International Seminar on "Advances in Design, Construction and Operation of Tunnels“

19-21 April 2023 at Dehradun, India

Indian Roads Congress

Ventilation systems and strategies for mountainous regions - taking the Austrian alpine tunnels as an example

[1)]Peter Sturm, [1)]Michael Bacher, [2)]Patrik Fößleitner

[1)]Graz University of Technology, Austria
[2)]FVTmbH, Austria

International Seminar on "Advances in Design, Construction and Operation of Tunnels"
19-21 April 2023 at Dehradun, India

Ventilation design - background

Ventilation plays a key role for a safe operation of a tunnel.

Clear guidelines for design and operation of ventilation systems are given in various international publications, like PIARC, but also on national level.

Very often, however, special boundary conditions given by geological conditions in mountainous areas or existing buildings and other structural constraints in built-up areas force special solutions for ventilation systems that deviate significantly from standardized specifications.

PIARC design and operation guidelines

Technical committees within PIARC have dealt already since decades with topics like:

- Safety of road tunnels
- Design of ventilation systems for normal operation
- Design of ventilation for incident (fire) operation
- Definition of ventilation design parameters
- Operation of tunnels
- Guidelines for fixed fire fighting systems
- Impact of new energy carriers on tunnel safety
- ….

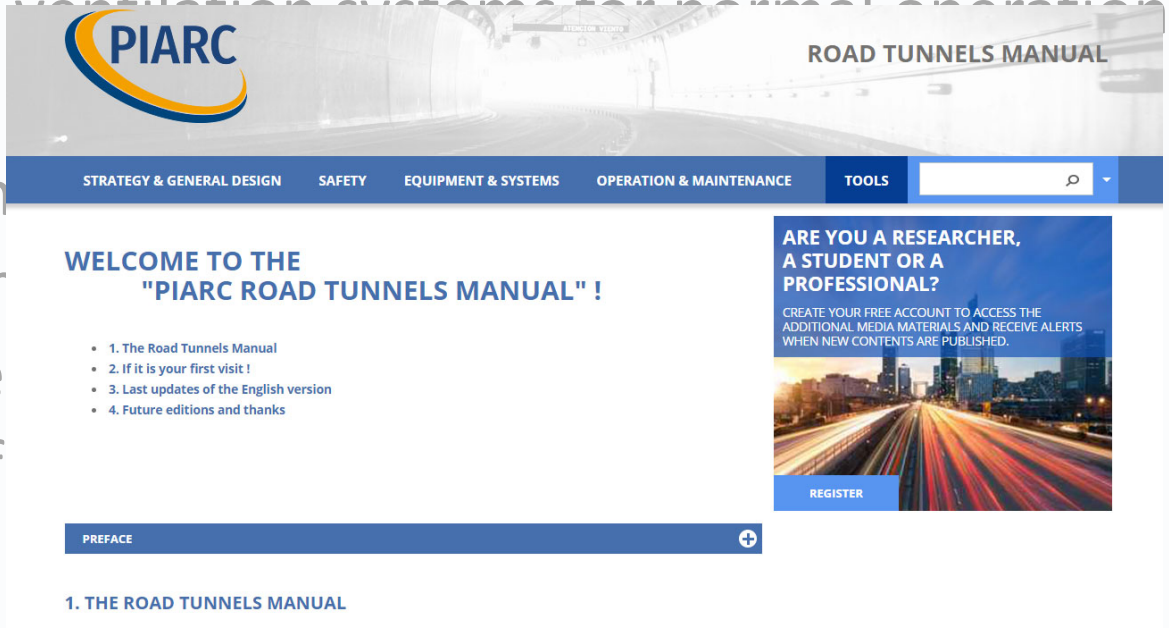
Design guidelines

Technical committee[illegible] already since decades with topics like:

- Safety of road tun[illegible]
- Design of [illegible]
- Design of
- Definition
- Operatior
- Guideline
- Impact of
- ....

PIARC Tunnel Manual

https://tunnelsmanual.piarc.org/en



Ventilation systems and strategies

A ventilation system aims at providing a certain safety level for tunnel users in road and rail tunnels

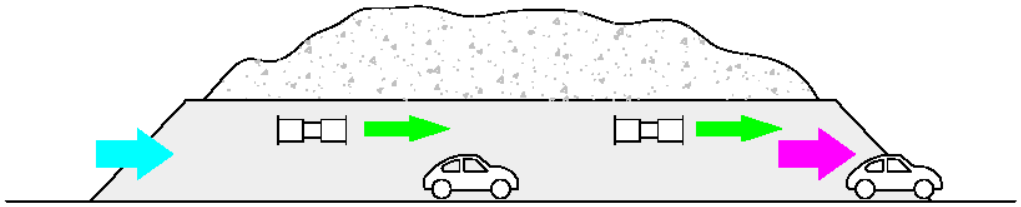
The choice of a particular ventilation system depends on a variety of parameters that ultimately lead to a system decision based on an accepted residual risk.

The most important message, however, is that the simpler the system, the less prone it is to malfunction.

This results in the main design question: does the simplest system still provide the required level of safety?

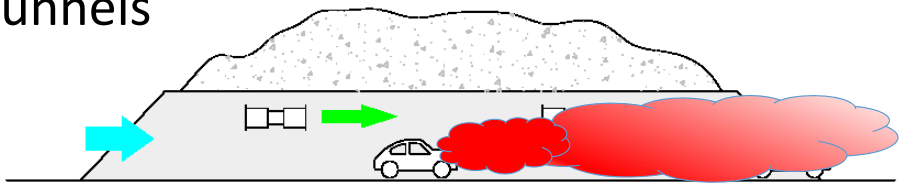
Ventilation systems and strategies

Longitudinal Ventilation System



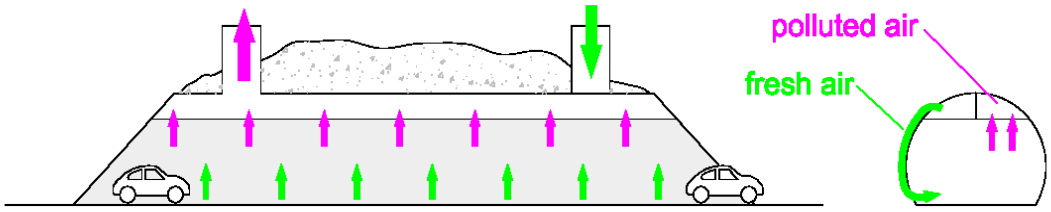
Source: PIARC 07

- Air movement along the tunnel
- Simple in construction and installation
- Problem in fire case as the smoke is transported through the tunnel
  - might be ok for twin tube tunnels
  - definitely a problem for single tube tunnels with bidirectional traffic
- Application in general restricted by tunnel length



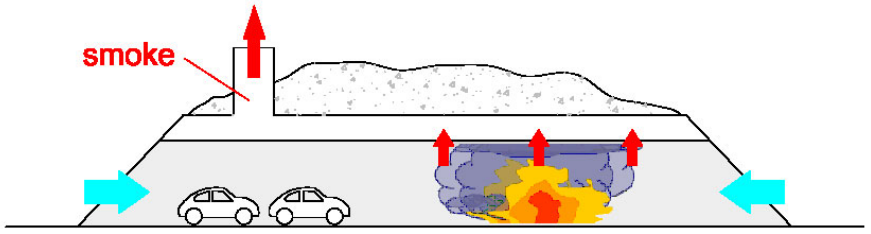
Ventilation systems and strategies

Transverse Ventilation System



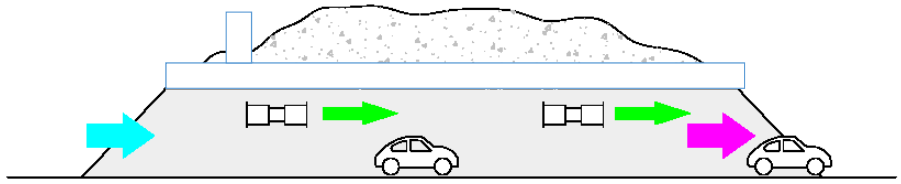
Source: PIARC 07

- Air movement across the tunnel
- Requires much more space in construction, more technical equipment as well as more maintenance
- Big advantage of smoke extraction close to fire location
  - Smoke confinement in fire region requires additional ventilation elements
  - Smoke extraction require installation and maintenance of big remotely controlled extraction dampers
  - Air ducts and shaft(s) required
- Application in general for long tunnels

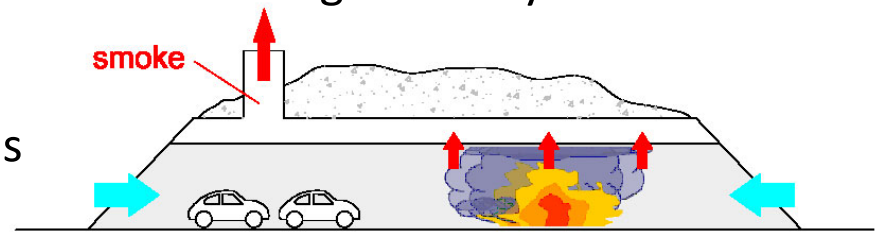


Ventilation systems and strategies

Semi-transverse Ventilation System



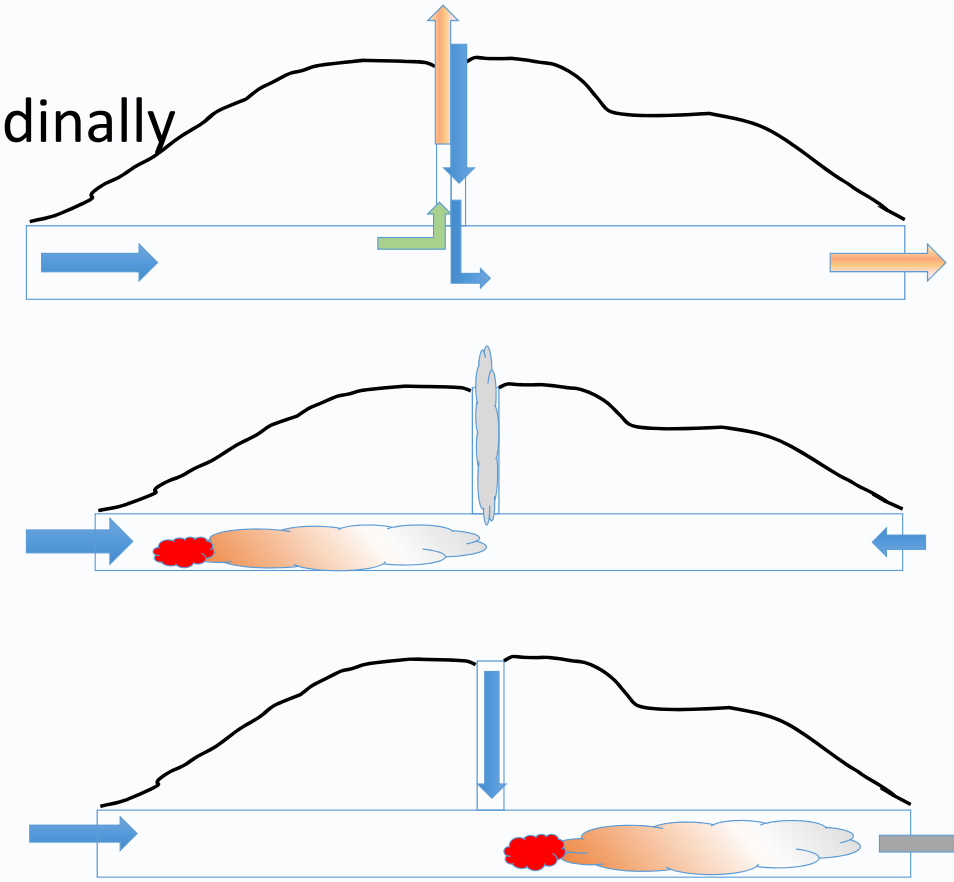
- Air movement in normal operation along the tunnel
- Smoke extraction in a fire case
- Requires much more space in construction technical equipment as well as maintenance
- Big advantage of smoke extraction close to fire location
  - Smoke confinement in fire region requires additional ventilation elements
  - Smoke extraction require installation and maintenance of big remotely controlled extraction dampers
  - Air ducts and shaft(s) required
- Application in general for longer twin-tube tunnels



Ventilation systems and strategies

Ventilation system with air exchange

- Virtual split into two (or more) longitudinally ventilated tunnels
- Pros and cons as in a longitudinal ventilated tunnel



- Application for long tunnels

Ventilation systems and strategies

System selection

- Based on a risk assessment
  - E.g. predefined “standard” tunnels (RVS 09.02.31, Austria)

Traffic volume (AADT/lane)	Congestion level	Tunnel length [m]	Ventilation type
-	-	≤ 500	Natural Ventilation
< 5,000	low	≤ 700	Natural Ventilation
≥ 5,000 to < 10,000	average	500 - ≤ 3,000	Longitudinal
> 5,000	high	500 - ≤ 1,500	Longitudinal
> 5,000	high	1,500 – ≤ 3,000	Longitudinal + Point extraction*
-	-	> 3,000	Extraction via false ceiling

Uni-directional traffic

Congestion level:

low	≤ 25 h/year
average	25 – 75 h/year
high	> 75 h/year

  - Or detailed risk assessment for individual tunnels

Longitudinal ventilation system

Semmering road tunnel

- Length 3.5 km, twin tube, one-way traffic
- Traffic: ~24‘000 veh/d, 8.7% HGV
- Longitudinal ventilation system
  - Downhill tube => 16 Jet-Fans
  - Uphill tube => 11 Jet-Fans
- Egress ways: ~ every 250 m
- In operation since 2004

Longitudinal ventilation system

Tunnel lay out

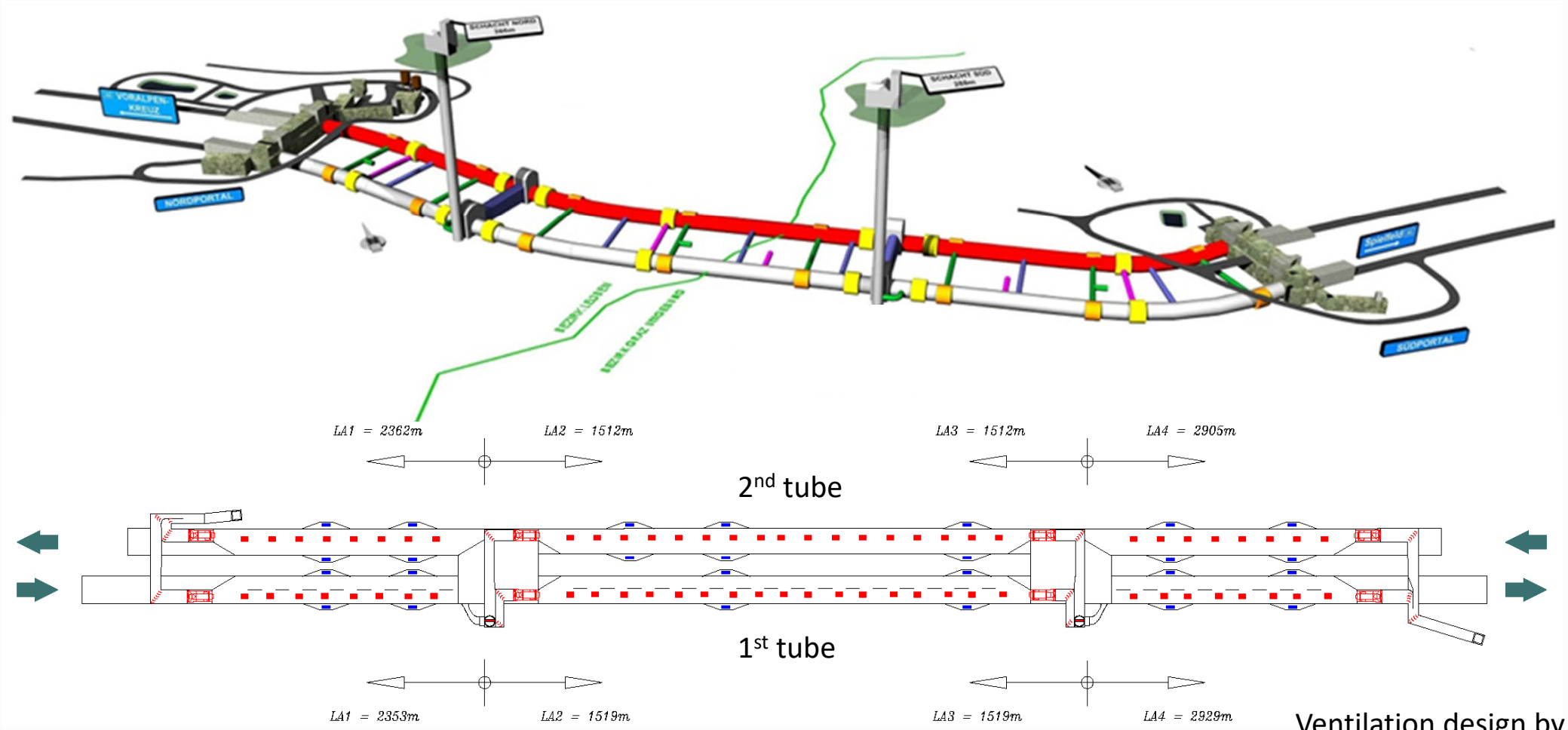
Ventilation design by
FVTmbH/TUG

Semi-transverse ventilation system

Gleinalm road tunnel

- Length 8.3 km, maximum overburden 500 m, twin tube, one-way traffic
- Traffic: ~25‘000 veh/d, 18% HGV
- In operation since 1978 (single tube, bi-directional traffic)
- Full-transverse ventilation system, 4 ventilation sections
- Second tube and upgrade of ventilation and safety systems since 2017
- Since that time conversion to semi-transverse ventilation system with smoke extraction → strongly increase extraction volume as the area of the extraction duct doubled
- Egress ways: ~ every 350 m

Semi-transverse ventilation system

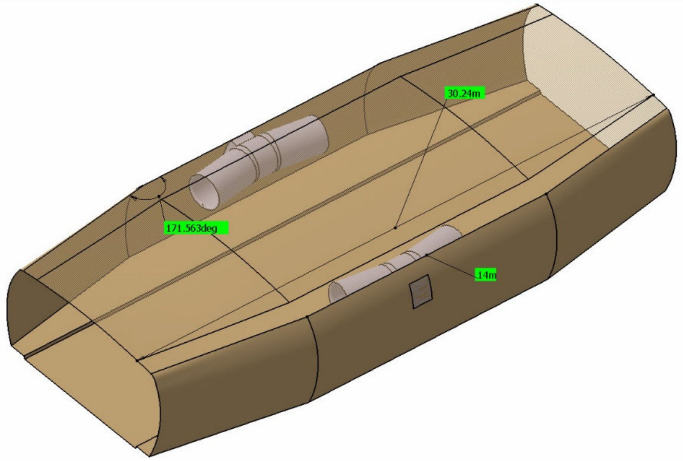


Ventilation design by FVTmbH/TUG

Semi-transverse ventilation system

Transverse or semi-transverse ventilation system
Jet fans for normal operation and for smoke confinement

High barometric pressure difference between both portals require 6 jet fans á 3000 N per tube



Gleinalm tunnel, A

Full transverse ventilation system
Upgrading of an existing tunnel

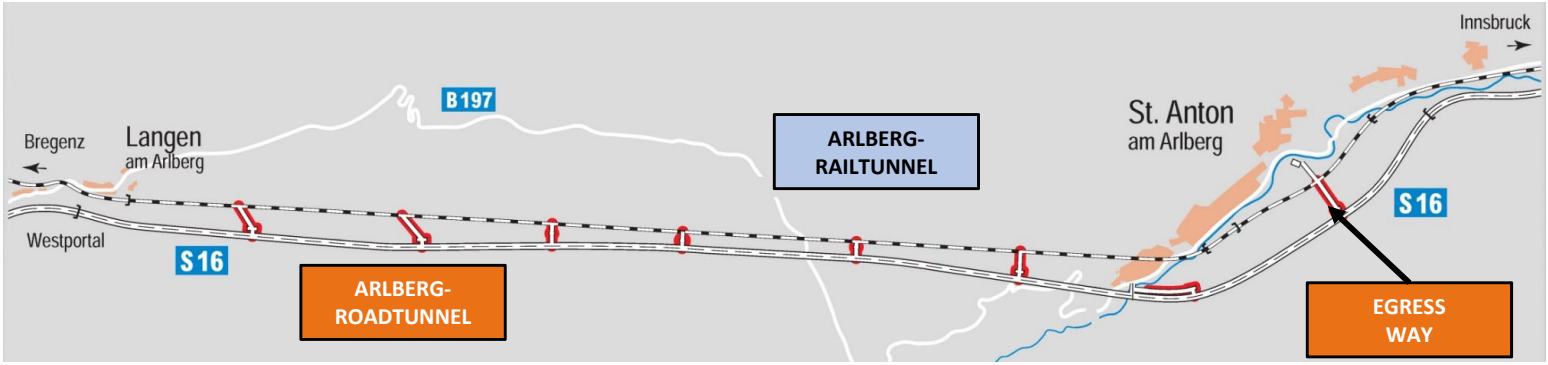
Arlberg Tunnel (A)

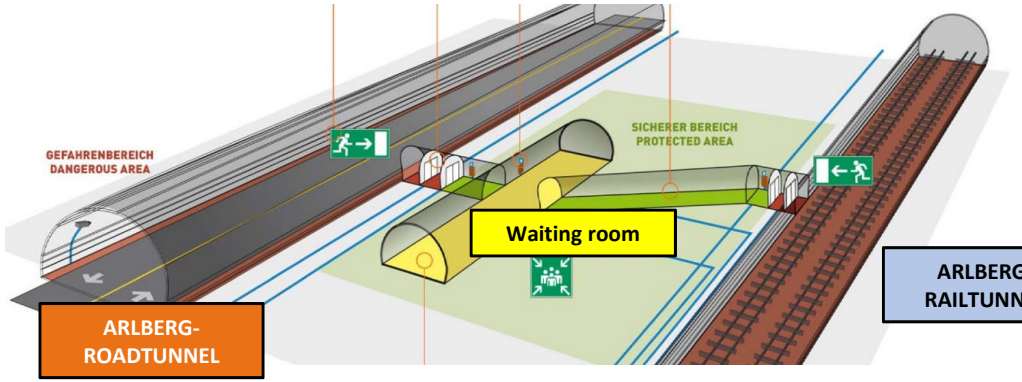
- Length 15.5 km, maximum overburden 800 m, single tube, bidirectional traffic
- Traffic: ~8‘000 veh/d, 17% HGV
- Full transverse ventilation system, 6 ventilation sections with fresh and exhaust air fans
- In operation since 1978
- Egress ways to the parallel running rail tunnel ~ every 1’700 m
- Since 2015 full upgrade for ventilation and safety systems, egress ways every 500 m

→ Upgrading resulted in massive changes in the ventilation system and the safety/egress concept

Full transverse ventilation system
Upgrading of an existing tunnel

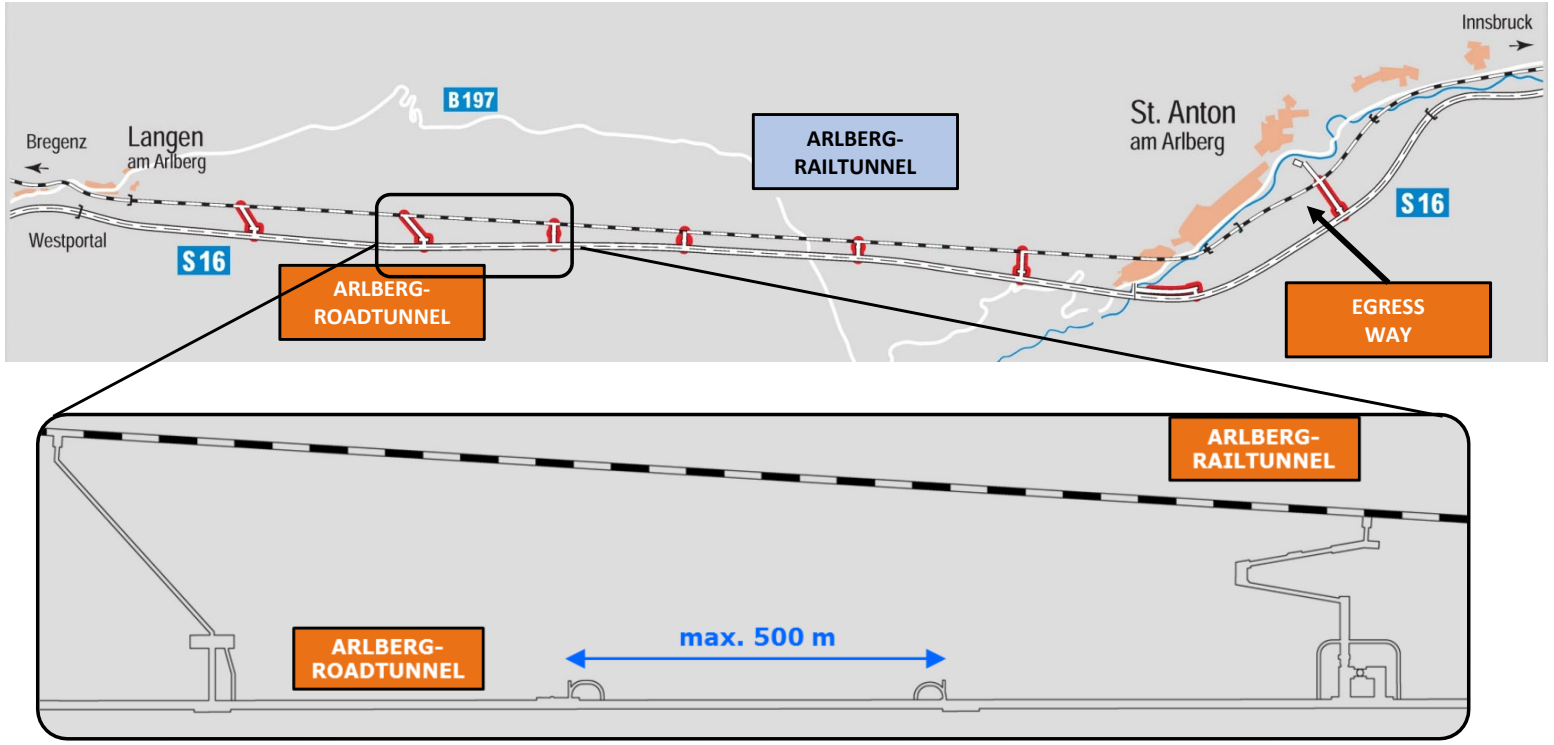
Before Upgrading





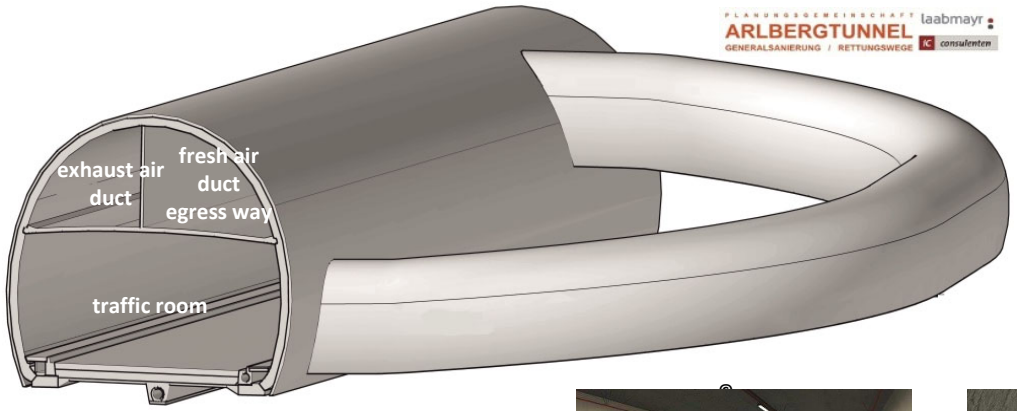
Full transverse ventilation system
Upgrading of an existing tunnel

Upgrading

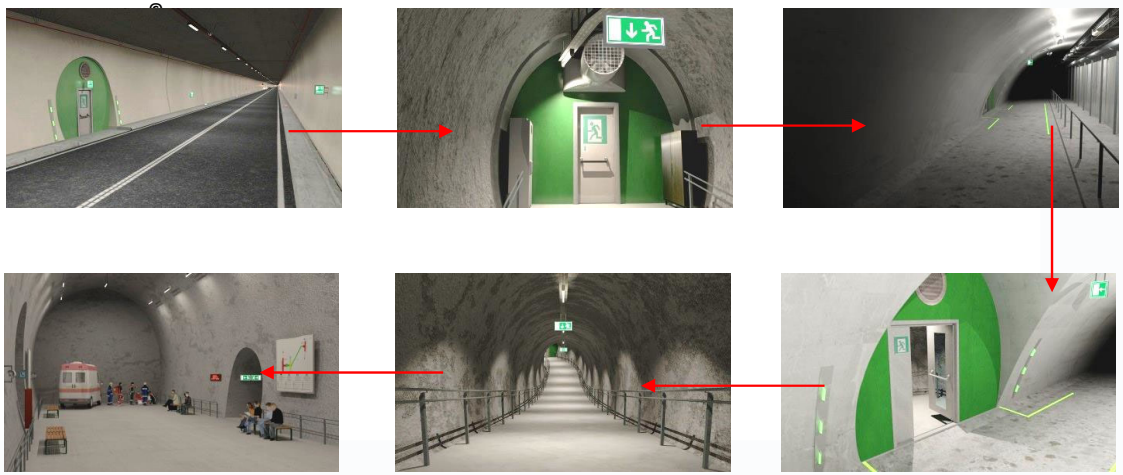


Ventilation design by
FVTmbH/TUG

Full transverse ventilation systems
Upgrading of an existing tunnel



Upgrading: Egress from roadway into fresh air duct



Full transverse ventilation systems
Upgrading of an existing tunnel

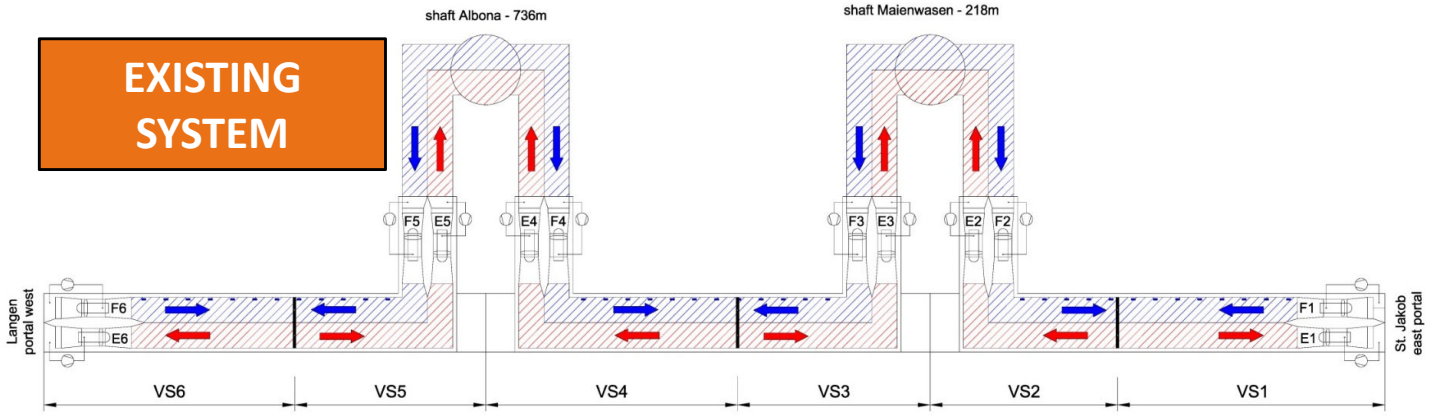
Protection of the false ceiling with a high pressure water mist system

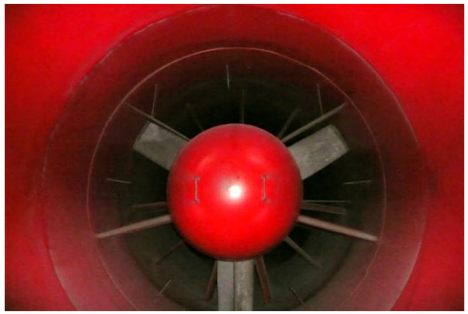
- ⊗ Liquid pool fire: 200 MW
- ⊗ Operation time: 120 minutes
- ⊗ Length of one section: ~32 m
- ⊗ Simultaneous section activation:
  - ⊗ regular cross section: 3
  - ⊗ including a break-down bay: 3 + 1

1 % -

Full transverse ventilation systems
Upgrading of an existing tunnel

Changes in the full transverse ventilation system

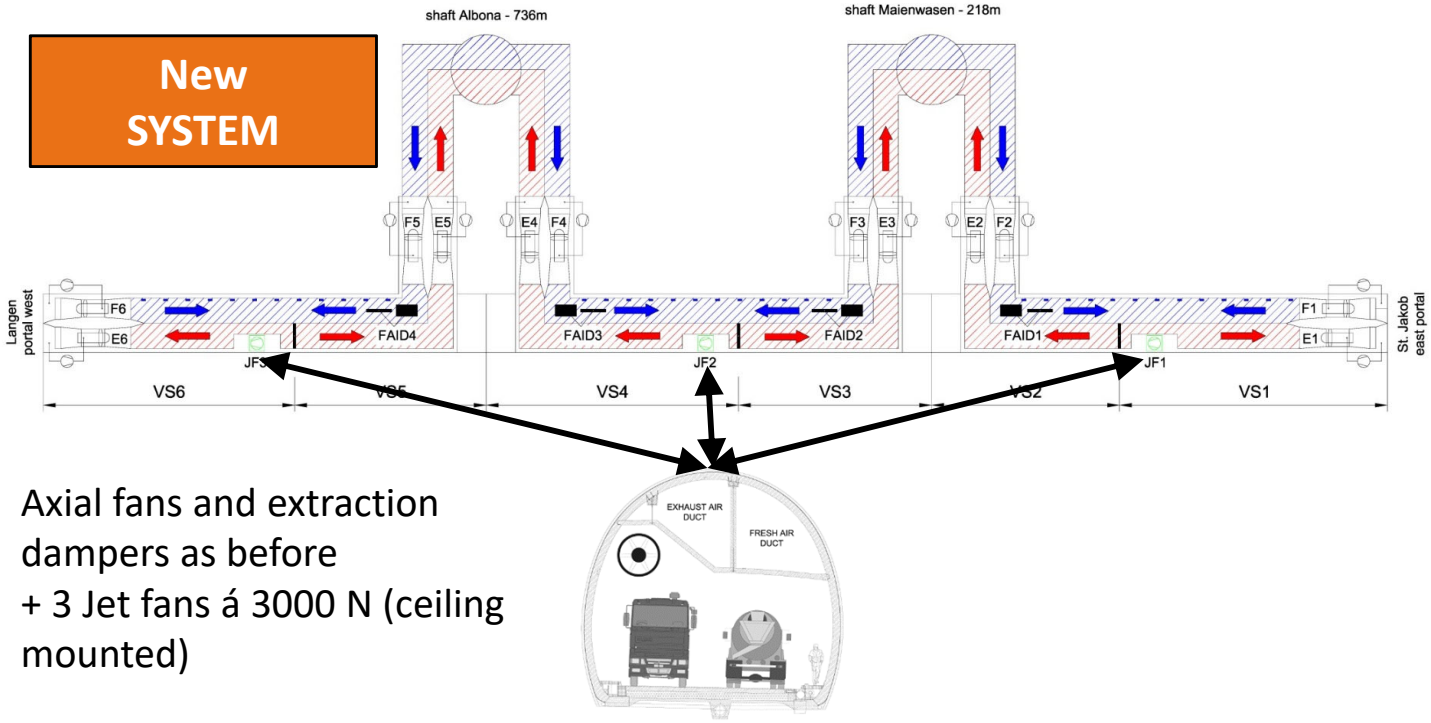




Axial fans: 6 supply and 6 extraction fans á 300 m³/s
150 extraction dampers remotely controlled á 10 m²

Full transverse ventilation systems
Upgrading of an existing tunnel

Changes in the full transverse ventilation system

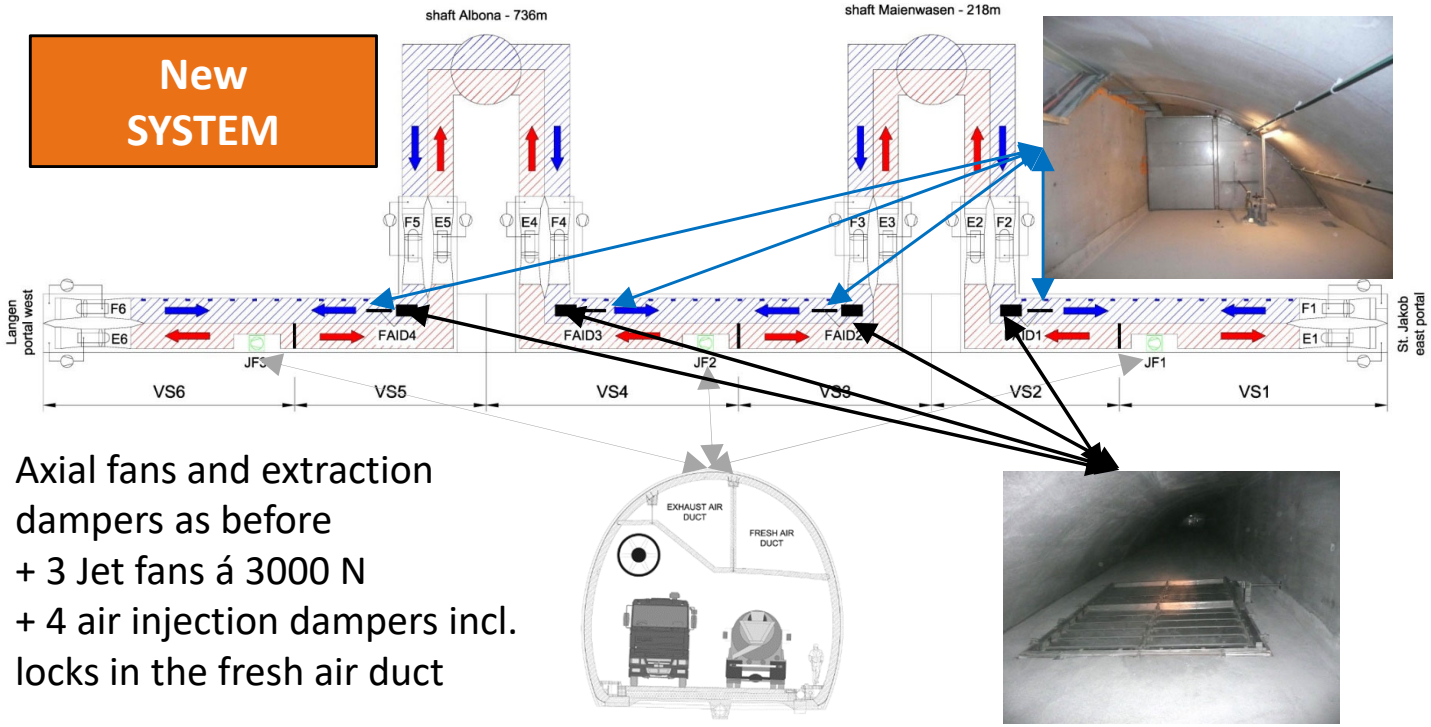


Axial fans and extraction dampers as before
+ 3 Jet fans á 3000 N (ceiling mounted)

Ventilation design by FVTmbH/TUG

Full transverse ventilation systems
Upgrading of an existing tunnel

Changes in the full transverse ventilation system



Axial fans and extraction dampers as before
+ 3 Jet fans á 3000 N
+ 4 air injection dampers incl. locks in the fresh air duct

Full transverse ventilation system – fire test

Cha

Axia
dam
+ 3
+ 4
lock

Ventilation of a long railway tunnel

Koralm Rail Tunnel (A)

- Length 33 km, maximum overburden 1,100 m, twin tube, single track
- Ventilation system mainly for incident ventilation (smoke extraction) and air conditioning in normal operation
- Egress ways to the parallel tube every 500 m
- Emergency stop station in the centre of the tunnel


PIARC
TU Graz
Thank you very much for your attention
Peter Sturm
Graz University of Technology, Austria
Email: sturm@tugraz.at
https://ivt.tugraz.at/vuu