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SAFETY HAS TO BE MANAGED
an integral approach for loss prevention of accidents due to major tunnel fire disasters

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ABSTRACT

The number of extended street and railway tunnels increases continuously. Consequently we have to cope with much more traffic which might cause fatal accidents such as major tunnel fires. The recent fire desasters in the European Alps focused the public interest on problems concerning traffic and safety. Shortly after the fire in the Mont Blanc Tunnel the Deutsche Montan Technology Ltd. (DMT) as an expert body for tunnel safety carried out a preliminary audit for some twenty tunnels in Europe. The authors will describe safety measures which are typical of the current practise in many tunnels. Then important key elements of safety management systems, such as safety policy, systematic risk analysis, organisational structures and resources, training of personnel, communication and audit will be explained. Due to the implementation of a tailor made safety management systems the risk due to major fire disasters can be reduced for a new tunnel as well as for an existing tunnel to a small acceptable level. Therefore the integral approach proposed by DMT and RISC RUHR considers a tunnel more as a living organ than as a static building. This is why the individuality of a tunnel system and the financial effort to maintain the safety management system are taken into account.

TRAFFIC AND RAILWAY TUNNELS IN EUROPE

The art of tunnel building is age-old. Since the Ancient Ages subterranean hollow spaces have been constructed for religious purpose, for water supply or for passenger transport. When the first railway lines were set up tunnels and bridges were the only means to avoid inclines. Nowadays Europe disposes of about 14,000 km tunnel for the railway-, long-distance and local traffic. In Germany with 1,400 km build another 200 km tunnel in 1999, and about 370 km tunnel were planned in the sam,e year. In Europe, three important tunnelling projects are planned to cross the Alps. The NEAT the Swiss project is planning a 57 km - long railwaytunnel.
In March and May of the year 1999 two accidents with fire happened in the long road tunnels of the Alps. This accident brought the aspects of safety in tunnels to a wide public.

RECENT FIRE DISASTERS IN EUROPEAN TUNNELS

The Mont Blanc tunnel, a 11 km long single tube, two-way tunnel between France and Italy was built mainly in granite and was completed in 1965. Initially the tunnel was designed for a traffic volume of 350.000 cars per year. In the last years traffic load increased to 2 million cars per year with 750.000 heavy good trucks. No escape routes have been built, later the tunnel was refurbished to include refuge bays every 600 m. These were designed to accommodate 25 people in a fire, but only for 2 to 6 hours. Therefore these safety facilities provide just a limited protection.

The fire started on March 23rd 1999 in the refrigerator system of a Belgium truck driving from France to Italy loaded with margarine and flour. The driver was forced to abandon his vehicle near the tunnels

centre-point and escaped safely. The tunnel ventilation system was flowing against the traffic. 24 trucks and 9 cars were caught in the fire and the fume, so that people lost orientation. Rescue teams and fire fighters approached the fire from both sides but could not get closer than 1000 m due to the intense heat and dense fume reducing visibility to zero. The rescue teams were overcome by fire and fume and two rescue trucks burned out. 41 people perished in the fire and the fume.

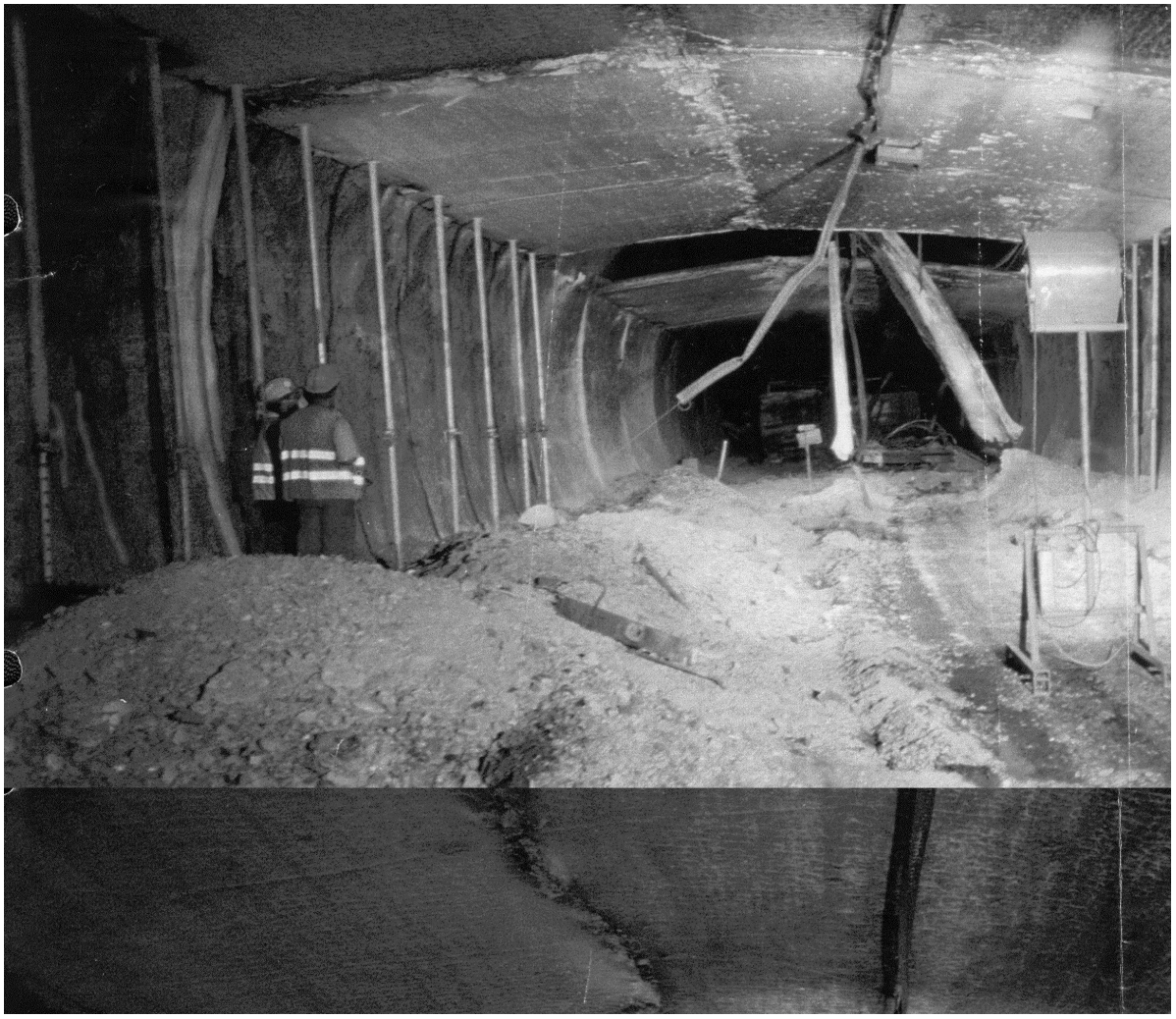

Fig. 1: after the fire in the Tauerntunnel

The fire was brought under control after 3 days and investigations into the disaster are under way. A provisional report of independent authorities claimed that the fire and emergency control situation in the Mount Blanc Tunnel was a disaster waiting to happen. Specific faults which have been reported so far are:

- Only one trained fire man was on duty
- The ventilation system is out-of-date and had a poor general ventilation control. This was the major factor in the spread of the fire, smoke and fume along the queue of halted vehicles
- The emergency warning system is ineffective
- The communication system between the French and the Italian side was inadequate

The Mount Blanc Tunnel fire is one of the most damaging tunnel fires in Europe - repair works will last for six to twelve month.

The 6.4 km long Tauerntunnel is one of the main road connections between the North and South of Europe. It was built in 1975 as a single tube tunnel without escape routes. It accommodates over 5 million cars per year. A second tube was intended for construction but has not been realised so far.
The fatal accident occurred on May 29th 1999 as a truck travelling north carrying spray paints failed to stop at a traffic queue waiting at a red light at a maintenance sight 500 m from the northern portal.

The truck ploughed into the queue sandwiching four cars between it and another truck before exploding. 7 people in this accident. The fire spread and set several other cars on fire. 5 people died in the fire and smoke and over 50 people were injured.
The tunnel was refurbished over a length of 150 m with pre-casted segments and sprayed concrete. The electro-mechanical system was irreparable damaged over 2 km. The tunnel was reopened only 3 months after the accident. The second tube is now under preparation for tendering and is expected to be completed within five years.

RESULTS OF SAFETY AUDITS

The German Mining Technology (Deutsche Montan Technologie) having its origin in mining has been caring for safety and people and equipment in mining for about 100 years.

The fire disaster on 24March 1999, in the Mont Blanc Tunnel causing 41 deaths, has generally led to focus on safety in tunnels. In May for instance, the Deutsche Montan Technologie (DMT) in Essen tested 20 road tunnels on the most important holiday routes in Austria (12), Switzerland (4), France (2) and in Germany (2) on behalf of the German Automobile Association (ADAC).Almost the half of them were assessed as „risky“ or even „sub-standard“. Only 5 were quoted „good“ and the best mark „very good“ was not awarded at all.

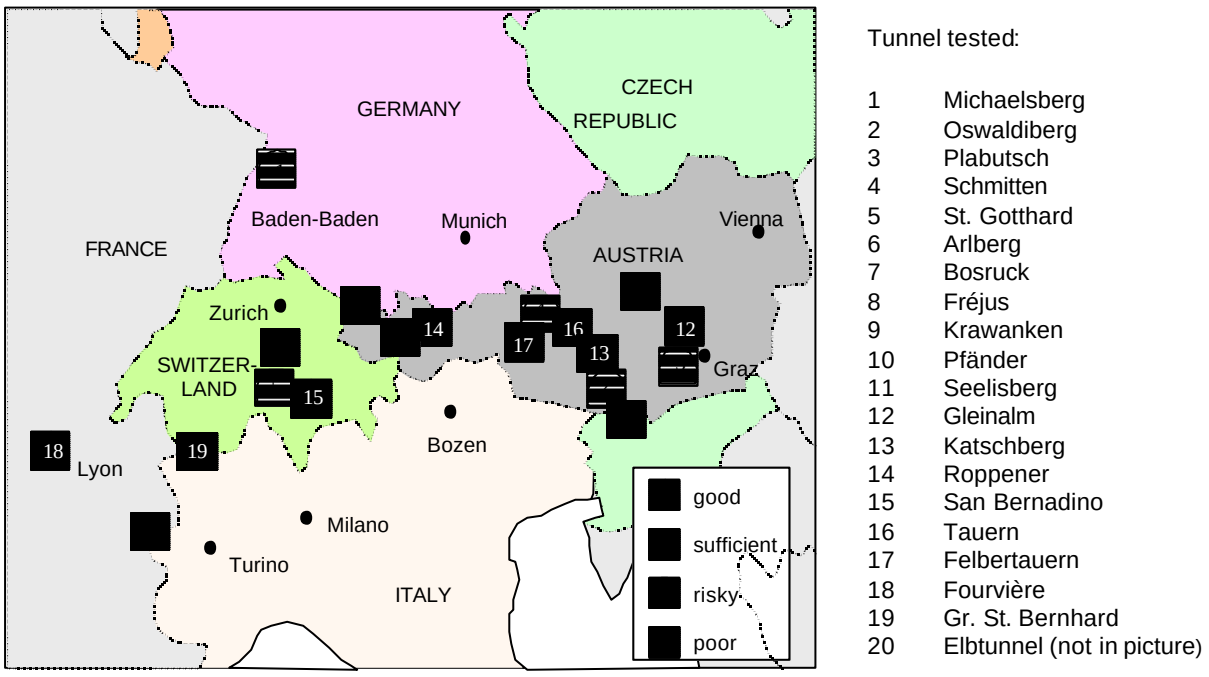

Fig. 2: Tunneltest in Europe

The 20 tunnels that were tested have a total maximal length of 140 km with a daily traffic density of more than 400,000 vehicles, with lorries counting 14% on average (max. 60%) of this total number.
For the test, a checklist with the most important considerations relating to safety was drawn up and operators checked the tunnel safety at random. For the technical assessment pertaining to safety, the following factors were taken into account:

- tunnel system, constructive state (also) carriageway surface and markings, lighting, signs) and traffic values. There should be limited possibilities to stop the event of breakdowns or accidents with breakdown bays, which should exist on both sides in tunnels with two-way traffic.
- traffic monitoring (TV- cameras, tailback reports, etc.)
- traffic control measures (speed and tailback indicators, breakdown bays at both sides, etc.) Sets of traffic lights should be erected in the tunnels and traffic should be stopped in front of the tunnel if it is necessary.

- communication (emergency phones in bays or protections against noise, mobile network, etc.)
- fire protection measures (fire alarms, hydrants for extinguishing water, ventilation systems and verification of their efficacy through fire test in the tunnel, etc.)
- possibilities to escape (rescue rooms, fire-protected escape chambers, escape galleries, crosscuts between 2 tubes at gaps of no more than 350 m, especially exits) and
- emergency facilities (tunnel fire service with infra red cameras and its own vehicles, relatively short approaching ways; central control room, and corresponding training should be set up

The most frequent faults in the case of fire in the tested tunnels are:
- only a single tube with two-way traffic
- no hard shoulders and no or only narrow foot paths

For escape purposes there are:
- no escape tunnels or special exits (shafts or galleries) and
- no escape chambers.
- The need of well trained and equipped fire fighting specialists

For many tunnels and underground stations still a major fire cannot be prevented. In order to end up with an acceptable remaining risk in each individual tunnel a safety management system is required. Such a safety management system has to be implemented by the operating company as it is already a common practise in the process industries.

Whereas in the past the safety demands mainly focused on safeguards and equipment the fire disasters in the Mont Blanc and Tauern Tunnels makes us think about another very important aspect: the safety demands on the organisation.

The tragic of those fire disasters has brought all private companies and municipal or governmental institutions in charge of the operation of a tunnel. They will have to consider that there might be a risk fire fighters will no more be able to handle. As soon as we accept this fact we can and we have to discuss this with all people dealing with preventive safety measures as well as with the emergency management teams and especially with the public.

Fig. 3: test fire in a subway tunnel under realistic conditions

THE NEW APPROACH - SAFETY MANAGEMENT SYSTEMS

For many tunnels and underground stations still a major fire cannot be prevented. In order to end up with an acceptable remaining risk in each tunnel a tunnel must not be seen as a static building any more but as a living organism, a dynamic tunnel system. The result of this approach is to claim for a tunnel safety management system. Such a safety management system has to be implemented and maintained by the operating company as it is already common practice in the process industries [2].

Key elements of safety management systems are

A) risk analysis

In order to design a safety management system at first an interdisciplinary team of experts has to carry out a systematic risk analysis. These experts must provide excellent knowledge in fire science, civil engineering, tunnel ventilation, psychology etc. In addition to the detailed examination of the normal operation of the tunnel all safety related installations and measures have to be registered and evaluated. Typical safety installations may be fans for fast smoke extraction, sprinkler systems to the extinguish initial fires, safe havens for tactical progress of the fire fighters etc.

B) safety policy

Management of a tunnel system must have a safety policy which shows that safety belongs to the major goals. Furthermore this document illustrates that safety belongs to all employees of the tunnel company.

Fig. 4: A tunnel system with various safety installations

C) organisation

The normal organisation of a tunnel is intended to operate the tunnel sufficiently under normal conditions. Usually extraordinary situations such as jammed traffic, collisions etc. can be handled. Experience shows that if a certain point is reached, for example, when an initial fire in the tunnel gets out of control the pressure on the normal organisation might get so high that it leads to collapse. Therefore an adequate emergency organisation [1] has to be prepared including employees of the operating tunnel company and external emergency organisations such as municipal fire brigade etc.

D) training

In order to provide experience for each individual fire fighter and emergency manager DMT has founded a training centre in Dortmund called RISC Ruhr Ltd.. This training centre is the first Public Private Partnership in Germany whereas besides DMT RISC Fire&Safety Training B.V. Rotterdam and the City of Dortmund (represented by the Municipal Fire Brigade) act as stakeholders.
RISC Ruhr Ltd. obtains two tunnels, a railway line connection, a fire multi story fire house, a flashover module for a realistic, safe and environmental agreeable training. Currently an area for loss control due to the transport of hazardous materials is installed.
At the training centre the trainees learn what happens in case of fire, how to protect their own safety and how to react sensibly. For instance in the flashover module the trainees learn about the phenomena of time dependent increase of the temperature and the creation of a smoke layer under the ceiling of confined spaces as well as the rapid ignition and the risk due to a flashover. Later on they will learn about modern methods about how to fight such situations. In the firehouse and in the tunnels they can practise various methods as for example how to orientate under invisible conditions, how to work with long-term expiratory equipment or how to find and rescue people under such difficult conditions.
For instance in the training tunnel the trainees have to fight a burning car or burning goods up to fire loads of 5 Megawatt and even more.

Fig. 5: training of fire fighters under realistic conditions

Realistic training of emergency teams creates a certain degree of experience in order to know about the individual limits and thereby to promote personnel safety. For many years the role of the fire brigade has been seen as the last instrument in *a chain* of safety measures which should beat the fire when all other measures failed. The recent experiences due to the fire disasters in the Mont Blanc Tunnel and the Tauern Tunnel and the experiences during training at RISC Ruhr's Training Centre make clear that also the efficiency of fire fighters ends at a certain limit. Beyond this limit a tunnel fire disaster cannot be beaten any more.

E) communication

Major tunnel fire disasters develop within minutes and may last over hours. Huge numbers of drivers, passengers and different emergency teams can be on the spot. In such a complex situation functionality of media esp. radios and the discipline concerning the communication is of extraordinary importance.

Shortly after a major tunnel fire occurs the press will be on the spot requesting for interviews with the emergency management. Relatives and friends of drivers and passengers will ask for information. Such items must be addressed to a professional representative of the tunnel management.

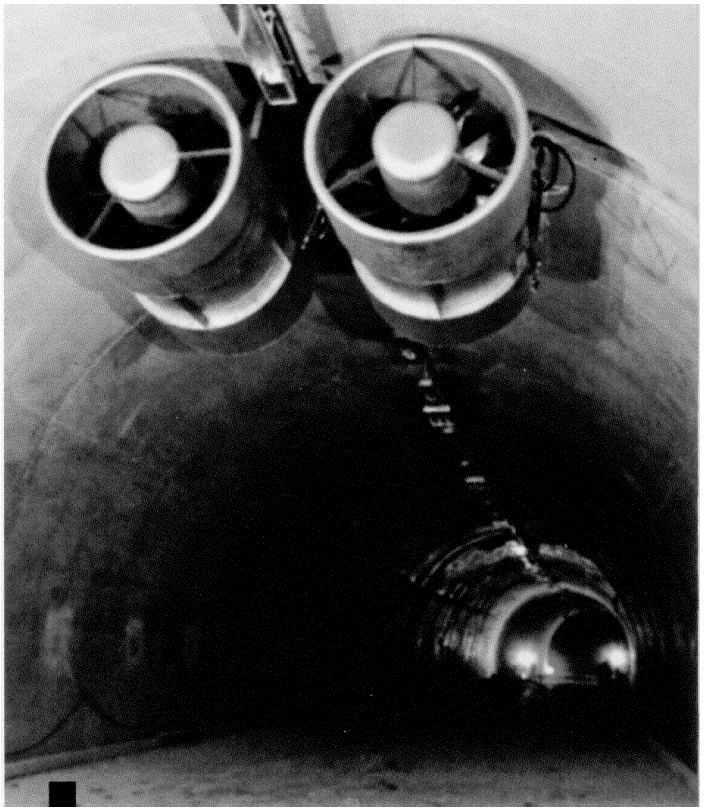

Fig. 6: Ventilation, one major aspect of a tunnel audit

F) audits

The role of the audit is to establish an instrument providing a top down and bottom up information flux between management and staff concerning current safety conditions. The audit may be carried out based on checklists. The results are documented in a written report. Frequent audits provide management with the necessary information about possible safety gaps. Management then can maintain those installations or measures.

DMT propose to carry out a very detailed audit the first time taking into account technical documentation and local inspection.

After significant changes in the tunnel system e.g. the construction, the safety installations or a fire an audit is urgently recommended.

In cases where a tunnel system is operated under normal conditions a frequent audit is recommended after two years.

Conclusions

Based on their specific experiences in auditing European tunnels and in training fire brigades and emergency management teams DMT and RISC RUHR conclude that

1 traffic and railway tunnels must be seen as living organisms in other words as tunnel systems.
2 tunnel fires are no rare events and may end up in huge disasters.
3 the operational company must not leave the responsibility to deal with a huge disaster exclusively to the fire brigade.
4 in order to achieve best management of safety based on limited financial resources an integral approach is substantial
5 in order to end up with a small remaining risk the operational management of a tunnel system must implement and maintain a safety management system.
6 Safety of tunnel systems may be marked individually but must in principle be managed systematically.

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