

## **Upgrading the Karavanken Tunnel According to the EU Directive 2004/54/EC**

### ***Nadgradnja predora Karavanke skladno z Direktivo EU 2004/54/EC***

---

Dr. Rune BRANDT  
HBI Haerter Ltd, CH-8002 Zurich, Switzerland, [www.hbi.ch](http://www.hbi.ch)  
Tel. +41 44 289 39 12, Fax +41 44 289 39 99 Email: [rune.brandt@hbi.ch](mailto:rune.brandt@hbi.ch)  
Mr. Andrej CUFER u.d.i.a., MBA  
OrbiPark d.o.o. SI-4275 Begunje, Slovenia, [www.orbipark.com](http://www.orbipark.com), [www.aka-pcb.com](http://www.aka-pcb.com)  
Tel + 386 4 5333 206, Fax + 386 4 5333 202, [andrej.cufer@orbipark.com](mailto:andrej.cufer@orbipark.com),

### **Abstract**

The Karavanken tunnel forms an important link between Slovenia and Austria. The almost 8 km long tunnel is operated with bi-directional traffic and does not have dedicated escape routes. Moreover, the ventilation in case of fire is not up to date.

The EU Directive 2004/54/EC [1] specifies the minimum requirements for tunnels in the trans-European road network. In case of existing tunnels, the requirements are in some areas less stringent than for new ones.

The paper presents a case study that was undertaken in order to reach the required level of safety according to [1] at relatively low costs. It is shown that with simple but novel adaptations of the ventilation system, a sizeable increase in the overall level of safety can be achieved.

**Keywords:** Karavanken tunnel, EU-directive 2004/54/EC, tunnel ventilation, tunnel safety, novel ventilation system, moderate cost, ITA, PIARC, RVS

### **1 Introduction**

The Karavanken tunnel imposes an important liaison on highway A11 between Slovenia and Austria and is hence a part of the trans-European road network. The about 8 km long tunnel is operated with bi-directional traffic. Since the inauguration in 1994, national and international safety requirements have been increased considerably. Tunnels in the trans-European road network shall adhere to the minimum safety requirements set by the EU-directive 2004/54/EC [1]. For existing tunnels, the requirements are somewhat lower than for new ones. Some national standards demand even higher levels of safety and are often more specific than outlined in [1].

The tunnel ventilation is an important element of the tunnel safety systems in particular for the Karavanken tunnel, as the only escape routes are the tunnel portals. According to [1], emergency exits every 500 m should be present. However, in existing tunnels, this has to be evaluated in a cost and feasibility study for each individual case. On the other hand, transverse ventilation is mandatory for tunnels that have a control centre.

Consequently, this study is devoted to develop a feasible ventilation concept at minimum cost that would adhere to modern standards as stated in [1]. The objective

## 8. mednarodno posvetovanje o gradnji predorov in podzemnih prostorov

### TEMA 1 | VARNOST, UPRAVLJANJE IN NADZOR

is to have localised smoke extraction using remote-controlled dampers. In this way, the smoke can be extracted close to the fire and therefore reduce the smoke spread to a short zone. Consequently, the escape routes are safe enabling the tunnel users to escape. The study is at conceptual level and further investigations are necessary in order to refine details of the proposal.

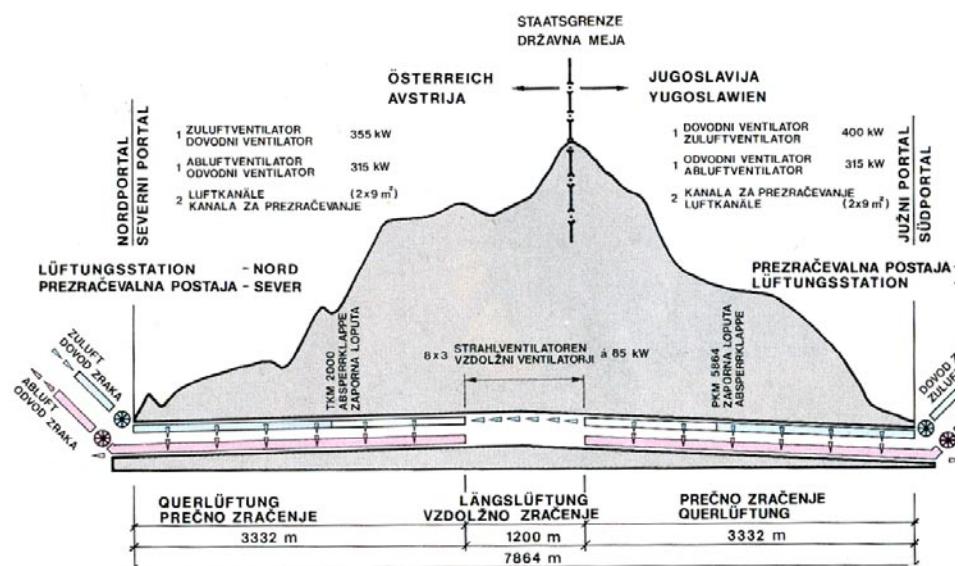
### 2 Existing tunnel

#### 2.1 Geometry

The geometry of the tunnel, as shown in Figure 2.1 and Figure 2.2, was extracted from [2].

- Length of tunnel:	7'864 m
- Length of fresh-air and exhaust-air ducts on Austrian side:	3'332 m
- Length of fresh-air and exhaust-air ducts on Slovenian side:	3'332 m
- Length of tunnel in middle without ducts:	1'200 m
- Cross section of fresh-air and-exhaust air ducts	9 m <sup>2</sup>
- North Portal:	
o Kilometre	16,069 km / 0 km
o Height above sea level	655,30 m
- Summit:	
o Kilometre	19,949 km / 3'880 m
o Height above sea level	673,60 m
- South portal:	
o Kilometre	3,450 km / 7'864 m
o Height	620,68 m
- Longitudinal slopes from north to south:	
o +0,50 % over	3'880 m
o -1,35 % over	3'984 m
- Cross section of traffic space	48,80 m <sup>2</sup>

Figure 2.1 Longitudinal profile showing ventilation system. No ducts for smoke extraction over 1'200 m in the middle of the tunnel



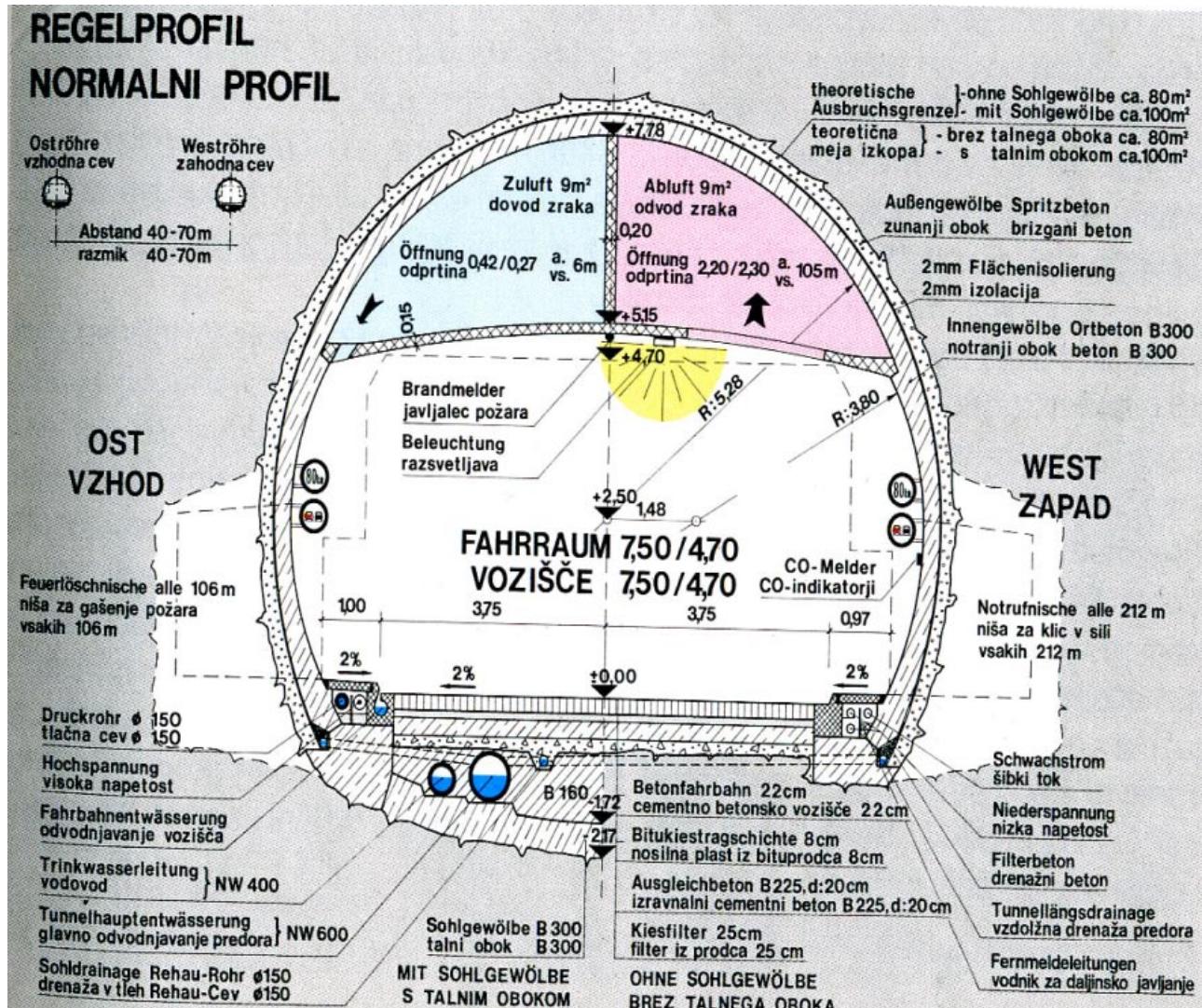


Figure 2.2 Cross section showing the two ducts for fresh air and exhaust air

## 2.2 Escape routes

Only the tunnel portals are escape routes.

## 2.3 Traffic

The average daily traffic is estimated to 14'000 with about 15% heavy-goods vehicles. From a traffic capacity point of view, the tunnel is not operating at its limits and a second tube is therefore not called for. This is also supported by [1] that demands a second tube when the average daily traffic exceeds 10'000 vehicles per lane. With two tubes, the tunnel could be equipped with cross passages for escape routes and would operate with unidirectional traffic, which inherently increases the level of safety.

## 8. mednarodno posvetovanje o gradnji predorov in podzemnih prostorov

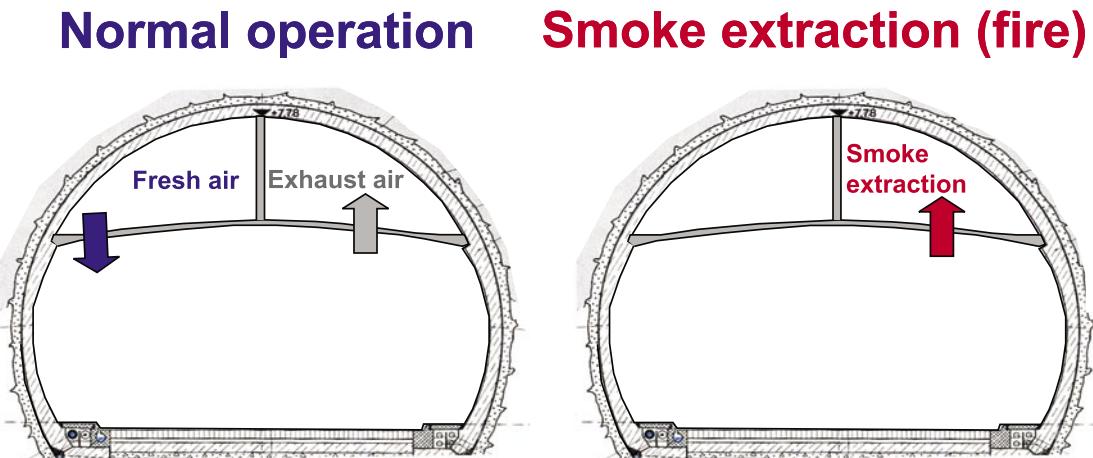
### TEMA 1 | VARNOST, UPRAVLJANJE IN NADZOR

#### 2.4 Current ventilation system

The Karavanken tunnel is equipped with semi-transverse/transverse ventilation as well as longitudinal ventilation. The jet fans used for the longitudinal ventilation system are installed at the central 1'200 m of the tunnel, see Figure 2.1. Consequently, in this section, no smoke extraction is possible.

Fresh air is injected over the openings in the false ceiling. About 2 km from the portals, a damper can block off the ends of the fresh-air ducts. In this case, no fresh air is injected over about 5 km of the middle part of the tunnel, see Figure 2.1. Exhaust air is extracted through dampers at distances of 105 m. The openings are 2.20x2.30 m<sup>2</sup>, see Figure 2.2.

Figure 2.3 Left:  
ventilation in  
normal operation  
as semi-transverse  
(only fresh air)  
or transverse ventila-  
tion. Right: Smoke  
extraction in case  
of fire.



During normal operation, either one duct is used in order to have semi-transverse ventilation or both ducts resulting in transverse ventilation. In case of fire, only the exhaust duct is used in order to extract the smoke, see Figure 2.3. Moreover, the jet fans could be used for longitudinal ventilation in case of fire and during normal operation.

### 3 Current Requirements

#### 3.1 Safety installations: escape routes and tunnel ventilation

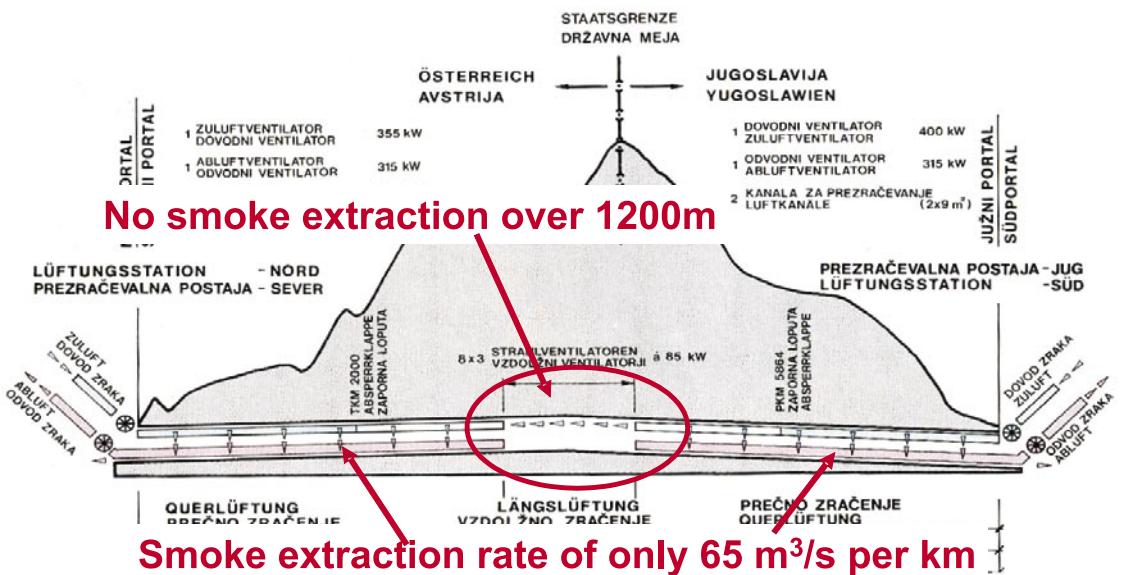
The safety level should reach the demands according to national requirements i.e. from Slovenia and Austria. Moreover, the EU-directive 2004/54/EC [1] shall be satisfied. Presently, it can be assumed that these minimum requirements specified for the trans-European road network eventually will be applied world wide.

The Austrian design guideline RVS 9.261/09.02.31 [3] and the EU-directive [1] demand that the Karavanken tunnel is equipped with a smoke extraction. The minimum smoke-extraction rate is 120 m<sup>3</sup>/s, which are extracted over a maximum length of 150 m. The distance between the remote-controlled dampers used for the smoke extraction should not exceed 110 m. Further valuable information about the state of the art considering tunnel fires is stated in the PIARC report 1999 [4].

For the Karavanken tunnel, the feasibility and benefit of the construction of escape routes has to be examined [1]. However, there is no explicit demand to construct such escape routes as long as other safety measure e.g. tunnel ventilation ensures an adequate level of safety for the tunnel users. It also appears that the Austrian design guide does not implicitly demand the construction of escape routes [3].

The heat-release rate in case of fire for the dimensioning of the ventilation system is 30 MW [3]. However, if the percentage of heavy-goods vehicles exceeds 15%, 50 MW can be envisaged. The smoke extraction system has to function 120 min at temperatures of up to 400 °C. Furthermore over a period of 60 min, the mechanical installations may not be destructed even at temperatures of 750 °C.

Figure 4.1 Short comings of existing ventilation system



### 3.2 Ventilation during normal operation

The computation of the fresh-air demand is to be conducted according to the newest version of the Austrian guide line RVS 9.262 (09.02.32) [4] and the PIARC 2004 [6] recommendation.

## 4 Novel ventilation concept to reach required level of safety

### 4.1 Short comings with existing ventilation system

The smoke management in case of fire does not meet current standards, see Figure 4.1. Firstly, no smoke extraction is available over the middle 1'200 m of the tunnel. Secondly, the smoke-extraction rate is only 65 m³/s per km. Compared with the required 120 m³/s over 150 m, the extraction capacity is less than 10% of the required one.

### 4.2 New ventilation concept

The prime idea behind the proposed new ventilation concept is to connect the fresh-air and the exhaust-air ducts across the middle 1'200 m of the tunnel, see

## 8. mednarodno posvetovanje o gradnji predorov in podzemnih prostorov

### TEMA 1 | VARNOST, UPRAVLJANJE IN NADZOR

Figure 4.2:  
Connection of  
ducts enabling  
ventilation from  
both portals

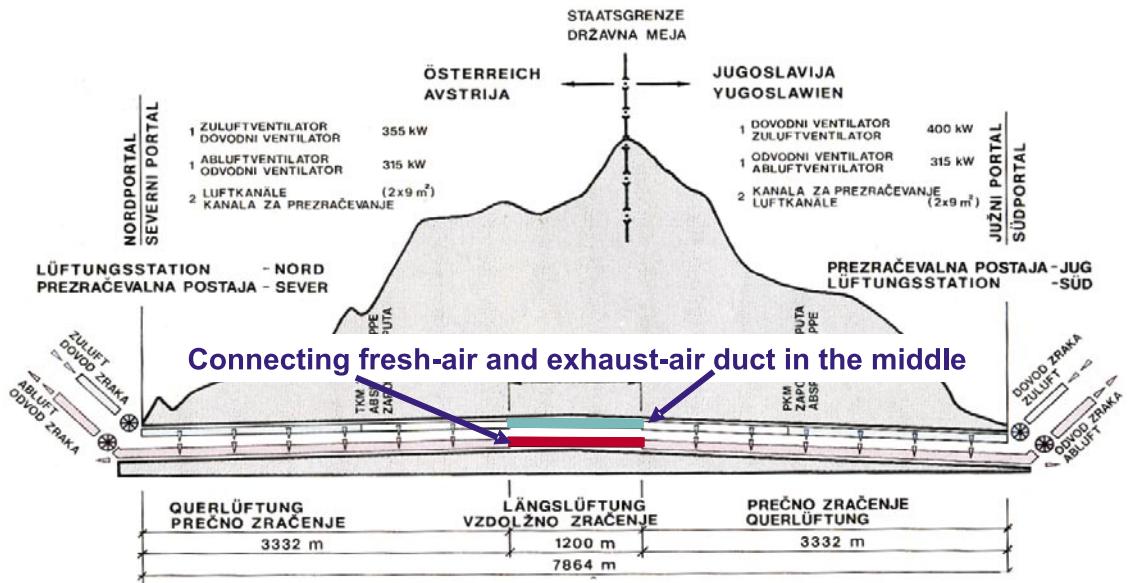
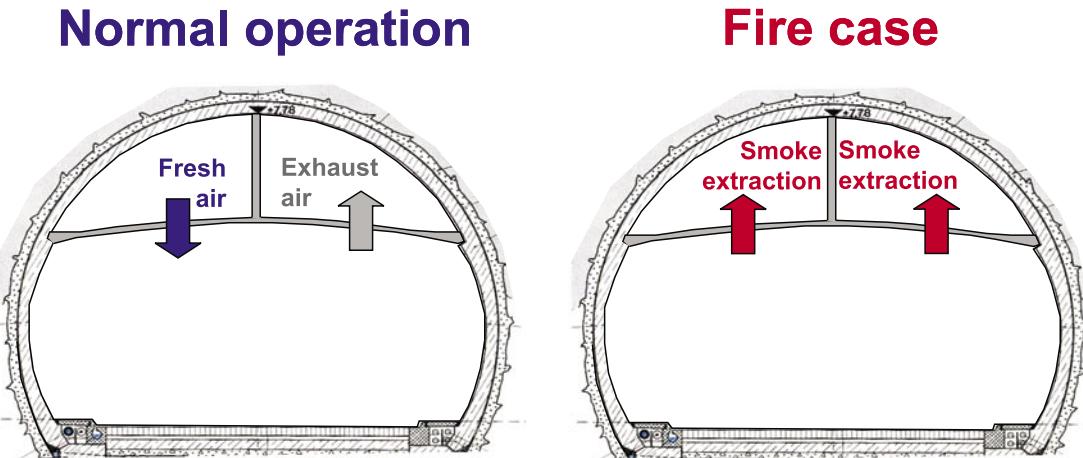


Figure 4.2. Consequently, smoke extraction is enabled from both portal-ventilation stations concurrently. This reduces the power consumption and implicitly ensures a certain degree of redundancy. Dampers are installed at 100 m intervals as for the current exhaust duct.

The fresh-air ducts are also connected. The existing fresh-air openings are closed and replaced by dampers at intervals of, say, 50 m. Having 180° variable-pitch fans, the flow can be reversed without changing the direction of rotation of the fans. Therefore, the flow can relatively quickly be reversed from fresh-air supply to smoke extraction.

Figure 4.3 Left:  
normal operation  
that can also be  
operated only  
using only one  
duct.



During normal operation, the dampers are only slightly opened achieving a uniform fresh-air respectively exhaust-air distribution over the length of the tunnel, as it was done e.g. in the Vué-des-Alpes tunnel (Neuchâtel, Switzerland). In case of fire, 2 dampers in the exhaust-air duct and 4 dampers in the reversible air duct are opened

and the extent of the extraction zone is 150 m. Smoke is extracted at full capacity, see Figure 4.3.

With this concept, a minimum of 200 m<sup>3</sup>/s can be extracted without increasing the currently installed power consumption of the axial fans. In this case due to leakage of the ducts, the four axial fans would extract in total 320 m<sup>3</sup>/s. If more power at disposition, the smoke extracted at the location of the fire could be increased to at least 280 m<sup>3</sup>/s. These proposed extraction rates of 200 m<sup>3</sup>/s and 280 m<sup>3</sup>/s are to be compared with the minimal one of 120 m<sup>3</sup>/s according to [3].

### **Right:** smoke extraction using both ducts

In order to obtain an efficient smoke extraction, air should flow towards the extraction zone from both sides at about equal speed. In the centre of the extraction zone, the flow speed is insignificant i.e. close to zero. Consequently, ventilation equipment is needed that can influence the longitudinal flow during the smoke extraction. Due to the relatively small longitudinal slope of the tunnel, primarily the meteorological forces need to be outbalanced. Several options are at disposition:

- Installation of jet fans in niches imbedded in the new 1'200 m long false ceiling that connects the ducts
- Installation of unidirectional jet fans or Saccardo fans at the portals that blow into the tunnel
- Use of air curtains
- If lower extraction rates than assumed so far are permissible, no reversible flow ducts are needed. Consequently, the tunnel would have one dedicated fresh-air duct and another dedicated duct for smoke and exhaust air. In this case, the fresh-air duct can be used to influence the longitudinal flow in the tunnel.

It has to be examined whether or not existing fans and dampers can be refurbished to meet current requirements in particular with respect to temperature resistance. Also the fan buildings need examining in particular in case of the reversible flow duct.

### **4.3 Aspects of tunnel-ventilation control**

The operation of the tunnel is to be considered during the detailed design of the ventilation system in order to ensure that the design is adequate. For this purpose, the tunnel including duct and ventilation equipment with sensors of air quality and flow velocities in the various sections is to be modelled e.g. using an adaptation of the program IDA RTV [7]. The control routines are part of the modelling that assumes time-varying traffic.

It is proposed to use this computer model as a tunnel simulator during the testing of the control system. In this way, numerous inevitable flaws and possible short comings can be resolved during the factory tests of the SCADA system prior to installation

## 8. mednarodno posvetovanje o gradnji predorov in podzemnih prostorov

### TEMA 1 | VARNOST, UPRAVLJANJE IN NADZOR

on site. This was successfully conducted for the Cross City Tunnel (Sydney) [8] with the benefit that the commissioning time was shortened tremendously and the quality much higher. As a matter of fact, no adaptation of the ventilation-control system was required after installation on site although the numerous project-specific requirements were difficult to meet.

Several systems are used in order to detect fires and it should also be envisaged to engage the opacity sensors for smoke detection by using novel data analysis [9].

In case of smoke extraction and longitudinal smoke management, it is paramount to control the longitudinal velocity correctly in order to optimise the extraction efficiency [10].

A distinct a rigid hierarchy, which requires careful engineering, shall ensure that the automatic operational procedures cater for adequate air conditions at all times [11]. The transitions between various scenarios e.g. between normal operation and fire mode has to be considered also for the equipment-redundancy situations.

### 5 Cost estimate

At this conceptual level, the cost estimate is bound to be rather coarse. The installation of the false ceiling in order to connect the ducts is estimated to EUR 3 million. This is to be compared with other civil measures. A parallel escape tunnel is estimated to cost at least EUR 60 million. A second traffic tube would amount to more than EUR 340 million. Consequently, the proposed concept costs between 1% and 5% of alternative solutions to enhance the level of safety.

Irrespective of solution, some renewal of the ventilation equipment is probably needed which is estimated to cost from EUR 7 to 10 million. A complete renewal of the electromechanical equipment would require investments in the order of EUR 40 million.

### 6 Conclusion

A novel ventilation concept that would fulfils the current safety standards can be realised at relatively moderate efforts.

Other measures such as a parallel tube or an escape tube would require much higher investments.

### References

- [1] EU-directive 2004/54/EC, Directive 2004/54/EC of the European Parliament and of the Council of 29 April 2004 on minimum safety requirements for tunnels in the Trans-European Road Network
- [2] Tunnel brochure Karavanken
- [3] RVS 9.261 (09.02.031), Austrian design guide, ventilation systems, draft from 31.08.2006
- [4] RVS 9.262, Austrian design guide, ventilation systems, fresh-air demand, 1.11.2004
- [5] PIARC 1999, Fire and Smoke Control in Road Tunnels
- [6] PIARC 2004, Road Tunnels: Vehicle Emissions and Air Demand for Ventilation
- [7] D models for thermal and air quality prediction in underground traffic systems, P. Sahlin, L. Eriksson, P. Grozman, H. Johnsson and L. Aalenius, EQUA Simulation AB, Sweden, paper presented at the 12th International Symposium on Aerodynamics and Ventilation of Vehicle Tunnels, Portoroz, Slovenia: 11 – 13 July 2006

# 8th international symposium on tunnel construction and underground structures

## TOPIC 1 | SAFETY, MANAGEMENT AND CONTROL

- [8] On the design and control of complex tunnel ventilation systems applying the HIL tunnel simulator, I. R. Riess and P. Altenburger, HBI Haerter Ltd Consulting Engineers, Switzerland, P. Sahlin, Equa Simulation AB, Sweden, Papaer presented at the 12th International Symposium on Aerodynamics and Ventilation of Vehicle Tunnels (bHr), Portoroz, Slovenia: 11 – 13 July 2006
- [9] Smoke Detection of low Temperature Fires in Road Tunnels using Visibility Sensors, Matthias Wehner, HBI Haerter AG and Ingrid Simon, Regierungspräsidium Karlsruhe, paper presented at the fift internation Conference für Safety in Road and Rail tunnels, 6 - 9 Oktobe 2003, Marseille, Frankreich
- [10] Smoke Control in Road Tunnels, Petr Pospisil and Rune Brandt, Papers presented at the Conference 'Significance of Tunnels in Transport', Podbanské, 16.-18.6.2004
- [11] A systematic approach to the supervision of road networks and its application to tunnel ventilation, Pierre Schneider, République et Canton de Neuchâtel, Rune Brandt, HBI Haerter Ltd., Alain Gilibert, Cegelec Entreprise Centre Est, Paper Presented at the Fifth International Conference on Safety in Road an Rail Tunnels (SIRRT), 6 - 9 Oct. 2003, Marseille, France



## **Safe FIREMAN, Fire Distinguisher Integrated Concept in Tunnels**

### ***Safe FIREMAN, koncept integriranega gašenja v predorih***

---

Andrej Čufer  
OrbiPark d.o.o., Tel + 386 4 5333 206, ,  
<http://www.orbipark.com>, <http://www.aka-pcb.si>  
[andrej.cufer@orbipark.com](mailto:andrej.cufer@orbipark.com)

Andreas Zeller  
Rosenbauer International AG, Tel. +43 732 6794 529  
<http://www.rosenbauer.com>  
[andreas.zeller@rosenbauer.com](mailto:andreas.zeller@rosenbauer.com)

Roger Barrett James  
UNIFIRE AB, Tel.: +46 303 248 403  
[www.unifire.com](http://www.unifire.com)  
[roger@unifire.com](mailto:roger@unifire.com)

#### **Summary**

##### **Problems in tunnels:**

Current fire extinguishing equipment in tunnels is insufficient

##### **Consequences:**

Casualties, repair expenses, economical loss

##### **Solution to the problem:**

##### **Integrated fire extinguishing system SafeFIREMAN includes:**

- First extinguishing - TLA hydrant
- Extinguishing "by wire" - UNIFire monitors
- Automatic extinguishing with water fog and BONPET
- Adequate safe ventilation 2K or 3K reversible
- Indispensable Firefighters and rescue teams

#### **Abstrakt**

##### **Problemi v predorih:**

Današnja gasilna oprema predorov je nezadostna

##### **Posledice:**

Žrtev, stroški popravila, izpad cestnin, gospodarska škoda

##### **Rešitev problema:**

##### **Integriran gasilni sistem SafeFIREMAN, ki vključuje:**

- Začetno gašenje – TLA hidrant
- Gašenje »po žici daljavo« UNIFire monitorji
- Avtomatsko gašenje z vodno meglo in dodatkom BONPETa
- Varno ventilacijo 2K ali 3K reverzibilno

## **8. mednarodno posvetovanje o gradnji predorov in podzemnih prostorov**

### **TEMA 1 | VARNOST, UPRAVLJANJE IN NADZOR**

#### **Ključne besede**

#### **Nepogrešljive ekipe gasilcev in reševalcev.**

- SafeFIREMAN – varen in učinkovit način gašenja vseh vrst požarov v predoru
- TLA hidrant + - (Tunnellöschanlage) poseben hidrant razvit za predore,
- UNIFire monitor - poseben ustnik – šoba, ki jo je mogoče usmerjati na daljavo
- SafeFOG SCN - samo-očiščevalna šoba za gašenje
- BONBPET – gasilo kot dodatek vodi ali kot samostojno gasilno sredstvo

#### **1 Predstavitev**

Minuli večji požari v predorih, dokazujejo dejstvo, da prihajajo gasilci do portala v svojih časovnih zmožnostih, to pa se je pri večjih požarih pokazalo kot, odločno prepozno, za učinkovito preprečitev širjenja požara.

Povečevanje prometa, nova vozila na alternativna goriva (plin, vodik, akumulatorji), naključni dogodki (odpoved vozila, odpoved voznika) ter nenazadnje terorizem povečujejo nevarnost v vse večjih in daljših predorih. Zato je skrajni čas, da se ustrezeno preizkusi nove gasilne sisteme in se jih verificira, kot ustrezeno gasilno opremo za predore.

Mnogo je zamisli kako pristopiti, k gašenju v predoru. Dejstvo pa je, da je trenutno predpisana oprema v predorih le ročni gasilni aparat in navadni hidrant. Izkušnje kažejo, da ročni gasilni aparati vsebujejo premalo gasila za učinkovito posredovanje in da so navadni hidranti, ki uporabljajo za gašenje vodo, nevarni in popolnoma neutrenzni.

#### **Zato predlagamo koncept integriranega gašenja, ki vsebuje:**

- TLA hidrante + vsakih 120m
- UNIFire monitorje, daljinsko vodene (v krajsih predorih na 50m in v odstavnih nišah obojestransko)
- SaefFOG SCN inštalacijo v daljših predorih s spuščenim stropom
- Dobro opremljene in dobro usposobljene gasilce v bližnjem kraju

Ustrezni praktični preizkusi in ekonomski izračuni pa naj potrdijo (našo) trditev, da so gasilni sistemi ekonomsko upravičeni in prinašajo veliko večjo požarno varnost v predore.

#### **2 Obstoeča gasilna oprema**

##### **2.1 Ročni gasilni aparati**

So se pokazali za neuporabne, saj se plameni širijo izredno hitro in je dragocen čas za iskanje gasilnih aparatov ponavadi že predolг za učinkovito posredovanje. Domet gasilnega curka je odločno premajhen za gašenje višjih delov tovornjaka ali avtobusa. Poleg tega zahtevajo ročni gasilni aparati izurjenega uporabnika in redno kontrolo, samih aparatov.

##### **2.2 Običajni hidranti - gasilo voda**

Običajne hidrantne niše so v nekaterih predorih zaradi varnosti še vedno zaklene in namenjene izključno gasilcem. Voda iz hidranta, brez penila ni primerno gasilo za gašenje tekotih goriv, plastike, gum, različnih tovorov...

### **2.3 Gasilna vozila**

So bolje ali slabše opremljena, predvsem pa je težava, čas dostopa, vidljivost, prevoznost mimo vozil, zaloge zraka za zagotovljen umik iz predora, pomanjkljiva informacija o stanju v predoru (tovor, ki ga je zajel požar, število ljudi, ostali tovori, ki jih ogenj še lahko zajame, vremensko - ventilacijski pogoji, orientacija, komunikacija med samimi reševalci kot z nadzorništvom predora, več jezičnost....)

Številni požari v minulih letih v predorih so vzpodbudili razmišljanje in obrodili prve sadove.

#### **Razvijalo se je v smereh:**

- IFEK posebne cevi, kjer se voda ali voda z dodatki izpihne iz cevi s pomočjo stisnjenega zraka in tako oblak fino razpršenega gasila deluje trenutno z veliko površino.
- Razvoj posebnih hidrantov za predore (TLA)
- UNIFire monitorji za gašenje z vodno peno, ki se jih lahko upravlja na daljavo
- Avtomatski monitorji za gašenje s peno
- Posebne ohlajevalne prhe
- Šprinkler sistem
- SILVANI sistem gašenja šprinkler - pena.
- Različni sistemi za gašenje z vodno meglo
- SafeFOG SCN sistem za gašenje z vodno ali BONPET meglo
- Dovajanje zraka z manjšim % kisika

Ker ne obstaja univerzalen gasilni sistem za gašenje v predorih smo se odločili za kombinacijo, ki se najbolje prilagaja dolžini in profilu predora in tako nudi tudi najvarnejšo in cenovno dostopno tehnično rešitev.

Slika 1 TLA hidrant in ročnik s ročko za upravljanje s curkom



## 8. mednarodno posvetovanje o gradnji predorov in podzemnih prostorov

### TEMA 1 | VARNOST, UPRAVLJANJE IN NADZOR

#### 3 Alternativna gasilna oprema

##### 3.1 TLA Hidranti

so namenjeni za samo-reševanje in gašenje prvih reševalcev. Gre za hidrant razvit posebej za predore. Sestavlja ga vitel in hidro dozirna črpalka s posodo penila. Vitel je konzolno pritrjen na zid hidrantne niše. Na vitlu je navita tanjša izredno lahka in trdna cev, stalnega profila, dolžine 120m.

Posebna ročka omogoča brezstopenjsko prehajanje od zelo široke razpršene pahljače, ki služi zaščiti in je namenjena za neposredno gašenje iz bližine do curka, ki ima domet do 20m.

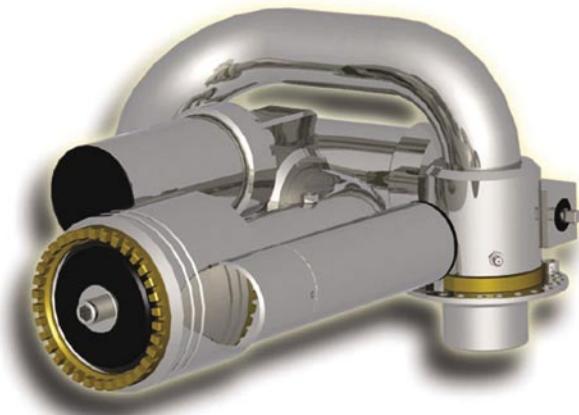
##### Prednosti so:

- Za napajanje Hidrant TLA je mogoče uporabiti obstoječe hidrantne cevovode v predoru
- Hidrant deluje zelo dobro v začetnem požaru
- Uporaba je izredno enostavna in varna

##### Pomanjkljivosti so:

- Hidrant ne deluje, če nihče ne prične z gašenjem
- V starejših predorih je potrebno povečati hidrantne niše za namestitve TLA hidrantov

Slika 2 UNIFire monitor z motorji za upravljanje gašenja na daljavo



##### 3.2 UNIFire monitorji za gašenje z vodno peno, ki se jih lahko upravlja na daljavo

Monitor je pritrjen ob robu predora. Ima posebno šobo podjetja UNIFire, ki s tremi motorji lahko uravnava vrtenje in vertikalno gibanje šobe, tretji motor pa uravnavava razpršenost curka. Monitorji so primerni za uporabo v krajsih predorih, ki nimajo spuščenega stropa saj omogočajo gašenje v loku preko vozil. Smiselna uporaba v daljših predorih pa je v odstavnih nišah, kjer je mogoče z namestitvijo na obeh straneh predora zagotoviti gašenje vozila.

##### Prednosti: so:

- Združljivost z obstoječo hidrantno inštalacijo
- Možnost hitrega posredovanje iz nadzornega centra še pred prihodom gasilcev
- Učinkovito gašenje

# 8<sup>th</sup> international symposium on tunnel construction and underground structures

## TOPIC 1 | SAFETY, MANAGEMENT AND CONTROL

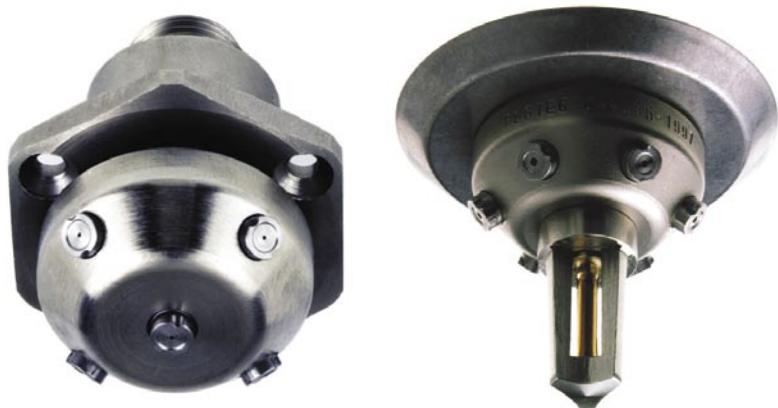
### Pomanjkljivosti so:

- Potrebno je hitro posredovanje saj v zadimljenem predoru ni mogoče več s pomočjo video kamер uspešno voditi curek in locirati žarišče požara.
- Vodna pena prekrije vozila in cestišče in tako ovira reševanje in evakuacijo.

### 3.3 Sistemi za vodno meglo

Obstajajo različni ponudniki za vodno meglo v predorih kot so: FogTec, Aquasys, Marinof...

Slika 3 Šoba za vodno meglo odprtega tipa in šoba za meglo tipa šprinkler 8-12 l/minuto



### Prednost sistemov vodne megle so:

- manjša poraba vode, kot če bi gasili s šprinklerji
- vodna megla gasi tekoča goriva
- delovanje na gasilnem odseku
- vodna megla veže dimne delce in hlađi vroče dimne pline

### Slabosti:

- občutljivost na onesnaženje vode
- dokaj draga inštalacija in črpalke
- zamudna inštalacija na strop predora
- izredna občutljivost na prepih v predoru, ki lahko izredno zmanjša učinek gašenja ali ga celo popolnoma izniči.

## 4 Samočistilna šoba za gašenje v predorih

Že leta 1997 smo pričeli z razvojem posebne šobe za predore. Drugi proizvajalci manjših gasilnih sistemov na vodno meglo takrat še niso razmišljali o gasilnih sistemih prav za predore.

Ker smo vzporedno izvajali testiranje smo sproti izpopolnjevali naš izdelek in vključevali nova spoznanja.

### Prednosti SafeFOG SCN šobe:

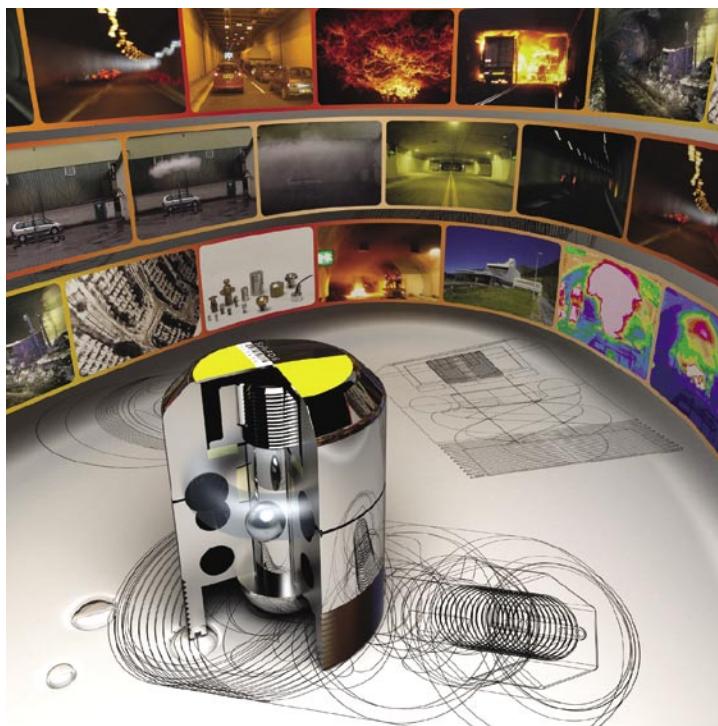
Da bi povečali gasilni učinek smo vodi dodali gasilno sredstvo BONPET. Učinek je bil preizkušen in je neverjetno povečal moč gašenja v prepihu.

Prikaz z manjšo standardno šobo pred portalom predora Sv. Rok za HTV je zelo očiten pokaz prednosti uporabe aditiva. (video posnetek na predavanju)

## 8. mednarodno posvetovanje o gradnji predorov in podzemnih prostorov

### TEMA 1 | VARNOST, UPRAVLJANJE IN NADZOR

Slika 4 Simboličen prikaz SafeFOG SCN samo očiščevalna šoba kapacitete 250-500 litrov / minuto



#### Prvi prikaz:

V kovinski posodi 1m<sup>2</sup> smo prižgali plamen in ga poskušali pogasiti v vetrovnem okolju z referenčno šobo kapacitete 8 l vode/minuto in manjšo črpalko kapacitete 10 l vode/minuto. Opazno se je zmanjšala količina dima zaradi stalnega dovajanja svežega zraka, ki ga je povzročalo vrtinčenje vode pri izhodu iz šobe se je spremenil način izgorevanja, ki pa je hkrati preprečeval uspešno gašenje. Megla je učinkovito ohlajala prostor a ni zmogla popolnoma izolirati svežega zraka od ognjenih zubljev tako do pogasitve ni prišlo.

#### Drugi prikaz:

V drugem preizkusu smo uporabili gasilo BONPET. Vidno je bilo boljše razprševanje kot posledica površinske napetosti viskoznosti gasila. Gašenje je bilo trenutno in je pokazalo učinkovit razpad kemijskih snovi na produkte N<sub>2</sub> in CO<sub>2</sub>. Proizvodi so povečali hladilni in ločevalni učinek vodne megle. Na površini goriva pa se je ustvarila mrena - tanek film, ki je zelo uspešno preprečevala vnovičen vžig goriva. Hladilni učinek megle in zaščitna plast preko goriva tudi preprečuje dvigovanje hlapov in nastanek nevarnih eksplozijskih mešanic.

BONPET gasilo lahko pri daljšem skladiščenju izkristalizira določene majhne kristale svojih sestavnih snovi. To je mogoče uspešno rešiti z uporabo ustreznih filterov v hranilniku snovi. Da bi popolnoma odpravili možnost zamašitve šob zaradi vsakršnih nečistoč smo v šobo vgradili posebno drobilno kroglo, ki zdrobi in očisti rotacijski kanal šobe. Sama šoba lahko izloči delce premera med 2-2,5 milimetra. Tako izboljšana šoba je mnogo bolj zanesljiva v svojem delovanju.

# 8th international symposium on tunnel construction and underground structures

## TOPIC 1 | SAFETY, MANAGEMENT AND CONTROL

Druga pomembna prednost gasilne šobe SafeFOG SCN pa je v dejstvu, da je bila razvita za predore in kot taka že v konceptu prilagojena uporabi v predoru.

Šoba ni občutljiva na nihanje tlaka ali različne tlake, je izdelana robustno, iz odpornih materialov in nezahtevna za vzdrževanje. Vse to bistveno poceni vzdrževanje in odpravlja neljube zapore predora.

Šoba pokriva eliptičen prostor dimenzij 20 x 30m. Ena šoba zadošča za 10 do 25 m predora. Nastavitev pretoka gasila skozi šobo je izredno enostavna.

	m	Število TLA	Cena * za TLA €	Število Monitorjev UNIFire	Cena * Monitorjev UNIFire €	Število šob SafeFOG
Kratek predor	1000	9	85.500	20	200.000	
Daljši predor s spuščenim stropom	4000	35	332.500	4	40.000	180

\* Okvirna cena brez montaže in hidrantnega zajetja, ter cevi za dovod vode.

## 5 Ocena stroškov

Težko je govoriti o natančnih cenah, ker vpliva preveč faktorjev na optimalno zasnova in izvedbo gasilnega sistema.

Sistemi za gašenje z vodno meglo za dolžino predora 4km stanejo nekje med 2.200.000 do 5.500.000 odvisno od proizvajalca, varnostnih zahtev in števila črpalk. Sistemi vključujejo visokotlačno in korozjsko odporno inštalacijo in črpalke, regulatorje ventilov za proženje in upravljanje sistema.

## 6 Zaključek

V predorih je potrebno zagotoviti večjo varnost za prihodnost. Slovenija ima možnost na ligu v »vadbenem in preizkusnem predoru za nove tehnologije gašenja« preizkusiti koncept SafeFIREMAN in ga mednarodno certificirati. To bi pomenilo tudi posel za naša podjetja, ki bi lahko v tujini instalirala tak integriran sistem v predore.

Predori so šivi Evrope in kot taki najpomembnejši za prost pretok prometa.

## 7 Reference

- [1] Fixed water sprinkling systems for fire control in road tunnels, Marc Tesson - Bruno Brousse - Ministre de l'Equipement – CETU, 15/07/03
- [2] An integrated safety study for the use of Fixed Fire Fighting Systems, P Carlotti, 2005 NFPA World Safety Conference, Las Vegas, June 6, 2005
- [3] Sprinklers in Japanese Road Tunnels, Bouwdienst Rijkswaterstaat Directoraat-Generaal Rijkswaterstaat Ministry of Transport, The Netherlands, Chiyoda Engineering Consultants Co.,Ltd., December 2001
- [4] TESTS ON FIRE DETECTORS IN SYSTEMS AND SPRINKLER IN A TUNNEL, ITC Tests on Fire Detection and Sprinkler Ir. J.W. Huijben – Bouwdienst Rijkswaterstaat, Conference Basel 2-4 December 2002
- [5] WATER MIST TECHNOLOGY IN TUNNELS. THE EXPERIENCE OF METRO DE MADRID
- [6] Road Tunnels An Assessment of Fixed Fire Fighting Systems, WG No. 6 - Technical Committee 3.3 – Tunnel Operations, Version September 2006
- [7] EU-directive 2004/54/EC, Directive 2004/54/EC of the European Parliament and of the Council of 29 April 2004 on minimum safety requirements for tunnels in the Trans-European Road Network
- [8] Predor Karavanke in dovozni cesti
- [9] PIARC 1999, Fire and Smoke Control in Road Tunnels
- [10] International Conference TUNNEL SAFETY AND VENTILATION Graz 8.-10.April 2002
- [11] Požarna varnost v cestnih predorih Ljubljana 2000

