TRAINING MATERIAL

GUIDELINES FOR STRUCTURAL FIRE RESISTANCE FOR ROAD TUNNELS

Prepared by WG. 6 “Maintenance and Repair”

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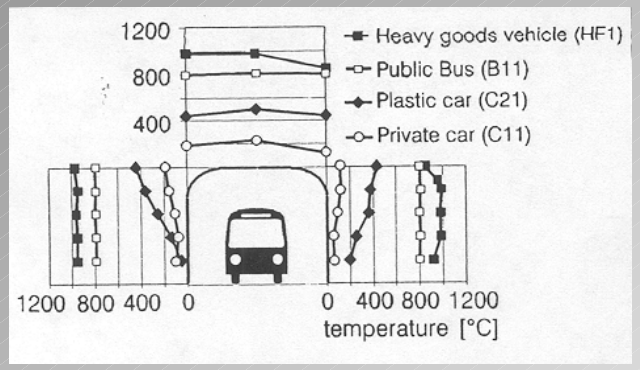
Index

Introduction

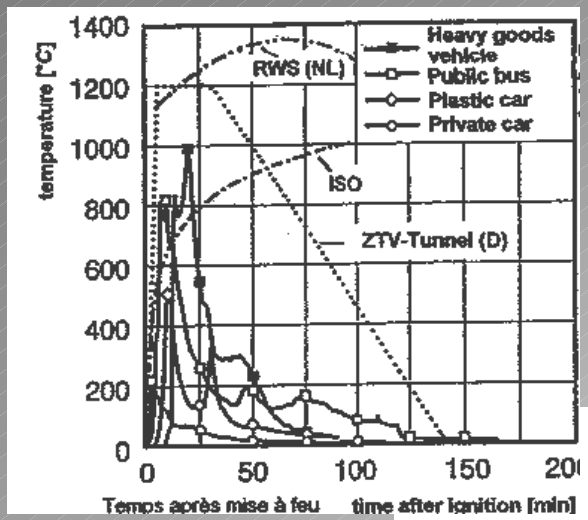
ITA presented in 2005 a “guideline for structural fire resistance for road tunnels” as the result of a cooperative effort between the World Road Association (PIARC) Technical Committee on Road tunnel Operation (C 3.3) and its Working Group 6 *Fire and Smoke Control*, and the International Tunnelling Association (ITA) Working Group 6 *Repair and Maintenance of Underground Structures*. The purpose of this cooperative effort was to develop guidelines for resistance to fire for road tunnel structures.

Design Criteria for Fire Resistance

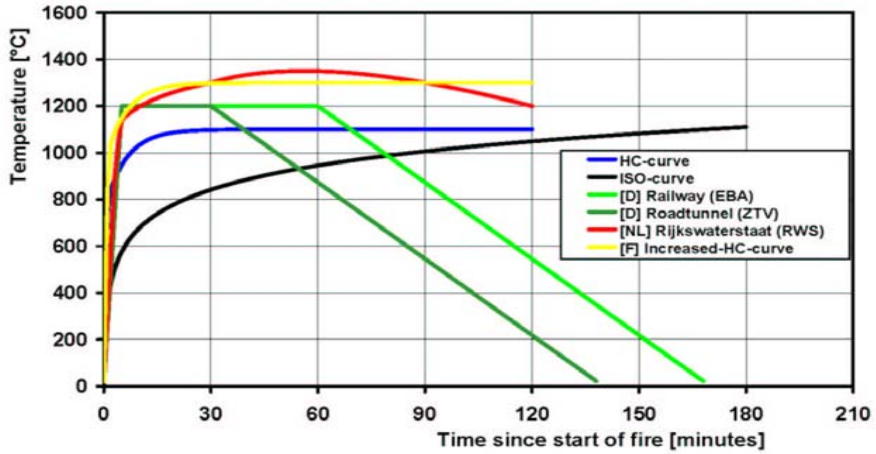


The temperature is highest on exposed surfaces and particularly at the higher elevations of the tunnel structure.

Design Criteria for Fire Resistance



Temperature-curves (France, Germany, Netherlands, ISO, EU)



Design Criteria for Fire Resistance

Traffic Type	Main Structure				Secondary Structures[4]			
	Immersed or under/inside superstructure	Tunnel in unstable ground	Tunnel in stable ground	Cut & Cover	Air Ducts[5]	Emergency exits to open air	Emergency exits to other tube	Shelters[6]
Cars/ Vans	ISO 60 min	ISO 60 min	2	2	ISO 60 min	ISO 30 min	ISO 60 min	ISO 60 min
Trucks/ Tankers	RWS/ HC_{inc} 120 min[1]	RWS/ HC_{inc} 120 min[1]	3	3	ISO 120 min	ISO 30 min	RWS/ HC_{inc} 120 min	RWS/ HC_{inc} 120 min[7]

Design Criteria for Fire Resistance

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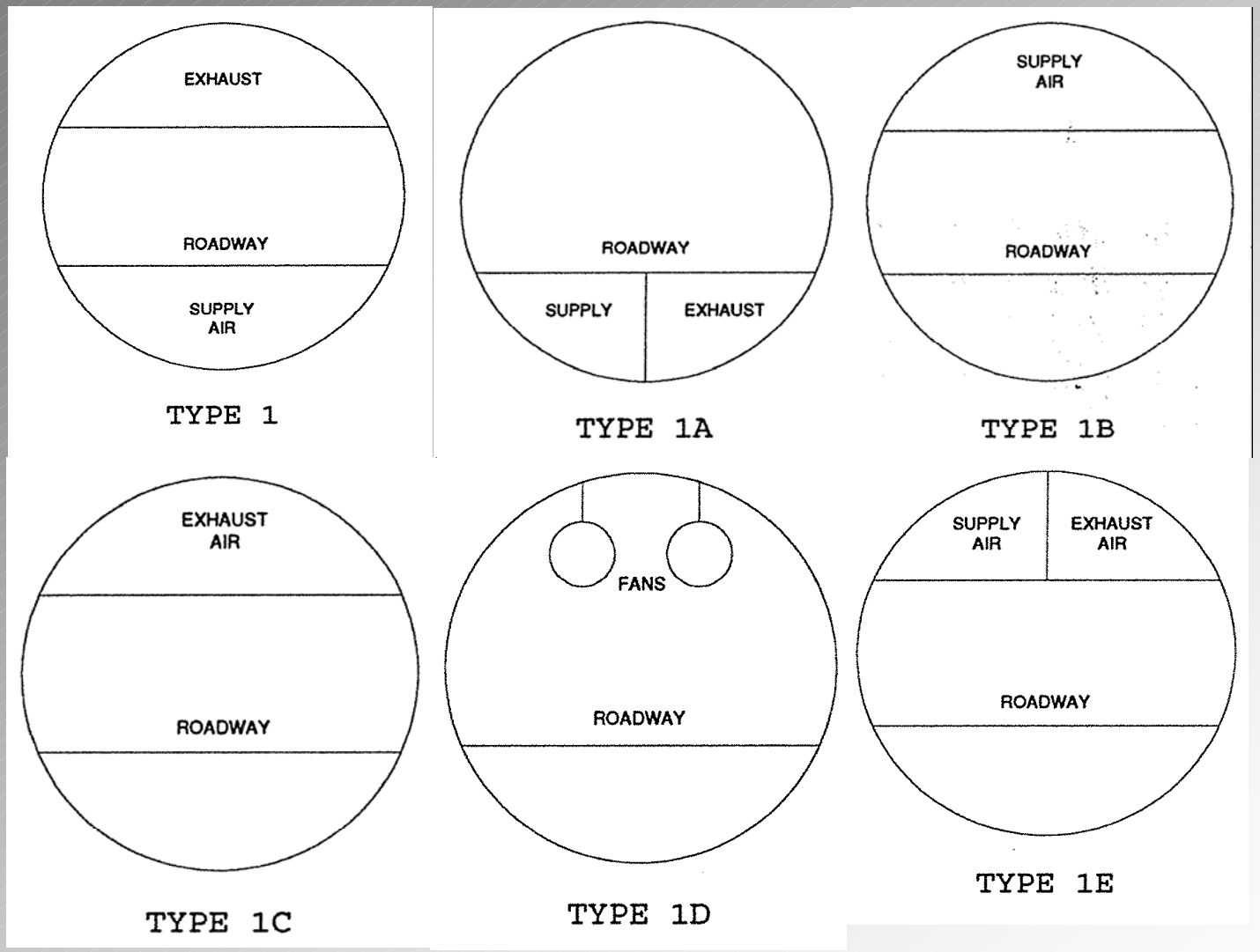
– Introduction of Tunnel Fire Curves into European and International Standards

PIARC has got in touch with the European Committee for Standardization (CEN/TC250 *"Structural Eurocodes"*) and proposed that a temperature-time curve representative of very severe tunnel fires (either RWS or HCinc) be introduced into the relevant European standard. CEN/TC250 answered in March 2001 that there was no fundamental objection to the inclusion of such a new curve. However, the Eurocode dealing with "Actions in case of fire" was in the process of being converted from a pre-standard into a full standard, and it was too late to include any new material. This should be considered at the first revision of the Eurocode. At the same time, the introduction of the supporting calculation rules should be considered for inclusion in the "material" dependent Eurocodes. In the meanwhile, they suggested that PIARC ask CEN/TC127, in charge of fire test methods, if it would be possible to define a tunnel fire curve for fire resistance tests. This could give a more official status to tests carried out using this curve.

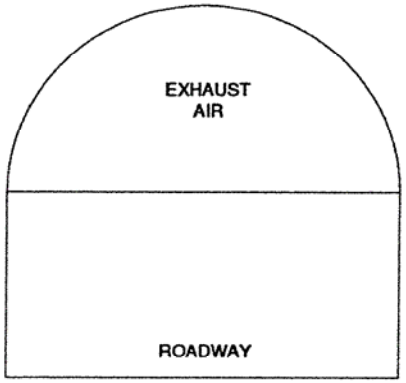
Lining Material Behaviour

Concrete Reinforcement

Tunnel Classification



Tunnel Classification



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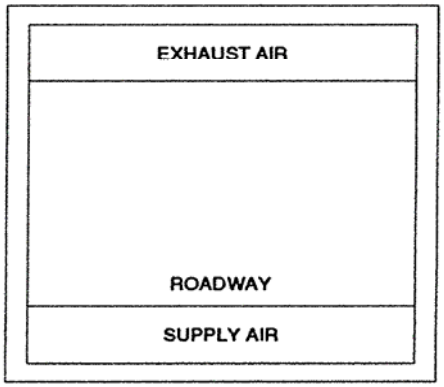
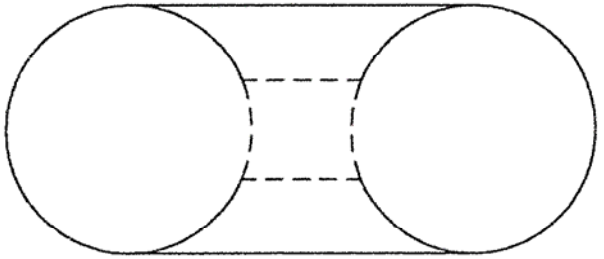
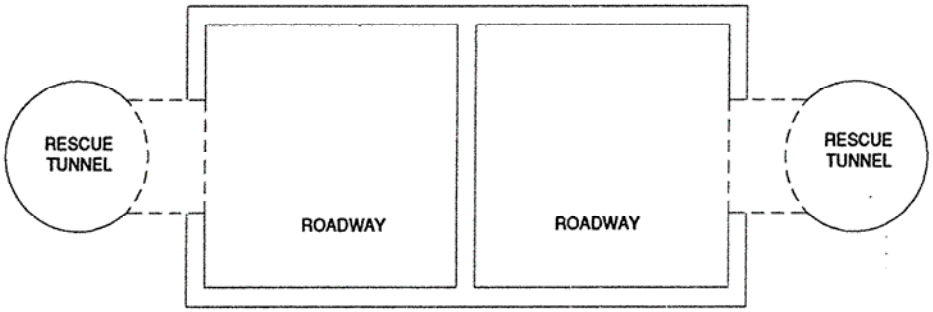


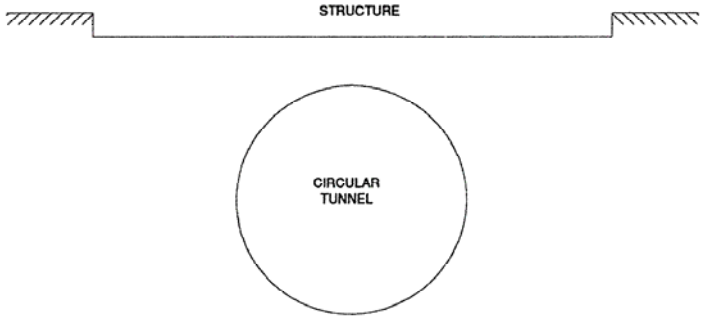
TYPE 3



TYPE 4
(Cross Passages)



Type 5 (typ)



Type 6 (typ)

Tunnel Classification

Tunnels can be rated or classified in regard to other modifies that are influential in the potential hazard /or benefit to the structure. They are:

Hazard /Benefit component coding

Type of Component	*Symbol*	*Description*
Stable Ground	SG	Ground that will not collapse in the event of fire
Unstable Ground	UG	Ground that will collapse if unsupported
Emergency Egress	EE	External rescue tunnels, emergency shafts
Cross Passages	CP	Cross passages to other tunnel
Safety Chambers	SC	Safety chambers with self contained air supply

Structural Elements

Construction materials used for main and secondary structures must be non-combustible or very little combustible (Euroclass A1 or Euroclass A2, s1, d0) from the point of view of reaction to fire. Lightweight roof structures may have less severe fire reaction requirements (i.e. Euroclass C) since the loss of these does not represent any risk to safety provided that fire propagation risks are limited.

Structural Elements

Fire Resistance Levels (1)

The four levels of fire resistance from the French Inter-ministry circular 2000-63 :

Level NO

No risk of progressive collapse in the event of a local failure. The loss of one element should not result in a transfer of load, which is likely to cause other parts of the structure to fail.

Level N1

It should be used for structures which are important for emergency action to take place. In tunnels where all types of vehicles are allowed, level N1 corresponds to resistance to the ISO curve during 2 hours.

Level N2

It should be required for structures which must resist the most violent fires during the period required to allow evacuation and action by the emergency services. In tunnels where all types of vehicles are allowed, level N2 corresponds to resistance to the HCinc curve during 2 hours.

Fire Resistance Levels (2)

Level N3

This level corresponds to the most onerous fire exposure conditions and applies to structures, which must resist the most violent fire throughout the prescribed exposure period.

In tunnels where all types of vehicles are allowed, level N3 corresponds to resistance to both the ISO curve during 4 hours and the HCinc curve during 2 hours.

Tunnels Reserved for Passenger Cars

Where only passenger cars and vans are allowed, levels N1, N2 and N3 are identical and correspond to resistance to the ISO curve during 1 hour.

Structural Elements

Lining, Material Types and Fire Behavior

The following types of concrete lining can be considered:

- Horseshoe Tunnels
  - Cast in-situ concrete lining
- Circular Tunnels:
  - Cast in-situ concrete lining
  - Segmental lining with gaskets and packers.
- Box/rectangular Tunnels
  - Cut and cover tunnels
  - Immersed tunnels including joints

Structural Elements

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The parameters affecting the remaining strength of the tunnel are

- amount of segment remaining after spalling
- temperatures reached during the fire and consequential concrete strength loss
- tunnel deformations and tunnel - ground interaction
- possibility of rehydration of cement
- position of damage within the ring relative to possible disturbed ground outside the lining

Discussion about

- *Loads*
- *Water and Ground Load*
- *Thermal Load*
- *Moment Action*

Structural Elements

1

Linings

2

Concrete Linings
Steel Linings

3

Cast Iron Linings
Masonry Linings
Gaskets

4

Immersed Tunnel Joints

Suspended Ceilings - Supported Floor/Deck

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Concrete
Steel

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Anchorages

Structural Elements

Mitigation Technology for Tunnel Structures

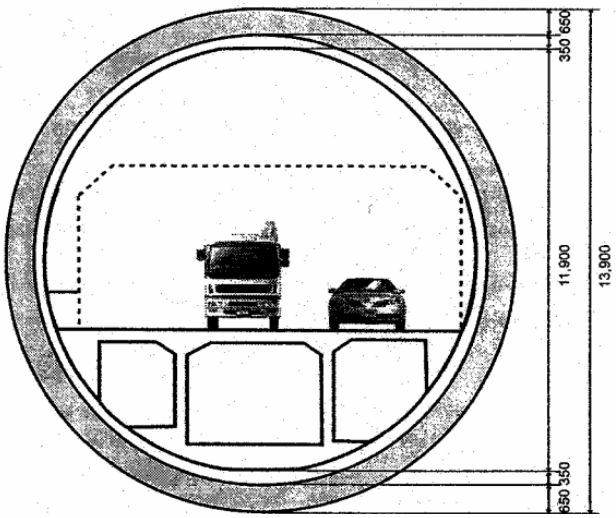

Figure 5.1 Standard TTB Cross-Section

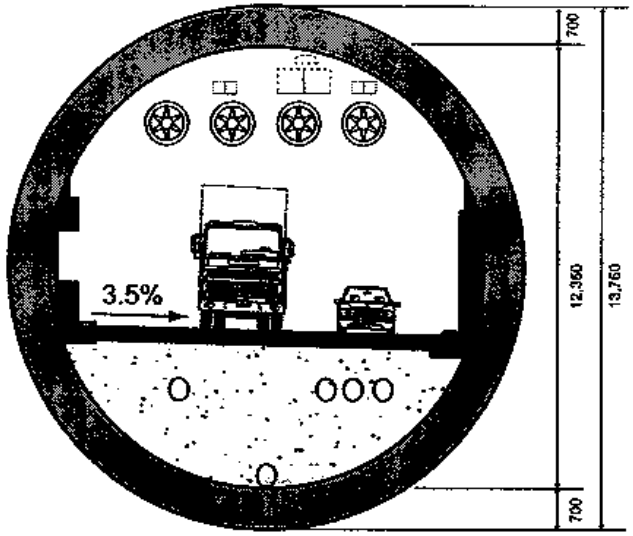

Figure 5.2 Standard Cross-Section of No.4 Elbe Tunnel

Conclusions

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- Concrete: Structural elements wall, ceilings, partition walls, cast-in-place concrete etc: Protect the concrete surface for a maximum heat rise at surface of 380° C
- Precast concrete elements: including high strength concrete segments, precast planks etc: Protect for a maximum heat rise at surface of 200-250° C
- Concrete Ceilings shall be suitably protected from collapse for a minimum of two (2) hours with a maximum temperature rise at the surface of 380° C
- Clay brick masonry and dimension (asher) stone are not considered critical and do not need protection.
- Segmental Steel and Cast Iron liners shall be protected at the surface for a maximum temperature rise of 550° C
- Leaded Joints in segmental liners shall be protected for a maximum heart rise of 200° C
- Ceramic fired tile finishes of tunnels shall be protected from explosive spalling to a maximum temperature rise of 200° C. (Note the use of ceramic fired tile finishes in new tunnels should be avoided)

Conclusions

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- Steel and Cast Iron structural elements and ceiling hanger rods shall be protected for a maximum temperature rise of 550° C
- Stainless steel structural elements and ceiling hanger rods shall be protected for a maximum temperature rise of 800° C
- Anchorages must be designed for a minimum factor of safety of 3.5 for fixity of anchor. Fixity is described as the bond/ attachment to the substrate
- Epoxy resin anchors shall be protected for a temperature heat rise at a depth of 6 cm from the surface of 200° C. (Note: France prohibits the use of epoxy anchors in environments that may be above 300° C)
- All epoxy anchors shall be designed with the bond zone not less than 6 cm from the surface of the concrete or material that the anchor is being installed within.
- Lead shield anchors, anchors with lead components and brass, zinc or other low melting point anchors are not permitted for structural or emergency equipment supports (i.e. dampers, fans, etc.).

Conclusions

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- All fireproofing materials shall not be degraded in regard to bond to the substrate or in fire resistance rating from the presence of water.
- All materials incorporated in tunnel structures or within tunnels shall be non-toxic and non-flammable.
- All emergency equipment to be installed shall conform to PIARC Guidelines and local codes, ordinances and regulations
- Emergency access/escape areas shall be designed not to exceed a maximum temperature of 40° C in areaways as per PIARC Guidelines and local codes, regulations and ordinances.

Meanwhile the European Commission published a Directive for the safety of road tunnels and a TSI for the safety in railway tunnels where most of these recommendations are included as requirements.

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