 2.00 m wide and 2.20 m high. The cross-passages shall be sealed off from the traffic space.

The doors to cross-passages shall be at least 1.00 m wide and 2.00 m high and shall be easy to use. Double doors shall allow opening in the direction of escape. The mode of operation for sliding doors, if used, shall be clear to the user.

Access to the cross-passage shall be possible for maintenance work over the whole width.

8.8.4.5 The penetration of combustion gases and smoke shall be prevented as far as possible by suitable measures or be of limited duration in the case of emergency exits. The effects of natural air currents and heavy gas shall be taken into consideration.

8.8.4.6 The fire rating of the airtight closures (emergency exit doors) at the exits shall be specified in the safety plan. The doors shall be operable at least until the completion of the self-rescue.

8.8.4.7 The airtight closures shall be designed for the dynamic pressures (overpressure and underpressure) resulting from passing trains.

8.8.5 **Protected areas**

8.8.5.1 The emergency escape routes shall always end in protected areas. Such areas are
- adits and shafts leading into the open-air,
- parallel running tunnels, service and rescue tunnels,
- emergency-stopping places,
- areas outside the tunnel in the open-air,
- sections of the tunnel, which are protected from smoke and gases if deemed necessary.

Protected areas shall be accessible from outside.

8.8.5.2 The penetration of smoke and dangerous gases into protected areas shall be prevented by means of suitable measures.

8.8.6 **Rescue adits and shafts**

8.8.6.1 The Safety Plan (see 4.4.1) shall determine the necessity for rescue adits and shafts in connection with the choice of the tunnel system.

8.8.6.2 The dimensions and equipment requirements shall be specified in the Safety Plan.

8.8.7 **Emergency-stopping point**

8.8.7.1 The emergency-stopping point in the tunnel serves as a place for passengers to alight from the train and consists of a platform and access to a protected area.

8.8.7.2 The protected area near the emergency-stopping point shall be designed to have a slightly higher pressure compared to that in the tunnel to effectively prevent the penetration of combustion gases and smoke. The protected area shall be provided with communication and first aid equipment.

8.8.7.3 The length of the platform shall correspond to the maximum length of a passenger train. The width shall permit the rapid evacuation of the train and ensure a quick transfer to the protected area.

8.8.7.4 The platform height for standard gauge railways is normally 0.55 m above the running surface. The platform height for other types of railway shall be suitable for the rolling stock.

8.8.7.5 The position of the edge of the platform (height, distance to track axis) shall be consistent with the Maintenance Plan.

8.8.7.6 The design shall ensure the removal of smoke in the platform area. The concept shall be specified in the Basis of Design.

8.8.8 **Access to the portals**

8.8.8.1 The tunnel portals and the rescue adit shall be generally accessible for rescue vehicles using the access roads. Access roads shall be situated on both sides of the track and provide turning possibilities.

8.8.8.2 The design of the access roads, spaces and equipment shall be defined in the rescue plan. The possibility of providing landing pads for rescue helicopters near to the portals shall also be investigated.

8.8.8.3 Permanent equipment shall be provided for earthing the contact line at the portal, leaving the kinematic envelope free for the passage of rescue trains or other vehicles.

8.8.8.4 The route away from the portal to the “Meeting Point” shall be designed to prevent escaping persons from falling (provision of emergency lighting, signage).

8.9 Tunnel portals

8.9.1 Road crossings above the portal require protective installations at the side of the road (e.g., guard rails, perimeter walls, protective barriers against falling loads with an avalanche net construction), which prevent road vehicles or loads from falling onto the railway line. The design shall take the BAV Guidelines into consideration; see Appendix H [1].

8.9.2 A safety rail preventing people from falling over shall be provided if the roof area of the tunnel is accessible.

8.9.3 The Requirements for the Protection against Dangers due to HV (Prevention of Physical Contact), the AB-VEAB, Art. 15, shall be taken into consideration.

8.9.4 The possibility of a tunnel boom (sonic boom) at the portal shall be taken into consideration for operating sectors of high-speed railway lines. Suitable precautions shall be taken, if deemed necessary.

8.10 Ancillary plant

8.10.1 Plant niches

8.10.1.1 Plant niches serve to house equipment outside the design cross-section. A basic grid shall be specified in the Service Criteria Agreement for the spacing of the niches.

8.10.1.2 The following dimensions for the niches shall apply, nominal values of:
- floor area 12.00 m^2
- height above floor level of niche ≥ 2.50 m

These dimensions take the usual arrangement of equipment cabinets and cable installations into consideration. The required dimensions shall be specified for each structure corresponding to the requirements of railway technology and of the Maintenance Plan.

8.10.1.3 A height of at least 0.50 m shall be provided if cable laying requires a hollow floor.

8.10.1.4 The niches shall be designed in such a way that they create no interference to operations (e.g., off-loading of equipment cabinets from a rail vehicle and moving them to their position).

8.10.1.5 The entrance area of the niches shall fulfil the requirements for safety niches.

8.10.1.6 The climatic requirements such as waterproofing, the maximum admissible temperature and relative humidity as well as the dust seal shall be specified in the Service Criteria Agreement. Air-conditioned containers or separate rooms (Section 8.10.2) shall be provided, if deemed necessary.

8.10.2 Plant rooms

8.10.2.1 Additional plant rooms may be necessary for safety plant, contact line plant, electric power supply for the railway, ventilation plant and other technical railway plant.

8.10.2.2 The climatic requirements, such as watertightness, maximum admissible temperature, relative humidity and dust seals, shall be specified in the Service Criteria Agreement. The rooms shall be air-conditioned if deemed necessary.

8.10.2.3 The doors and enclosure walls shall be designed for the dynamic pressures (overpressure and underpressure) resulting from passing trains.

8.10.2.4 Rooms with hollow floors shall be drained (condensation water).

9 OPERATING AND SAFETY EQUIPMENT

9.1 General

9.1.1 Operating plant

Operating plant is divided into the following categories
- Plant for operating the tunnel, such as LV power supply, tunnel lighting, ventilation plant, communications equipment, and in some cases the tunnel operations control centre, and the
- plant for operating the railway, such as equipment for HV traction power supply for the railway, contact line, safety equipment, communications equipment.

9.1.2 Safety equipment

Safety equipment serves to safeguard operational and maintenance personnel during operations as well as the safety of passengers and operator's personnel in the case of an accident. It can include: emergency lighting, equipment for the emergency escape routes and emergency exits, fire-fighting equipment, and in some cases a rescue control centre, etc.

The Requirements of UIC Codex 779-9 and UNECE Recommendations in Appendix H [2] and [4] shall also be taken into consideration with respect to safety equipment.

9.1.3 Reliable system components with low-maintenance characteristics shall be used. The climatic conditions in the tunnel shall be taken into consideration in their selection.

9.1.4 Operating and safety equipment are described in the following only insofar as they are of importance for the design of the tunnel.

9.2 LV power supply, HV traction power supply for the railway, earthing

9.2.1 Power supply

9.2.1.1 The type and performance of the power supply, the required cable routes, rooms and plant shall be specified in the Electrical Plant Requirements.

9.2.1.2 Power distribution panels shall be provided for maintenance purposes. The number, type, performance and location shall be derived from the Maintenance Plan.

9.2.1.3 The functionality of the safety equipment, such as emergency lighting, communications equipment, etc., shall be guaranteed up to the completion of self-rescue in the case of an incident (e.g., fire). Failure of individual system components caused by the incident (e.g., individual lights) shall not affect the overall system.

9.2.1.4 A redundant emergency power supply shall be provided for safety equipment either from both portals, other access points or from a standby power supply, if deemed necessary. The necessity and the requirements shall be specified in the Safety Plan.

9.2.1.5 The requirements of the Regulation on LV Power Plant (NIV) and the Regulation for Electrical Plant for the Railways (VEAB), where the local network and the railway network meet, shall be taken into consideration regarding protection against electrical hazards.

9.2.2 Power supply for the railway, contact line equipment

9.2.2.1 The space requirement for the contact line shall be specified in the Tunnel Concept (Structure and Plant). The space requirement for the contact line of the traction vehicles shall be given in the Service Criteria Agreement.

9.2.2.2 Space shall be provided for the following equipment in the tunnel cross-section for electric railways:

- Inclined overhead contact line (contact wire, catenary, wire-tensioning devices, feeder) or contact rail
- Earth wire or current return conductor (at least one cable per track)
- Earthing between the earthing wire or current return conductor and rails
- Power supply support structure for the contact line and the earthing or current return conductor
- Space for the pantograph of the traction vehicle.

9.2.2.3 Additional space may be needed for the contact line

- in the vicinity of points (switches),
- at the locations of wire-tensioning devices,
- at the feeder points of the contact line sections (the subdivision of the contact line into sections shall be adapted to the Operating, Maintenance and Rescue Plans for the operating sector of the railway line).

9.2.2.4 Between electrically live and earthed parts there shall be a safe electrical distance *be* according to the Construction Requirements of the Railways Regulation (AB-EBV).

9.2.2.5 The construction clearance for future measures *b* may be used for the power supply support structure carrying the contact line and the wire-tensioning devices.

9.2.2.6 The design of the contact protection against coming into contact with electrically live parts and for the safety marking shall be in accordance with the Construction Requirements of the Regulation for Electrical Plant for Railways (VEAB).

9.2.2.7 Section breaks and neutral sections of track shall be located outside the tunnel, if possible.

9.2.2.8 The design shall be in accordance with The Regulation for Protection against Non-ionising Radiation (NISV). Sensitive third party facilities may be affected in the case of a shallow earth cover.

9.2.2.9 The forces from the contact line acting on the lining during erection, in operation and in case of incidents shall be taken into consideration in the design of the lining.

9.2.3 **Earthing**

9.2.3.1 The earthing scheme shall take the design of the lining and internal finishes into consideration, and vice-versa.

9.2.3.2 The earthing scheme shall take the project-specific conditions affecting structures and plant (e.g., connecting point of different earthing systems, DC, substations in the vicinity) into consideration.

9.2.3.3 The earthing measures are specified in Regulations VEAB, AB-VEAB in Appendix H [11] and [12].

9.2.3.4 The following principles shall apply in the case of railways using AC:

- The propagation resistance of the traction current return conductor system (part of the rail earthing) to the surrounding rock mass must be sufficiently low.
- The conductivity in the direction of the tunnel axis must be sufficiently high.
- Potential equalisation is to be provided perpendicular to the tunnel axis.

In case of influence by railways using DC close to the tunnel special measures are to be considered (insulating the earthings, protection against corrosion).

9.2.3.5 The following principles shall apply in the case of railways using DC:

- The railway earthing and the structure earthing shall in general be insulated from each other.
- Protection measures against dangerous contact voltages shall be implemented.

9.3 Lighting

9.3.1 **Tunnel lighting** (general)

9.3.1.1 No tunnel lighting is generally necessary for rail traffic. The maintenance services provide their own mobile lighting for maintenance.

9.3.1.2 Emergency lighting (see Section 9.3.2) shall be installed which can be connected to the mobile lighting and switched on at any working area in the tunnel for tunnels longer than 1 km in the case of an incident. It is to be designed for use as orientation lighting by the operator's and maintenance personnel.

9.3.1.3 Tunnel lighting may be necessary in long tunnels if the Maintenance Plan envisages working during railway traffic operation. This is usually combined with a permanent warning system (PWA), which has to be activated on entering the corresponding tunnel-operating sector and simultaneously switches on the tunnel lighting.

The lights shall be arranged so that the entrances to the safety niches are visible.

9.3.1.4 Different conditions may be stipulated if the Maintenance Plan permits temporary closure to operations for a complete tunnel-operating sector.

9.3.1.5 The specification of the tunnel lighting shall be coordinated with the requirements for the rescue of persons.

9.3.2 **Emergency lighting**

9.3.2.1 Emergency lighting shall be provided in the form of individual lights at regular intervals or as continuous strip lights mounted on the tunnel wall. The lights shall be placed in general at the height of the handrail or just beneath it. They shall be designed not to dazzle and adequately light up the emergency escape route and emergency exits.

9.3.2.2 Local damage to the emergency lighting shall not lead to a wide-scale failure of the lighting. The emergency lighting shall therefore be subdivided into lighting sectors no greater than 500 m in length.

9.4 Equipment of escape routes and emergency exits

9.4.1 The handrail shall be placed at a suitable height. The handrail shall be taken around all obstacles (e.g., contact line, fastenings or protruding structural elements). The handrail shall be interrupted at niches and doors.

9.4.2 The lighting for the emergency escape route and the emergency exits shall be installed according to Section 9.3.2.

9.4.3 Signs denoting the emergency escape route with direction and distance information shall be placed at intervals of 100 m. Between these, the escape direction to the nearest tunnel portal or emergency exit can be shown by arrows. The signs and markings shall be placed near lighting.

9.5 Ventilation

9.5.1 **Purpose**

9.5.1.1 The required climatic conditions and adequate air quality shall be ensured by ventilation for normal railway traffic operations and work in the tunnel. The main objectives are:
– the health and safety of the users and the operating and maintenance personnel (limit values as defined in Appendix H [5]),
– to ensure the functionality and the required availability of the railway and tunnel-operating equipment and the safety equipment.

9.5.1.2 The climate and air quality requirements are defined by
- the properties and the agreed availability of the tunnel, the railway and tunnel-operating equipment and the safety equipment,
- the properties of the rolling stock,
- the health and safety requirements of the operating and maintenance personnel.

9.5.1.3 The climate and air quality can be determined using the following parameters:
- Temperature
- Humidity
- Concentration of hazardous substances
- Dust concentration (fine particles PM10)
- Visibility (fog, smoke, dust).

9.5.1.4 The following objectives shall be achieved in the case of an incident:
- The emergency escape and rescue routes shall be kept free of smoke, combustion fumes or other gases as far as possible by quickly controlling their spread (sufficient visibility, limited toxicity and temperature).
- The protected areas shall be kept free from the penetration of smoke, combustion fumes and other gases.
- Adequate air quality must be ensured in the protected areas.

9.5.2 Ventilation system

9.5.2.1 Tunnels can be ventilated by
- natural ventilation,
- the piston effect of trains passing through,
- a ventilation system without air removal in case of incident,
- a ventilation system with air removal in case of incident.

Natural ventilation normally suffices if helped by the piston effect of passing trains.

9.5.2.2 The choice of ventilation system depends on
- the climate and air quality requirements,
- the protection objectives in the case of an incident,
- the tunnel system, especially the tunnel length and the longitudinal profile (in the case of large differences in elevation between the portals or shaft exits),
- the composition of the traffic (percentages of passenger and freight traffic),
- the possible hazard scenarios with the number of trains and persons that could be in the tunnel and the distance of the trains in the tunnel from the scene of the incident (depends on traffic control and safety equipment),
- other factors e.g., any permanent gas inflow from the rock mass.

9.5.2.3 The ventilation concept influences the type of tunnel construction e.g.:
- size of standard cross-section
- position and design of the portals
- ventilation shafts and adits (number, diameter, length)
- ventilation control rooms (number, position, size).

The design (ventilation and structural works) concept shall therefore be integral and be designed in close cooperation with the technical experts involved in the project.

9.5.2.4 The most important factor in the design of the ventilation is the critical fire scenarios. These shall be defined at an early stage of the design and refined in the later design phases.

9.5.2.5 The recirculation of smoke or hazardous substances into the tunnel, into other tunnels bores or into service and rescue tunnels and adits shall be prevented.

9.5.2.6 The recirculation of warm, damp air into the tunnel shall be limited (especially for long tunnels with several running, service and rescue tunnels).

9.5.2.7 Traffic routes and other facilities in the vicinity of portals or ventilation shafts shall not be affected by air escaping from the tunnel (e.g., through the formation of fog or ice).

9.6 Safety equipment

9.6.1 The safety equipment for railway traffic operations is not specific to the tunnel, but shall be designed for the whole operating sector of the railway line.

9.6.2 The special requirements that are placed on the tunnel structure by the equipment and operation of the elements of the safety system in the tunnel (e.g., space requirements, temperature, humidity) shall be specified in the basis of design.

9.6.3 Standard gauge railways

The space available for signals primarily lies at the side, outside the kinematic envelope, and located above a height of 2.60 m above the running surface up to the construction space for the contact line. Other equipment may only be located there as long as the installation of the signals and their visibility is not impaired.

9.6.4 Other types of railways

The space available for signals shall be specified in the Service Criteria Agreement. Other equipment may only be located there as long as the installation of the signals and their visibility is not impaired.

9.6.5 The use of steel re-inforcement in the track support slab, especially of steel-fibre-re-inforced concrete, is only possible in a limited way if audio-frequency track-electric circuits are used. The reinforcement, depending on the execution, may interfere with the functionality of the system to notify that the track is free (e.g., axle counters or audio-frequency track-electric circuits).

9.6.6 The design of the track support slab and the safety equipment are to be coordinated. The conclusions of the investigation shall be recorded in the basis of design.

9.7 Communications equipment

9.7.1 The tunnels shall be equipped with communication systems that have to be adapted to the Operating and Rescue Plans.
- Radio: train radio system, construction walkie-talkie and radio system for rescue services.
- Telephone: connection to railway telephone or public telephone network in the plant niches, mobile telephone.

9.7.2 Adequate communications equipment shall be provided in the case of an incident. It shall be specified in the Safety Plan.

9.7.3 The space requirements for this equipment (apparatus, connections, emitting cable, antennas) shall be provided in the plant niches and in the tunnel cross-section. The distances between the niches shall be adapted to the maximum possible amplifier spacing. The fixing space for the sender cable or the antennas of the radio equipment shall be allocated permanently.

9.7.4 The complete transmission of important data to the train at any time and a train radio with high reliability are assumed.

9.8 Fire-fighting equipment

9.8.1 The planned fire-fighting plant shall be based on the rescue plan and discussed and agreed with the rescue services.

9.8.2 The use of fire-fighting and rescue trains (LRZ) or a fire-fighting water system for extinguishing fires shall generally be provided in the case of tunnels of over 1 km in length.

9.8.3 Supplies of fire-fighting water and fire-fighting equipment (e.g., fire hydrants, fire extinguishers) shall normally be provided at the portals and, if deemed necessary, at emergency-stopping places. Additional facilities shall be planned for the provision of fire-fighting water where the use of a rescue train (LRZ) is not planned.

9.8.4 The individual locations for the provision of fire-fighting water shall be designed for the following supply quantity:

- Individual supply locations at least 20 l/s
- Filling stations for fire-fighting and rescue trains 80 l/s (standard value).

The required number of supply points in use at any one time shall be specified in the rescue plan.

9.8.5 The pressure at the supply points may not fall below 0.6 MPa. The static pressure should not exceed 1.5 MPa.

9.8.6 The minimum quantity and reserves of fire-fighting water shall be specified in the rescue plan.

9.8.7 Fire-fighting water reservoirs shall be equipped with a standard overflow and an indicator of the water level with an alarm device in case the water level falls below a critical value.

APPENDIX A DESIGN WORKING LIFE (informative)

A.1 Remarks

- The following are nominal values only.
- The structural maintenance of the structure and the servicing of the operating and safety equipment to the required level are preconditions.
- Lower values for the design life shall be assumed for economic analyses.

A.2 Structure and plant

Table 1 Design life (assumed working life) for structures and plant components

Structural and plant components — **Design life Years**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Lining (unreinforced concrete)							X	X	X
Lining, niches, chambers (re-inforced concrete)							X	X	X
Waterproofing							X	X	X
Track support slab					X	X	X		
Ballast track bed	X	X	X						
Cable ducts							X	X	X
Drainpipes, manholes							X	X	X
Pieces of equipment (fittings, covers)	X	X	X						
Hydrant pipe, fire-fighting equipment			X	X	X				
Metal load-bearing structures		X	X	X					
Metal doors, etc. (structure gauge)	X	X	X						

APPENDIX B FIRE LOAD (informative)

B.1 Initial situation

A fire may develop quickly, within a few minutes. This produces heat (very high temperatures) and smoke (with toxic gases).

Heat and smoke can quickly make it unbearable for unprotected persons. Protected persons (fire service personnel with protective clothing and breathing masks) can endure these effects longer. The bearing capacity of structures is sufficient, in general, to withstand the effect of a serious fire much longer.

The fire resistance of the structural elements shall correspond to the anticipated hazard. The requirements shall be specified for the individual structural elements.

B.2 Basic principles for protection in the event of fire

The protection objectives in the event of fire result from the following principles:
- Persons, who are in the tunnel when the fire breaks out, should be able to save themselves.
- Intervention by the rescue services shall take place under safe conditions.
- Excessive damage to property shall be prevented by suitable measures.

B.3 Limit values of exposure for protected persons

The limit values of exposure for fire service personnel are a temperature of 400 to 450 °C and a heat radiation of 5 kW/m^2.

B.4 Thermal loads

B.4.1 The potential thermal load and the temperatures reached have been determined for various boundary conditions by means of tests in tunnels. The temperature development was determined as temperature versus time curves for different types of rolling stock (e.g., EUREKA tests; for documentation, see references in Sections B.6, [1] and [2]).

B.4.2 The existing fire energy, the duration of the fire and the maximum temperature occurring during the fire depend in particular on the type of rolling stock using the tunnel, the type of freight, the ventilation concept and the possible resulting fire scenarios.

A fire can develop very quickly after breaking out. Temperatures of up to 1,200 °C can develop within a short time (5 to 10 minutes), depending on the fire scenario. Such temperatures were measured in insitu fire tests in the Ofenegg tunnel (1965) in Switzerland, in the Zwenberg tunnel (1975) in Austria and in the Memorial tunnel (1993–1995) in the USA.

B.5 Design curves (temperature–time curve)

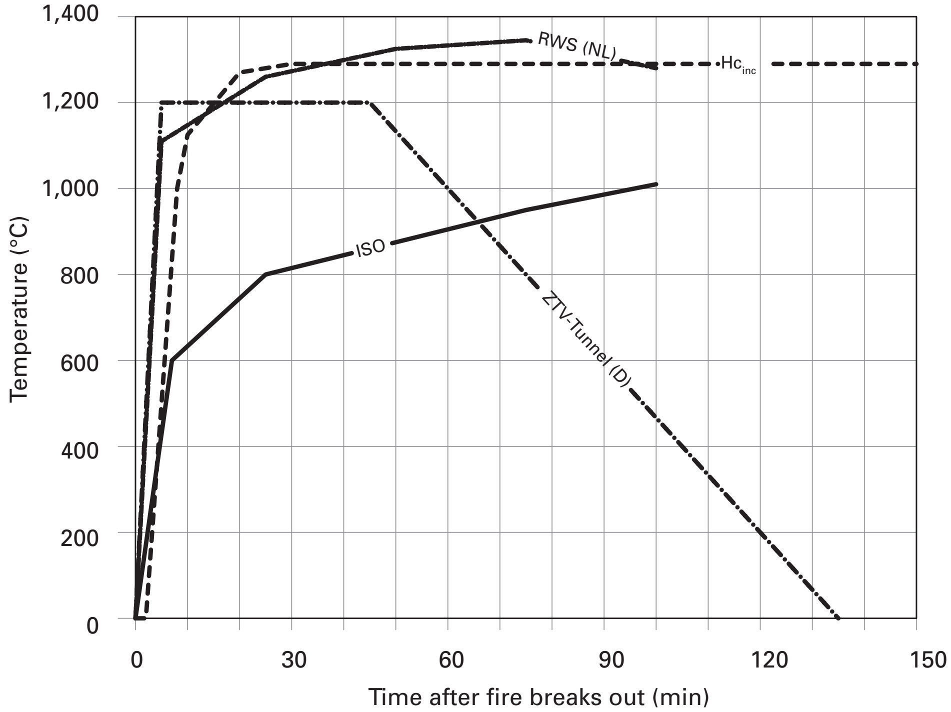
B.5.1 Examples of well-known design curves are shown in Figure 1. The design curves are practically the same in the initial stage. The temperature rises quickly during the first few minutes. This rise is decisive for the development of heat and smoke and for the duration during which it is still possible for persons to stay in the tunnel. The further progress is important for the structure and other structural elements of the tunnel, if special risks exist.

B.5.2 The following temperature–time curves are examples of possible design curves for tunnels and tunnel components according to SIA 197, Section 7.4.1.3:

- ISO 834
- Dutch design curve RWS (Rijkswaterstaat)
- Modified hydrocarbon curve HC_{inc}
- German regulation ZTV-Tunnel.

The modified hydrocarbon curve is the curve given in Eurocode EC1 increased by the factor 1,300/1,100. The design curve in EC1 only reaches a maximum temperature of 1,100 °C.

Figure 1 Dimensioning curves



The choice of the design curve and the corresponding duration of the action depends on:

- the type of traffic (e.g., only passenger traffic or also freight traffic) and thus from the possible thermal loads,
- the consequences of damage caused by the fire (e.g., instability of an important structural component).

The fire scenarios to be considered in the design and the associated design curves shall be specified in the Safety Plan.

B.5.3 The structural elements and the fastenings for equipment in the tunnel shall be designed such that they do not fail in the first phase of a fire. This phase is specified by a temperature of 450 °C with a duration of half an hour (limit loading for protected persons).

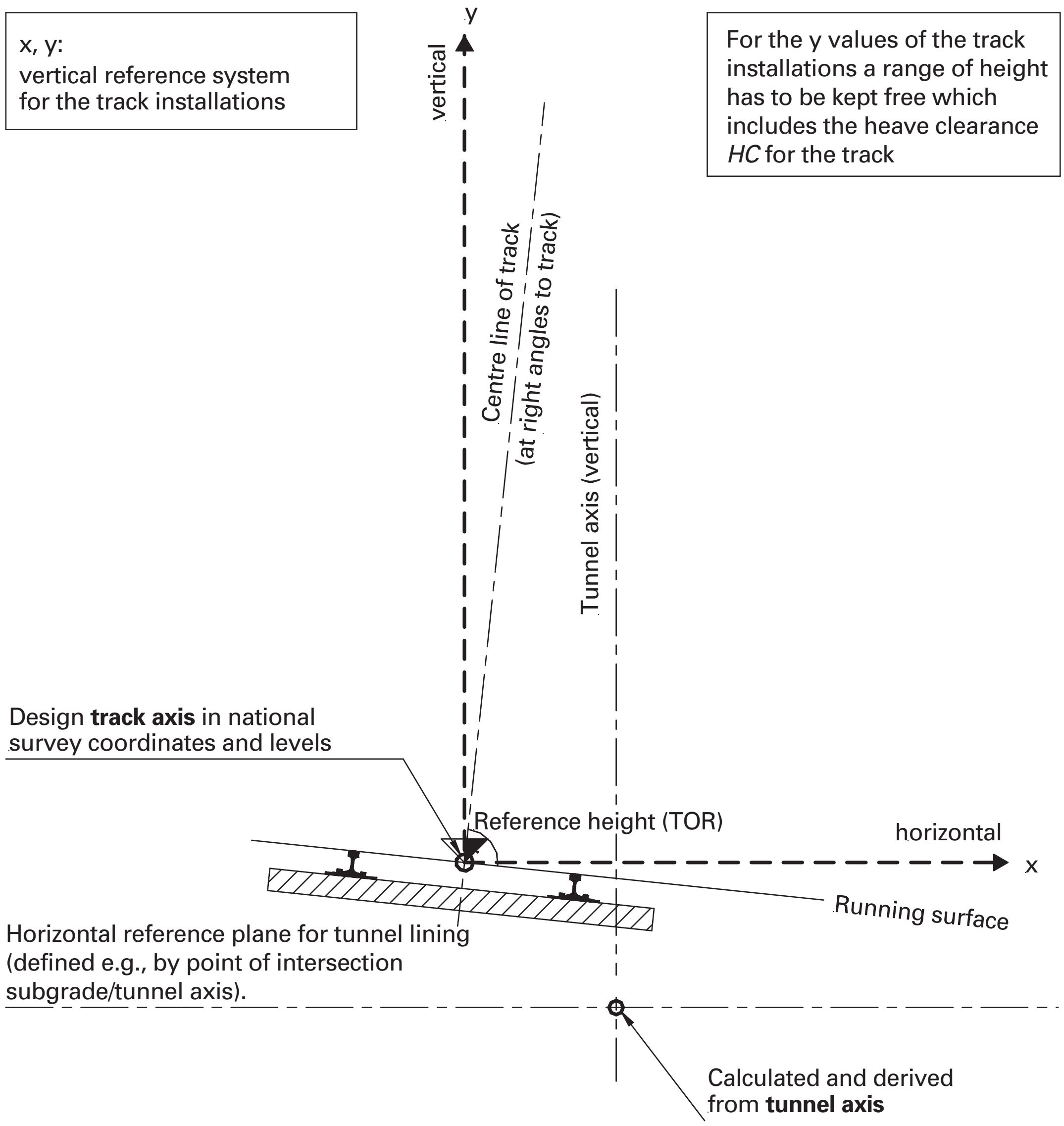
B.6 References

[1] Fires in Transport Tunnels, Report on Full-scale Tests, EUREKA EU 499 – Firetun Projekt, May 1995

[2] Proceedings of the International Conference on Fires in Tunnels, October 10–11, Swedish National Testing and Research Institute, Boras, Sweden, 1994

APPENDIX C REFERENCE SYSTEMS FOR SURVEYING THE TUNNEL (normative)

Figure 2 Reference Systems



APPENDIX D KINEMATIC ENVELOPES FOR NEW RAILWAY TUNNELS (normative)

D.1 The kinematic envelope to be used with the space requirements for the pantograph and the contact line shall be specified in the Service Criteria Agreement. The basis for this can be found in the corresponding Construction Requirements of the Railways Regulation (AB-EBV) and the requirements of this set of Standards.

D.2 The vertical dimensions for tunnels with a ballast track bed shall include a heave clearance *HC* for future track maintenance. The amount of heave clearance shall be specified in the Service Criteria Agreement.

D.3 The vertical dimensions for tunnels with ballastless track shall include a heave clearance *HC* for future track correction if deformations of the tunnel invert are expected (dependent on the geological conditions). The amount of this heave clearance shall be specified in the Service Criteria Agreement.

D.4 The electrical safety distance *be* shall be specified on the basis of the Construction Requirements of the Railway Regulation, if deemed necessary, taking into consideration future changes in the railway power supply.

D.5 The project-specific tunnel data and dimensions of the kinematic envelope are shown in Figures 3 and 4. They shall be applied analogously in the case of other kinematic envelopes.

Figure 3 Kinematic envelope for standard gauge railways – project-specific tunnel data and dimensions

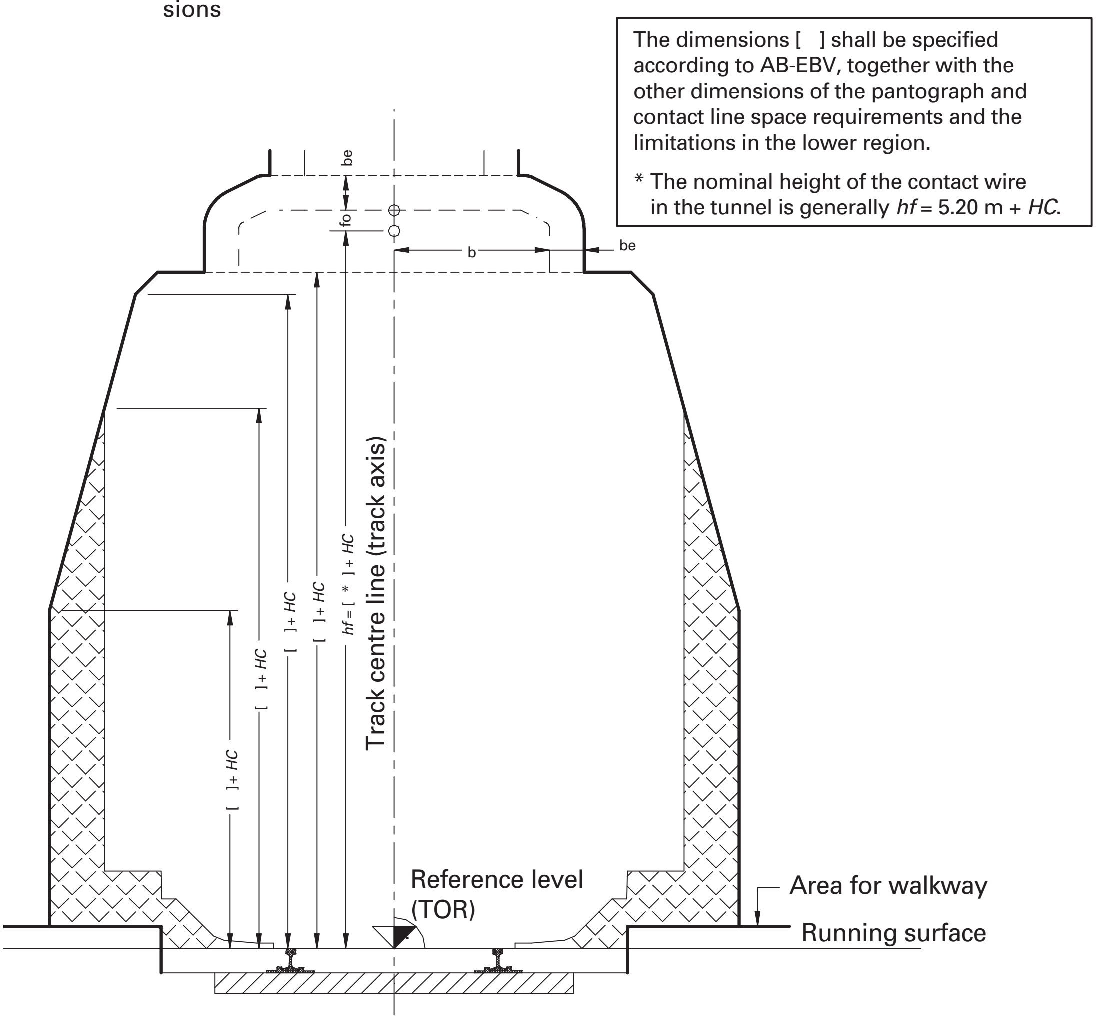


Figure 3 shows, as an example, the kinematic envelope EBV 4, reference line EBV O4 and UIC GC, with space for pantograph EBV S3 and the corresponding space for the contact line.

Figure 4 Kinematic envelope for multi-track railways – data and dimensions specific to the tunnel

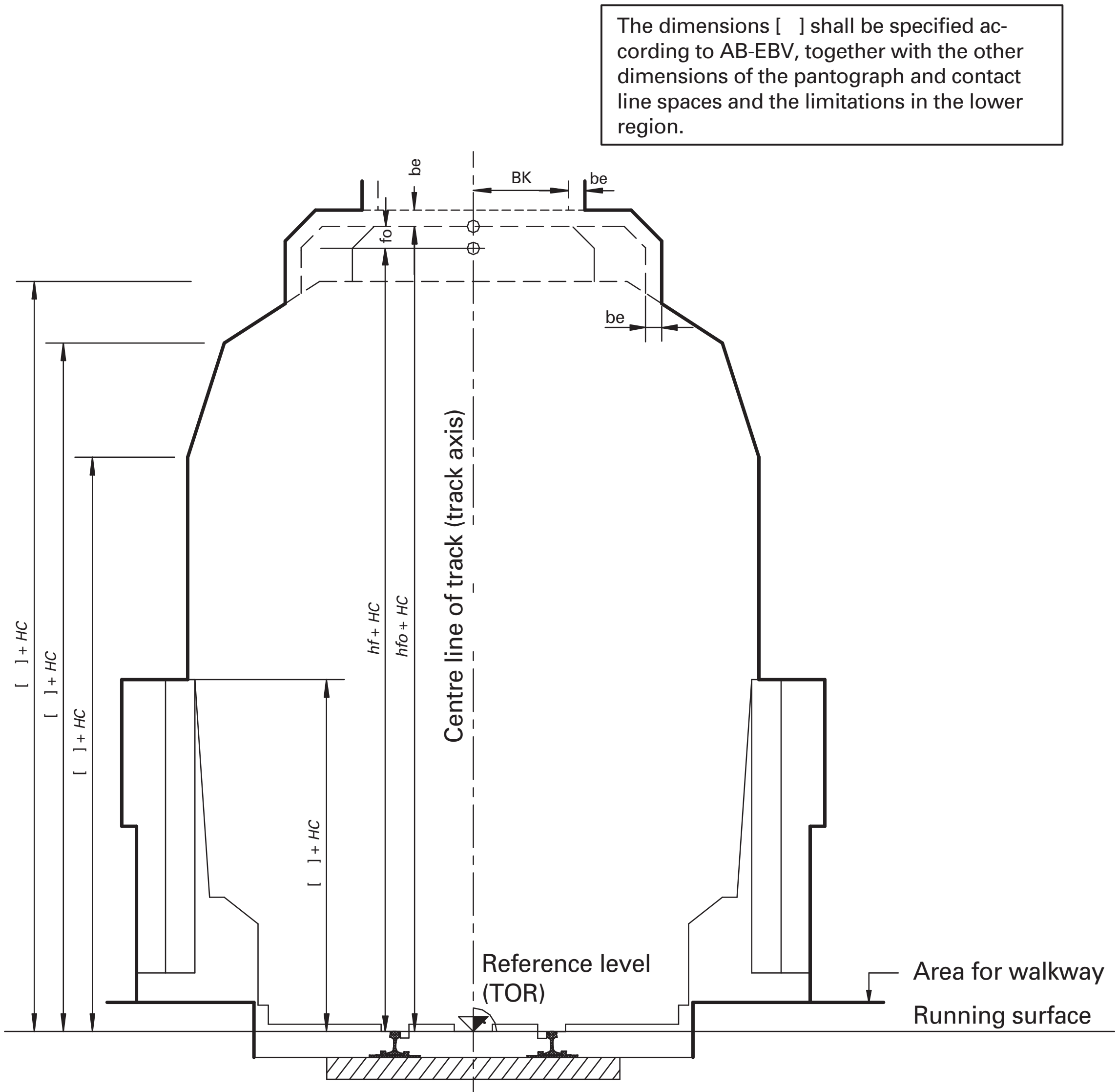


Figure 4 shows, as an example, the kinematic envelope EBV B, reference line B.

APPENDIX E STANDARD CROSS-SECTION OF TUNNEL (normative)

E.1 Basic principles

E.1.1 The space requirements and the elements that determine the size and shape of the tunnel shall be specified in the standard cross-section of the tunnel. This forms the design basis for the tunnel cross-section.

E.1.2 In the upper region these are
- the kinematic envelope (see Appendix D),
- the limits of the standard structure gauge, which includes within the shape of the tunnel cross-section the traffic space, the safety space and the space for equipment (design section without the space for construction measures *t*),
- the utilisable construction space *t*, including the tolerance clearance *a* and the construction clearance for future measures *b*,
- the design cross-section intended for the tunnel; it includes the limits to the kinematic envelope and the utilisable construction space *t*.

E.1.3 In the lower region these are
- the construction space requirements for track support,
- the construction space requirements for kerb and walkway.

E.2 Figures

E.2.1 Figures 5, 6 and 7 show the space requirements and elements that have to be specified.

E.2.2 In addition, the following space requirements shall be considered for:
- cable routes,
- drainage system,
- the additional structural elements required for safety, if deemed necessary,
- the operating and safety equipment,
- and the required free aerodynamic cross-section.

Figure 5 Standard cross-section for double-track tunnel with arch lining

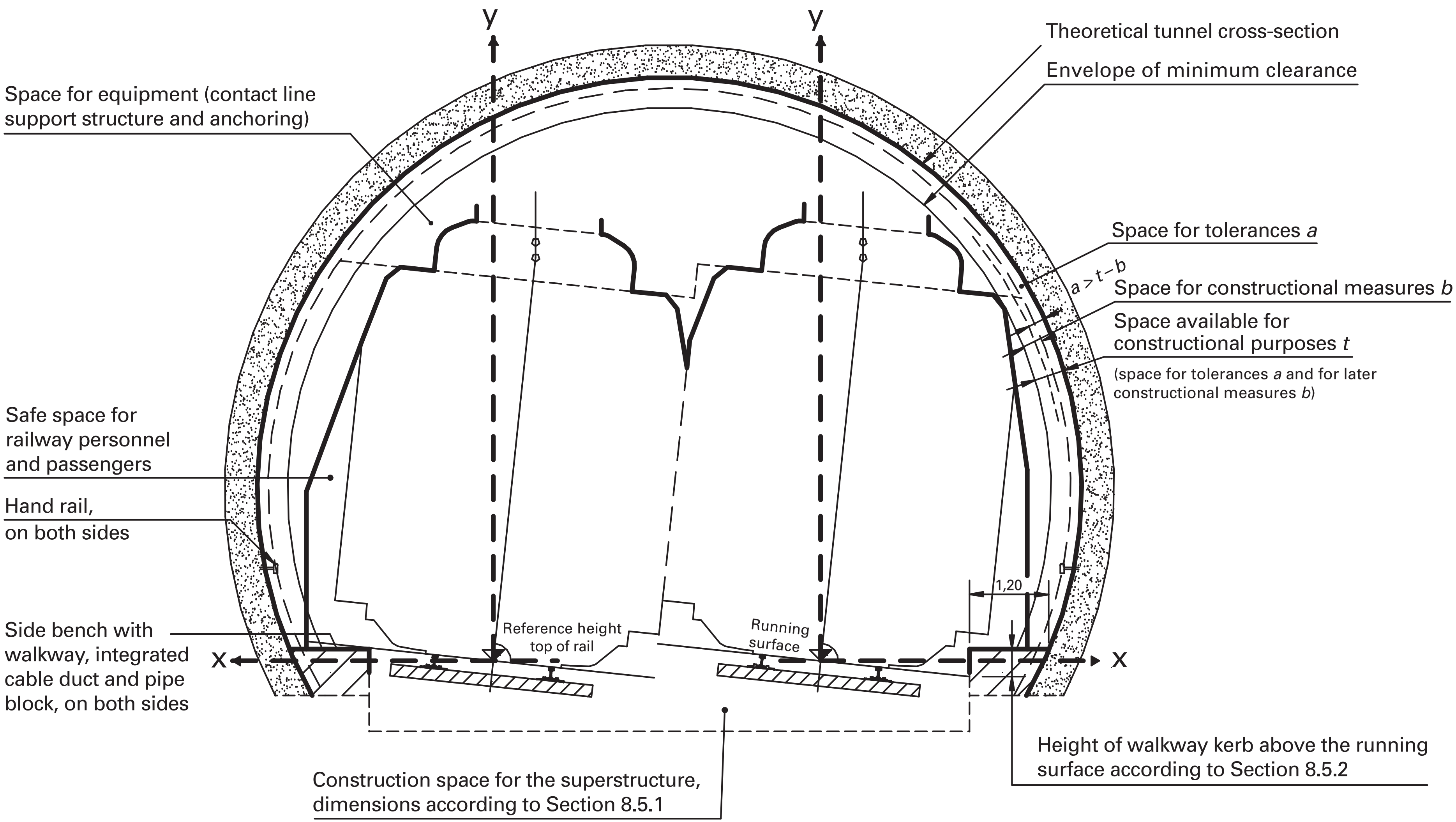


Figure 6 Standard cross-section for single-track tunnel with arch lining

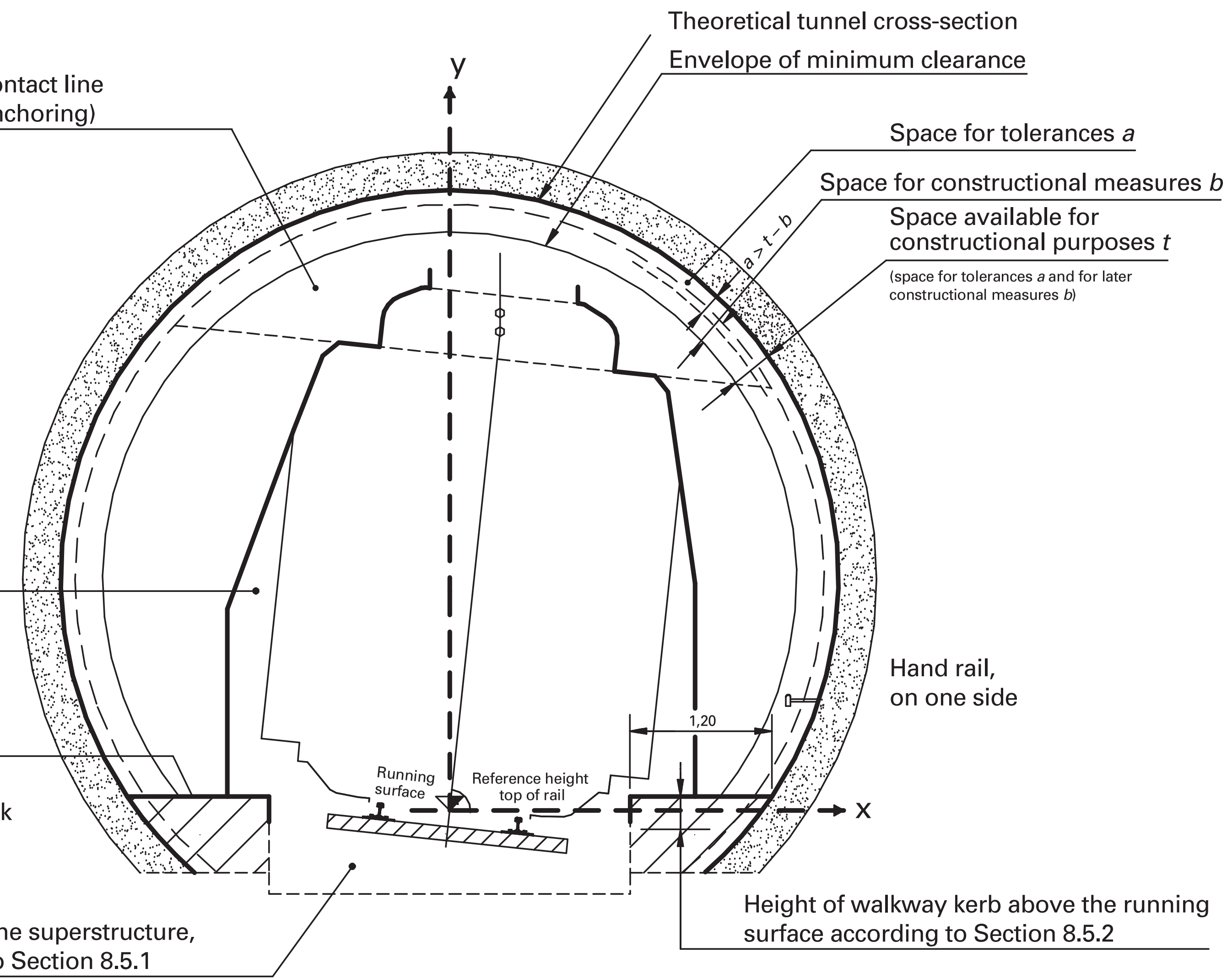


Figure 7 Standard cross-section of tunnel of rectangular form

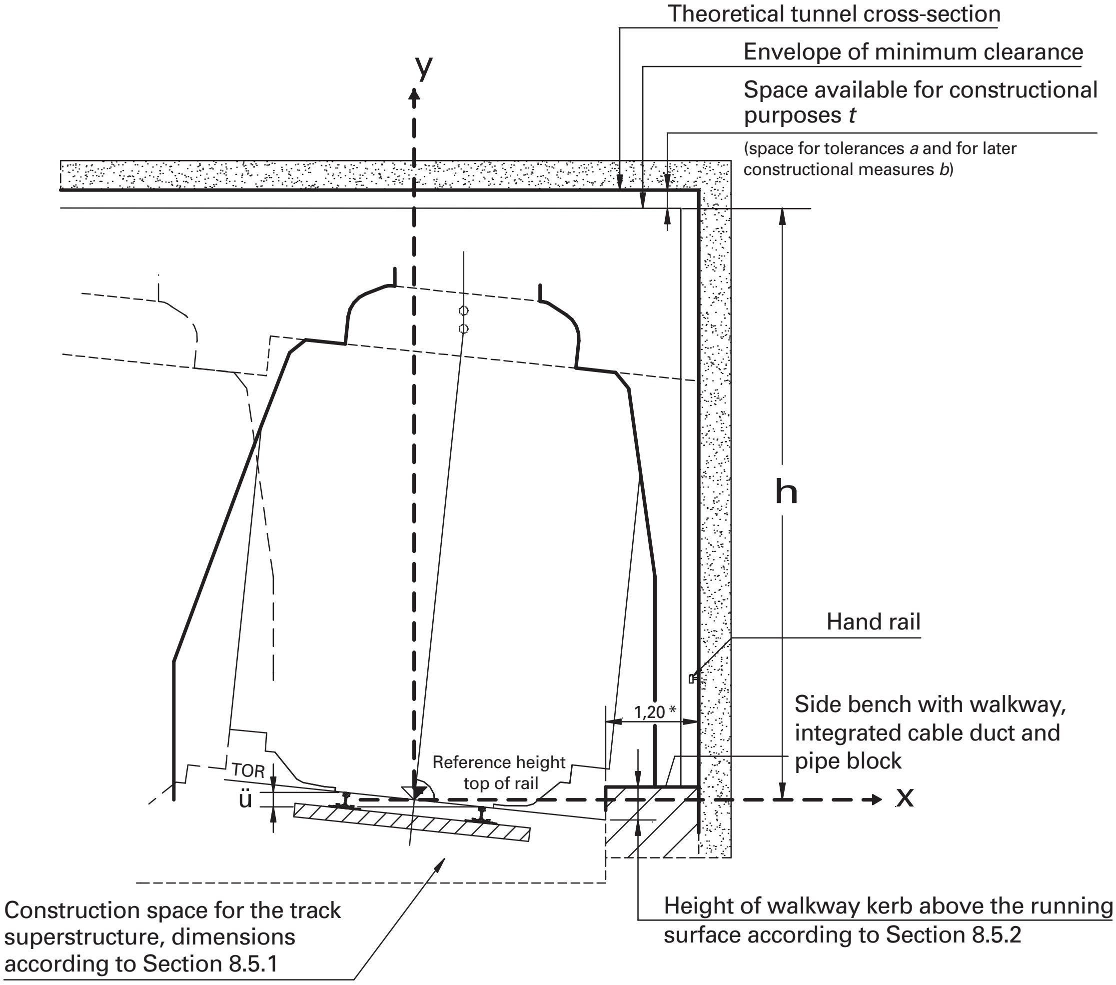


Table 2 Standard values of height *h* of the limit of the standard structure gauge

Speed *v* Distance from substation *u*		***v* ≤ 160 km/h and *u* > 5 km**	***v* > 160 km/h or *u* ≤ 5 km**
Height *h*	general case	≥ 6.20 m	≥ 6.50 m
	in the vicinity of Track Crossovers or Contact Line anchorages	≥ 6.40 m	≥ 6.70 m

E.2.3 The kerb shall be accessible and designed as a walkway free of obstacles. In the case of single-track tunnels with a walkway on one side only, at least Area 2 according to AB-EBV shall be kept free for the service route and the complete window space.

APPENDIX F DETERMINATION OF UTILISABLE CONSTRUCTION SPACE (normative)

F.1 The utilisable construction space t comprises the tolerance clearance a (if any) and the construction clearance for future measures b. It shall be determined by the relationship (1). Systematic errors are not considered. These can be avoided or kept to a minimum by means of suitable quality assurance measures.

$$t = \sqrt{a^2 + b^2} \tag{1}$$

F.2 The following dimensions shall be assumed for the utilisable construction space t until the final choice of construction method is determined:

- Employing tunnel-boring machine or shield machine (TBM or SM drive) techniques
  Double-shell lining t = 0.30 m
  Single-shell lining t = 0.35 m
- Employing drill and blast or machine-assisted techniques
  (with the possibility of modifying the cross-section) t = 0.20 m
  For cut-and-cover tunnels t = 0.20 m

F.3 The tolerance clearance a (if any) takes into consideration errors during construction due to surveying and construction inaccuracies (deviations from the design size, shape and position). The values of the variance of the individual, stochastically independent tolerances a_i are combined using the Gaussian law of error propagation to calculate a according to the formula (2).

The individual maximum tolerances a_i shall be specified in the design for the various possible influences:

- Error in basic surveying g (in particular the breakthrough error shall be taken into consideration)
- Setting out error f
- Guaranteed maximum error in the excavation of the tunnel v
- Guaranteed maximum deviation of the drive (TBM, Shield Machine) s
- Placement inaccuracy / deformation of the formwork or placement in the case of a single layer of lining segments d.

$$a = \sqrt{g^2 + f^2 + v^2 + s^2 + d^2} \tag{2}$$

F.4 The construction clearance for future measures b shall be reserved for measures, which may be necessary during operations (e.g., for strengthening of the lining, waterproofing, groundwater drainage, sound-proofing of the lining and equipment).

The extent of space b depends on the type of tunnel lining (and whether alterations to the finished structure are possible or not).

Nominal values for b:

- for lining with unreinforced concrete 0.10 m
- for lining with re-inforced concrete 0.15 m
- for single layer of lining segments 0.20 m.

F.5 Further tolerances (e.g., deformations due to rock pressure) shall be considered separately in the design of the cross-section. The tolerance can be divided up into a fixed part (this shall be added to the utilisable construction space t) and part, which may occur (this shall be introduced into the formula (2) for calculating a). This subdivision shall be agreed upon and laid down in the basis of design.

APPENDIX G DESIGN PROCESS TUNNEL STRUCTURE AND RAILWAY EQUIPMENT (informative)

Table 3 Design process

Tunnel lining **Project phases**	**Environmental Impact Assessment**	**Safety**	**Railway equipment** **Project phases**	**Process**
Preliminary study	Preliminary investigation, Schedule of responsibilities for Environmental Impact Assessment Report (EIAR)	Short report, schedule of responsibilities for risk analysis	**Conceptual study** Requirements and preliminary design for environmentally relevant design elements	Preparation, concession application
	EIAR 1st stage and schedule of responsibilities for EIAR 2nd stage	Initial evaluation of risks, involvement of rescue services	**Conceptual study** for further design elements	Concession application
Preliminary design			Verification of concepts, detailed conceptual studies	
Authority design	EIAR 2nd stage, emphasis on environmental effects of the design and the tunnel construction	Health and safety report with partial emphasis on the structure	**Preliminary design** Binding statements for the construction permit application	Preparation for construction permit
Modifications from construction permit application consultation procedure	Consultation about EIAR with risk report *(Risk Register)* as Appendix		Checking of the compatibility of railway equipment and tunnel structure after project modification resulting from construction permit process	Issue of construction permit
Tender documents	Ecological accompaniment of the design for tendering			Issue of tender for tunnel structure
Complete design documentation / detailed design	Ecological monitoring of the complete design documentation	Continuation of work on the health and safety report	**Complete design documentation, detailed design**	Issue of construction permit, detailed design
			Tender documents (depending on the organisation of the project, possibly at the preliminary design stage)	Tender for railway equipment (possibly already at an earlier stage)
Complete design for construction / Construction **Commissioning**	Ecological monitoring of construction phase	Preparation of operational measures to reduce risks, implementation of the concepts, introduction of health and safety measures	Verification of the compatibility of railway equipment and tunnel structure after the adaptation of the complete design for construction **Complete design for construction/ Construction, Commissioning**	Acceptance of tunnel structure Technical acceptances by BAV (Transport Ministry), Commissioning
Operation (use, maintenance)	Verification of success of ecological measures, imposed operational requirements (contracts, inspections)	Training of personnel. Continuous adaptation of safety measures	**Operation** (use, maintenance)	Guarantee acceptances

APPENDIX H GUIDELINES AND OTHER DOCUMENTS (informative)

The guidelines and documents referred to in this set of Standards are listed below.

[1] BAV-Richtlinie Nr. 1 zu Art. 27 EBV "Bauten an, über und unter der Bahn"; Bundesamt für Verkehr, Bern

[2] UIC-Kodex 779-9 "Sicherheit in Eisenbahntunneln"; Union Internationale des Chemins de fer, Paris

[3] UIC-Kodex 779-11 "Bemessung des Tunnelquerschnitts unter Berücksichtigung der aerodynamischen Effekte"; Union Internationale des Chemins de fer, Paris

[4] Recommendations of the Multidisciplinary Group of Experts on Safety in Tunnels (Rail); United Nations Economic and Social Council, Economic Commission for Europe UNECE

[5] Medizinische Prophylaxe bei Untertagarbeiten im feucht-warmen Klima, SUVA Infoschrift 2869/26.D; SUVA, Luzern

[6] Geometrische Gestaltung der Fahrbahn für Normalspur, R 220.46; SBB AG, Bern

[7] Handbuch für den Bau und Unterhalt der Fahrbahn, R 220.4; SBB AG, Bern

[8] Handbuch für den Bau und die Instandhaltung der Fahrbahn, R 30.1; Rhätische Bahn, Chur

[9] Unterbau und Schotter, Vorschriften für Neubau und Erneuerung, R 211.1; SBB AG, Bern

[10] Richtlinien für die Verlegung von Kabelschutzrohren aus Kunststoffen, Richtlinie 2.10; Verband Schweizerischer Elektrizitätsunternehmungen (VSE), Zürich

[11] Richtlinien zum Korrosionsschutz von erdverlegten metallischen Anlagen, Richtlinie C2; Korrosionskommission der Schweizerischen Gesellschaft für Korrosionsschutz (SGK), Zürich

[12] Richtlinien zum Schutz gegen Korrosion durch Streuströme von Gleichstromanlagen, Richtlinie C3; Korrosionskommission der Schweizerischen Gesellschaft für Korrosionsschutz (SGK), Zürich

Represented organizations in the commission SIA 197 and in the Working group SIA 197/1

ASTRA	Federal Roads Office
BAV	Federal Office of Transport
BUWAL	Federal Office for the Environment
EPFL	Swiss Federal Institute of Technology, Lausanne
MGB	Matterhorn Gotthard Railway
RKKF	Fire Services Coordination Switzerland
SBB	Swiss Federal Railways

Members of the commission SIA 197 *Design of Tunnels*

		Representative of
President	Dr. François Vuilleumier, ing. civ. dipl. EPF/SIA, Brig	Consultant engineer
Members	Dr. Ernst Berger, dipl. Bauing. ETH/SIA, Mühlethurnen	BUWAL
	Erwin Beusch, dipl. Bauing. ETH/SIA, Ennetbaden	Employer
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	Martin Känzig, dipl. Bauing. ETH/SIA, Bern	BAV
	Pierre Michel, Ing. civ. dipl. EPF/SIA, Vex	Consultant engineer
	Alex Sala, dipl. Bauing. FH. Regensdorf	Consultant engineer
	Peter Testoni, dipl. Bauing. ETH/SIA, Wabern	BAV
	Peter Theiler, dipl. Bauing. ETH/SIA, Lucerne	Contractor
	Willy Ritz, Ing. HTL, Kastanienbaum	Contractor
	Dr. Hans-Jakob Ziegler, Geologist, Bern	Consultant engineer

Members of the Working group SIA 197/1 *Railway Tunnels*

		Representative of
President	Martin Känzig, dipl. Bauing. ETH/SIA, Bern	BAV
Members	Josef Elmiger, dipl. Bauing. HTL, Langenthal	Railways (SBB)
	Dr. Peter Gerber, phil. nat. Physiker, Bern	Consultant engineer
	André Gerold, dipl. Bauing. ETH, Basel	Consultant engineer
	Dr. Jacques-André Hertig, Ing. civ. dipl. EPF, Lausanne	University (EPFL)
	Wolfgang Hüppi, dipl. Elektroing. HTL, Bern	BAV
	Roland Jordi, dipl. Bauing. HTL/Dipl. Wirtschaftsing. FH, Bern	Railways (SBB)
	Ernst Märki, dipl. Bauing. ETH/SIA, Bremgarten BE	Consultant engineer
	Peter Maurer, dipl. Maschinening. HTL, Brig	Railways (MGB)
	Hans Mundwiler, dipl. Elektroing. HTL, Zürich	RKKF (Fire Service)
	Claude Risch, Ing. civ. dipl. EPF, Lausanne	Consultant engineer
	Andreas Siegrist, dipl. Bauing. ETH/SIA, Thun	Employer
	Urs Wili, dipl. Elektroing. ETH/SIA, Bern	Consultant engineer
Minutes	Markus Meier, dipl. Bauing. HTL, Bern	Consultant engineer

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