UPgrading of existing TUNnels

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Recommendations for Prevention Solutions

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1. INTRODUCTION

Several major, high profile and costly tunnel fires have taken place in Europe in the past years, resulting in significant loss of life - about 500 persons were killed - and damage to the structures. The Channel Tunnel, Mont-Blanc, Tauern, Kaprun and Gotthard are examples of tunnels where accidents occurred due to fire, thus clearly indicating the inadequacy of current design procedures, or better the high risk consequences of possible fire accidents. This is the main technical limitation of existing tunnels, from technological, methodological and from standards points of view. Only the costs incurred by the Channel Tunnel fire - in terms of repair costs and loss of business from lengthy closure of the tunnel - amount to about 82 million Euros (source: European Commission 2003).

The risk of large fires is strongly connected to highly flammable, high combustible mass vehicles going through the tunnels. A reduction of the potential hazard can be achieved by either reducing the probability of accidents involving fire risk, reducing the hazard of vehicles and goods or by mitigating the consequences when a fire does occur.

Fires in tunnels are major hazard to human life and cause costly damage to the infrastructure. The considerable increase of the road traffic, together with the rising mobility of dangerous goods and the inadequacy of the structures resulted in the last three decades in a dramatic sequence of fires in tunnel with great damage in terms of human lives, structures and economy.

Moreover, is to be considered that an accident is more frequent in tunnel (of the 5.590 km of the AISCAT highways, only 25,4 km are in tunnels: that corresponds to a percentage of 0,45%. Nevertheless, 4,60% of the total number of incidents happened in the tunnels) and has more devastating effects, both in terms of human lives, both in terms of economic damage.

The goal of UPTUN 1.2 is to arrive at the definition of possible recommendation for prevention solutions; that means to indicate solutions aimed to avoid or at least to reduce probabilities of fire risks in tunnel.

2. GENERAL REMARKS

The present analysis have been performed by considering with particular attention all documents reported in the attached bibliography, mainly consisting of specific UPTUN partner contributions.

The drawn considerations, anyway, are coming out from data affected by evident limitations. For instance, in [1] the tunnel data elaboration and assessment are drawn with assumption that all fires are similar due to the fact that there is no available information to enable the properties and characteristic of the fires to be determined and analysed (This presents slight errors in the results as all the injuries have been based on similar accidents when in reality some of the fires might have been significantly different from others).

Rising traffic densities and the growing demand for underground communication links result in fact in a higher probability of accidents, injuries and damage.

The main factors causing fire accidents in tunnel are:

- the increasing length of modern tunnels
- the transport of hazardous materials
- two-way traffic (with undivided carriageways)
- higher fire loads due to growing traffic volumes and higher loading capacities

Prior to carrying out any analysis comparing various detection systems against each other, it is important to firstly analyse the effects (if any) each detection system has on its own. The main comparison factor used in measuring the effect of the detection systems is the number of injuries.

For this analysis the following detection systems were analysed:

- Temperature Fire Detectors: detectors that respond to the high temperatures given off from fires
- Smoke Fire Detectors: detectors that respond to the high temperatures from within the smoke layer
- Gas Fire Detectors: operated in response to any toxic gases in the tunnels such as Carbon Monoxide (CO) and Hydrogen Cyanide (HCN)
- Visual Fire Detectors: operated in response to a sighting of a fire

within the tunnels

- Close Circuit Television: similar to visual fire detectors

It's clear from the results of the analysis that the presence of any of the above type of detection system greatly reduces the number of injuries.

3. PREVENTIVE SOLUTIONS

By defining "Recommendations for prevention solutions" one must distinguish between possible solutions aimed to reduce the accident probability and solutions aimed, instead, to reduce the effects of the same event.

To establish the first ones, the following two issue are to be taken in account:

- crashes among vehicles due to insufficient security distance (high-car velocity) and distraction of the drivers
- mechanical defect in motor-vehicles or fire innex (superheating) in functional elements

About the second ones, to improve efficiency of detection and control systems and to use accuracy by managing accidents, are clearly basic actions to do.

In particular way, it is necessary that:

- Travellers self rescue must be improved in order to increase the chances of survival immediately after the accident, and before rescue services arrive on the scene
- Passengers have to be continuously informed on the conditions inside the tunnel
- The access on the place of the accident must be possible
- Safety measures and detection systems have to be adapted to the tunnels in order to be efficient
- All people involved (users, fire-brigade,...) need better information, communication and training

Even if the key-events possible cause of accidents are limited [2], recommendations for prevention solutions can be numerous.

First of all, big attention has to be dedicated to the realization of the safety infrastructures for the self rescue of the people. In case of any emergency, users and drivers must be able to leave the tunnel or to reach a safe place within 300 seconds. For this purpose, escape routes, emergency exits and/or safe havens have to be integrated in the structure of the tunnel. Moreover, areas for emergency actions and lay-bys at the portals of the tunnel have to enable rescue and emergency teams to perform their activities without interferences.

A general remark is that an efficient illumination or better an optimal visibility is a key factor to minimise the risk of crashes or accidents. At this aim it is to point out that good visibility means also to reduce the dazzling effect for the drivers entering a dark tunnel during a sunny day; it appears that large part of accidents occurs during the day (10.00-17.00 o'clock) when the traffic level is higher and the light (sun) - dark (tunnel) contrast is strong.

4. STATE OF THE ART

To point out or suggest possible recommendation data, the starting point was a detailed analysis of the existing State of the Art, as it results by the examination of the available bibliography, collected in activities of UPTUN project.

The most significant activity on the matter was performed in Task 1.2.2, wich includes a description of electronic fire signalization systems installed in automobile tunnels in the Czech Republic; so that in [3] an overview of used devices and their functions, capabilities and limitations is presented for each described tunnel.

One disadvantage can be seen in the fact that none of the fire incidents in tunnels in CR were ever detected by an automatic device, but were all detected by a human operator through video-surveillance. One of the issues in determining the interrelation between a developing fire and the fire detection is that before 2000, i.e. the year when tunnel reconstructions were started in general, only three tunnels had an electronic fire signalization installed. Till that time, fire detection was executed only through video-surveillance by the controller on duty. Based on reports of the Fire and Rescue Service, actually only one fire occurred prior to the indicated data.

A more systematic collection of data is contained in the FIT Database [4], where the technical equipment are structured in accordance with the following functional categories:

a) monitoring,

b) detection,

c) extinguishing,

d) communication,

e) ventilation,

f) indication,

g) traffic control,

h) rescue,

i) protection.

where, the ones indicated a-b-d-f-g are addressed to “prevention”.

In the database equipment types are scheduled in a table, where several sub-categories are also identified.

More specifically, the sub-categories are indicated for monitoring (visual and optic), detection (smoke, temperature, gases and radiation) and traffic control (indicator and counting)

All individual trade names are housed together under the relevant equipment type, e.g. 'water mist extinguishing systems' or 'video identification systems'.

The recorded information presents the application, its installation requirements, plus references and links to the different manufacturers.

RECOMMENDATIONS

It's clear that the optimisation of preventive measures aimed at reducing situations of risk is fundamental against possible fire accidents in tunnel and their dreadful consequences.

Preventive solutions can be achieved through various ways/means such as :

a) Self rescue infrastructures

- in case of emergency, users have to be able to autonomously reach a safe place within a maximum time of 300 seconds, through emergency exits, escape routes, safe havens or alternative solutions.
- at the portals of the tunnel, actions of the rescue teams must be possible without interferences due to properly dimensioned emergency areas and/or lay-bys.

b) Vehicles and goods control

- big attention is at present dedicated to the detection and possible stop of vehicles with abnormal temperature fields before tunnel entrance through thermographic portals installed just outside the tunnel [7]; such a systems, set up by employing infrared region scanning methods, reveal the presence of anomalous superheated spots and/or initial spread of fires within trucks before they access toll areas.
- the definition of rules and regulation for the transport of hazardous materials is basic (for the most part there are no general defined standards); rules (where existing) vary considerably among countries and even in the same country among various tunnel owners.

c) Traffic control

The continuous monitoring of distance and velocity of vehicles inside the tunnel as well as the possible stop or setback of car-truck is basic for prevention of accidents.

d) Optimised tunnel structure system design

It is quite clear the importance that an optimised system-structural design of the tunnel has as preventive solution; for instance: two ways, separate carriageways, highly adherent paving, sound proof materials.

e) Monitoring (temperature, air and visibility, smoke)

The most common and useful preventive solution is the detection of risk conditions inside the tunnel through video surveillance system and through the automated detection of accidents and traffic jams, violations of speed and safety distance limits and unusual temperatures, smoke and air conditions.

Monitoring systems largely used are both visual and optical ones (video identification, passive-infrared-detectors, optical absorption measuring,…)

It is fundamental the use of the best technical and functional fittings as:

- Fixed/mobile visualization and monitoring systems inside and outside the tunnel with video-photographic recording capabilities
- Efficient sign system (f.i. electrical ones for improved visibility / highly reflective and sound-making horizontal sign systems)
- Variable message panels with the possibility to visualize pictograms and alphanumeric messages through state-of-art technology
- Radio and telecommunication systems
- Digital video cameras.

f) Indication/communication

It is quite evident the importance of preventive actions for the information and awareness of the users and the use of a single command room and a centralized technical emergency management.

5. CONCLUSIONS

The goal of preventive solutions and in particular the possibility to reduce the fire risk is one of the basic items of the research effort in safety tunnel improvement.

First goal must be the safety of the people involved in the accident. Therefore, safety measures must favour their self-rescue, by allowing them to easily reach a safe place in short times (through emergency exits, safe havens, etc.), and the actions of the rescue teams, already before entering the tunnel, providing them with suitable emergency areas and lay-bys.

Specific attention is given to all measures acting to avoid the trigger and especially to the early or better “immediate“ warning of fire source so to prevent the fire flash-over.

Fundamental is the product and process innovation content, since the cutting edge of technology applied to mobility has enabled to predict any possible interaction between vectors and infrastructure, in the context of intelligent systems.

A last issue to be pointed out is that clearly the combination and/or connection of various monitoring/detection system increase reliability and control level but a compromise has to look at cost efficiency as many advices are very expensive.

It can be summarized that although it is impossible to achieve absolute safety in light of possibility of human error, no doubt novel technologies applied to the management of modern tunnels and relevant investments in upgrading the older plants enable to considerably reduce risks.

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