Full size testing of drainage systems for burning liquid in road tunnels

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Full Size Testing of Drainage Systems for Burning Liquids in Road Tunnels

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1. Introduction

Most vehicles transporting dangerous substances on road are liquid hydrocarbon tanks. When their passage is permitted in a tunnel, measures should be taken in order to limit risks in case of an accident. Thus, the recent French road tunnels are equipped with collecting systems for burning liquids spilled on the pavement. The objective is to reduce heat and smoke produced by a fire, to limit fire propagation to other vehicles, and to enable rescue teams to approach the fire.

On the occasion of the doubling of the Chamoise Tunnel, on the A.40 motorway between Lyon and Geneva, a general study of these sytems has been financed by the French Government and Société des Autoroutes Paris-Rhin-Rhône (S.A.P.R.R.), the semi-public Operator. The study was defined and followed up jointly by SCETAUROUTE, contractor to S.A.P.R.R., and Centre d'Etudes des Tunnels (CETU), which ensured the general guidance and conducted the hydraulic tests. The Institut National de l'Environnement Industriel et des Risques (INERIS) was charged with risk studies and fire and explosion tests.

2. Preliminary studies

Traditionally water running on the pavement in road tunnels is collected through open gutters along the pavement, then discharged into a collector through 50–100 m spaced gully holes. In order to improve absorption for dangerous substances SCETAUROUTE use gully holes at narrower intervals, about every 10 m. For their part CETU drew elements from the Swiss facilities and elaborated continuous slot gutters which communicate with the collector via gully holes with siphons, in order to extinguish burning liquids (figure 1).

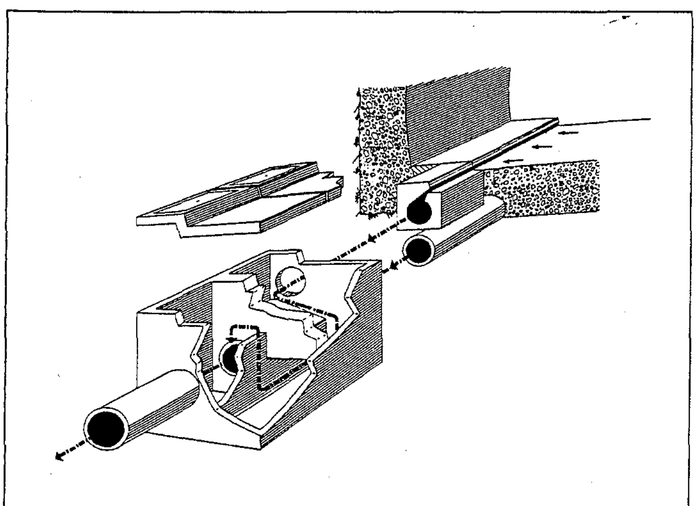

Fig. 1: Scheme of a drainage system with continuous slot gutters and siphons

Very few literature data are available on the efficiency and possible risks of such systems, either in tunnel or in other structures, e.g. oil industry. This justified a testing programme.

The statistics on dangerous substances accidents on open roads and in tunnels have been analysed and allowed to consider representative study cases:

- continuous leakage of 30–70 l/s corresponding to a component breakage or a puncture of 100–150 mm in diameter;
- sudden release of a volume corresponding to the average recorded spillages, i.e. 5 m³ excluding the extreme cases, or 10 m³ including the few most important cases.

3. Hydraulic tests

The first experimental phase was performed in six operated road tunnels, in order to make a hydraulic evaluation and comparison of the various collecting systems.

3.1. Testing methodology

Water was used for obvious reasons of safety and convenience. The continuous leakages were obtained by running water out of the tunnel fire hydrants. A prefabricated 3 x 3 m pool, with one side that could be opened suddenly, was used to simulate the sudden spillages of 5 m³ and 10 m³, under good reproducibility conditions.

Three camescopes recorded the tests in order to characterize the wet surface during the spillage operations. The pavement was squared by retroreflective, self-adhesive strips and numbered studs which also allowed to measure the water depth. When allowed by the site, the water height was permanently measured in the gutters.

3.2. Test results

The observation with time of the liquid sheet let appear three successive, interacting flowing zones (figure 2):

- A first zone can be qualified as inertia zone, because it is a function of the liquid release conditions, principally its ejection speed;
- The second zone is determined by the gradient, the transverse slope and the surface characteristics of the pavement: the liquid flows in the general direction of the principal line under the effect of gravity;
- In a third zone, also a gravitation one, the liquid not absorbed into the gutter flows along the sidewalk edge before being removed through the drainage system.

We called them zone B the first two surfaces together: it corresponds to the minimal sheet extension that would be obtained if all water reaching

Congrès Mondial des Tunnels et Journées STUVA, Stuttgart, 6-11 mai 1995, p. 230-236

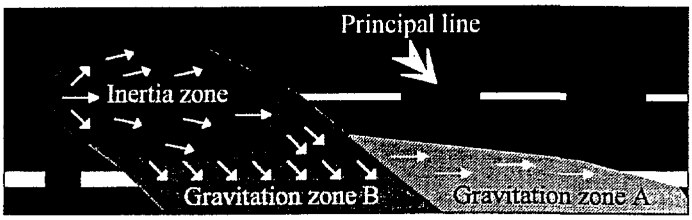

Fig. 2: Diagram of flowing zones

the edge of the pavement was immediately absorbed. The third surface, called zone A, expresses the fact that the device does not absorb the liquid perfectly: it therefore allows to compare the efficiency of the various systems.

Table 1 presents the characteristics of the tested tunnels, and gives as an example the main results obtained with the sudden release of 10 m³. Figure 3 shows the extent of the wet zones in this case. The continuous leakages and sudden releases of 5 m³ led to comparable situations, but obviously with smaller wet surfaces and lengths.

3.3. Main conclusions

In all cases it appears that the conventional system – moreover badly maintained – of the Monts Tunnel is particularly little efficient. The wet surface exceeds 1000 m³, even for a continuous leakage of 35 l/s !

The comparison of zones A shows that the slot gutters prove to be the most efficient facilities. Among the two tested types of slots (figure 4) those with the opening in the vertical plane behave best: the zone A is non-existent in the Cornil and Siaix Tunnels, even for a sudden release of 10 m³. This arrangement indeed allows to utilize directly the flow dynamics to remove the liquid. In the Grand Mare Tunnel, where the slot opening is in the horizontal plane, the liquid is collected under the action of gravity only and therefore not so well intercepted.

In this last tunnel, the slot gutter is also hindered by its inner diameter of 200 mm, which proves insufficient and forces the liquid back in case of heavy release.

The diameter of 400 mm installed in the two other tunnels is satisfying. Siphons there also showed a proper hydraulic behaviour: in the Siaix Tunnel, the volume of 10 m³ was drained through the gully hole within 50 s, which corresponds to an average flow of 200 l/s.

The lower performance of systems with gully holes at small interval in the Châtillon and Saint-Germain-de-Joux Tunnels can be explained by the very principle of the gully holes and their design, which only allow an insufficient absorption. In addition the presence of small open gutters, 30 cm in width and 3 cm in depth, along each sidewalk (including at the transverse slope top) induces the formation of very long liquid "tongues" on both sides of the pavement.

3.4. Other statements

Except the case of the Monts Tunnel, water needs less than 2 minutes before being removed from the pavement after the end of the continuous or sudden spillage. In the Grand-Mare Tunnel, however, where the pavement is coated with pervious bituminous concrete, some liquid continues to flow below the wearing course for over 15 minutes. Questions may be raised about the risks resulting from this lasting presence of dangerous substances inside the tunnel.

Lastly it must be mentioned the flowing problems noted in certain drainage systems, which induced liquid to be forced back onto the pavement, thus raising a potential risk. Such phenomena resulted either from a narrower hydraulic section at the gully hole entrance, or from the presence of debris due to insufficient maintenance. Obviously the strict avoidance of such situations must be reached.

Tunnel characteristics				Wet surface and lengths			
Tunnel name (location)	**Gra-dient (%)**	**Cant (%)**	**Drainage system**	**Wet surface (m²)**	**Wet length (m)**	**Zone A surface (m²)**	**Zone A length (m)**
Monts (Chambéry)	0.7	1	Conv.grid gully hole 75x30 cm² every 50 m	1 480	> 200	**1 080**	**> 200**
Châtillon (A 40)	0.6	1.8	Grid gully hole 30x30 cm² every 11m	385	105	**140**	**80**
Saint Germain de Joux (A 40)	1,8	3	Grid gully hole 13x50 cm²every 11m	405	120	**155**	**95**
Grand Mare (Rouen)	3.5	2.5	Horizontal slot gutters and siphons	535	90	**120**	**40**
Cornil (RN 89 - Corrèze)	3.2	2.5	Vertical slot gutters and siphons	300	35	**0**	**0**
Siaix (RN 90 - Savoie)	1.5	2.5	Vertical slot gutters and siphons	335	40	**0**	**0**

Table 1: Results of the sudden spillage of 10 m³

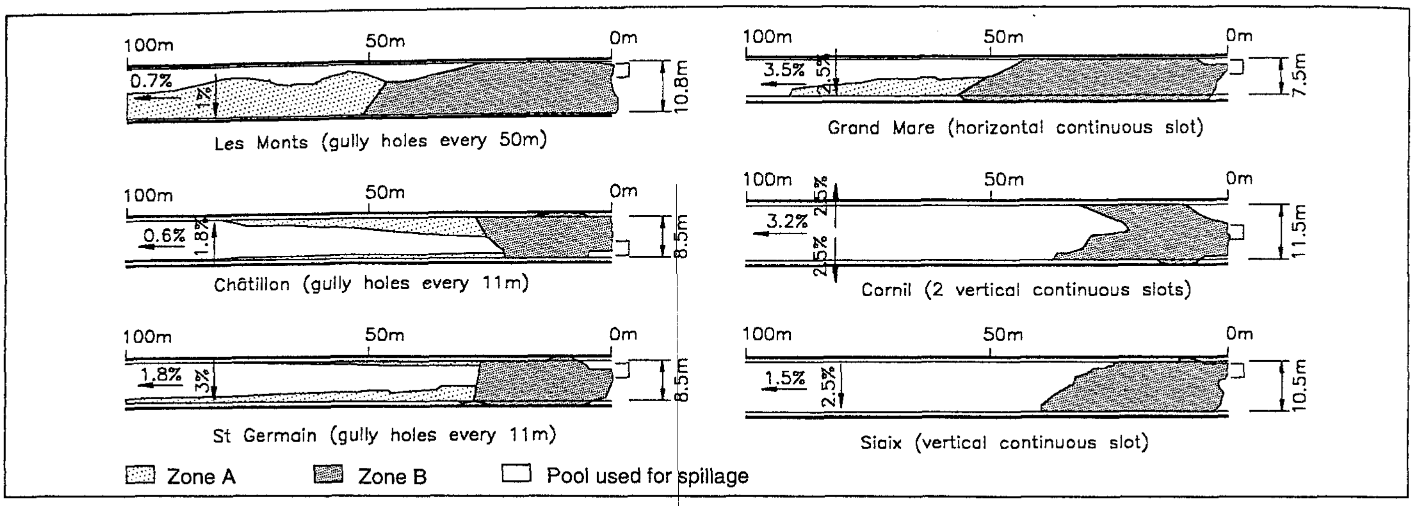

Fig. 3: Wet zones A and B for a sudden spillage of 10 m³

4. Fire and explosion test

As the systems including slot gutters proved to be properly operating from the hydraulic point of view, it appeared necessary to test them regarding fire and explosion risks.

The basic purpose of these tests was not only to check the efficiency of the facility for extinguishing and removing a burning liquid, but also to characterize the mechanisms implied in dysfunction situations. This explains that numerous tests have been devoted to such cases, although they are exceptional.

4.1. Methodology

4.1.1. The experimental facility

For safety reasons, tests could not be made underground. The selected site was the INERIS Montlaville open site in Verneuil-en-Halatte.

As no similarities allowing a reduced scale study were available, a section typical of a drainage system was reproduced in full size. It included two siphons separated by a 48 m long slot gutter communicating with a collector which crosses the facility from one end to the other (figure 5).

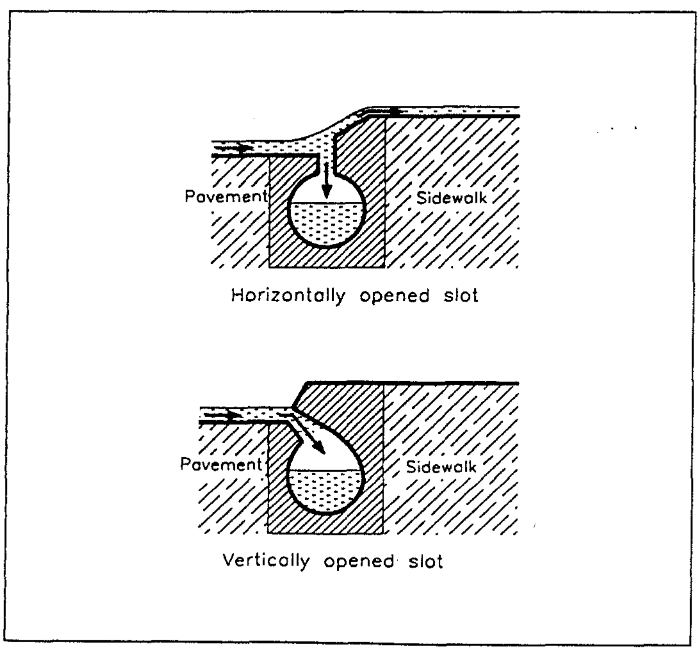

Fig. 4: Possible schemes for continuous slot gutters

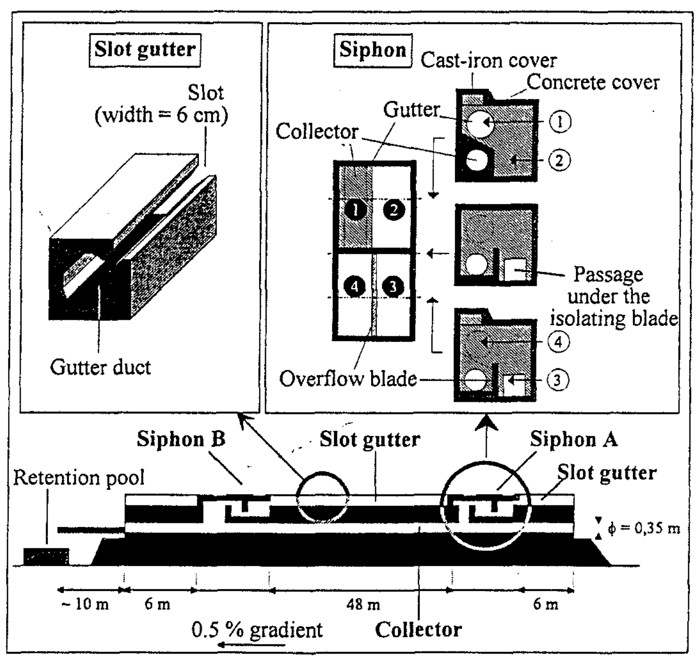

Fig. 5: Diagram of the experimental system

The gully holes and their siphons were the same as those installed in the Siaix Tunnel. The internal volumes were numbered from 1 to 4 in the liquid flowing direction.

A second facility, consisting only of two coupled gutter sections (6 m) allowed to characterize more stationary phenomena. The system is sealed at both ends, so that the combustion corresponding to various filling up levels can be tested.

4.1.2. Measuring principles

The facility is provided with a complex measuring equipment including thermocouples, flame detectors, pressure sensors, explosimeters, etc. These appliances are distributed in the sensitive zones according to the expected phenomenologies.

All data are sent back to a collecting station. This has a completely self-sustaining operation, since the personnel has to stay beyond a safety limit during most tests.

The visual observations are strengthened by four video cameras focused onto the sensitive points of the facility.

4.1.3. Spillage principles

The product selected for these tests was unleaded gasoline, because this liquid counts among the most dangerous ones which are representative of the risk connected with the transportation of inflammable liquids in tunnels.

For safety reasons, and in order to get a better characterization of the phenomena, the spillage implying burning gasoline did not use quantities so high as for the hydraulic tests. All tests were conducted with flows of about 3 l/s.

4.1.4. Survey of the experimental testing series

Two experimental testing series were conducted at an interval of one year.

In a first approach (in 1993) one tried to characterize the behaviour peculiar to each component of the drainage system. It appeared then that the exchanges occuring at the limits of each element were determining for the general phenomenology. The second series (in 1994) therefore focused on more global behaviours.

In total twenty-five tests were conducted. This figure does not include a few preliminary tests made without ignition.

4.2. Demonstrated basic phenomena

4.2.1. Fire

The fire developing in a drainage system is submitted to constraints in relation to the confined environment. This latter limits the oxygen quantities available for the combustion mechanisms and hinders the removal of burnt gases. These conditions may lead to self-extinction.

Maintaining the combustion requires a sufficient movement of gases. The mainspring of this system consists in the Archimedean stresses developed mainly at the fire level. This process of fresh air supply will be called below "respiration".

4.2.2. Explosion

The risk analyses show that gasoline can enter the drainage system without burning. Vapours therefore can develop there. The confined environment generally succeeds in maintaining them at a high concentration.

The explosion risk is a function of gasoline vapour concentration at the instant of ignition. For the unleaded gasoline used for the tests, the atmosphere is made deflagrable by hydrocarbon contents between 1.4 and 7.6 %.

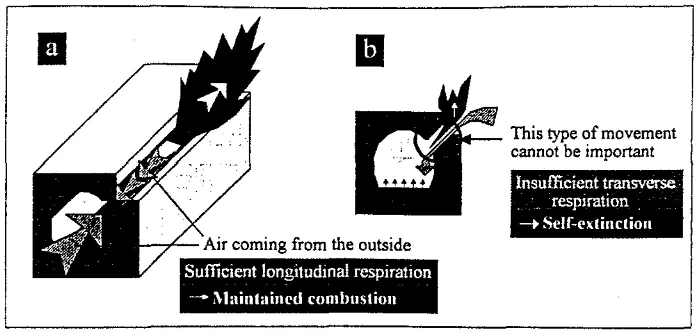

Fig. 6: Combustion or self-extinction mechanisms in the slot gutter

4.3. Behaviour of the facility in case of fire

It was demonstrated that the phenomena which occur at various points of the facility cannot be dissociated in a global phenomenology. It is possible, however, to describe the response peculiar to each system element to a fire.

All mechanisms described here have been brought out by the observation and analysis of recordings made during the experiments.

4.3.1. Gutter

In a normal operation situation the gutter is the only element in the drainage system to have a volume in direct contact with the tunnel atmosphere. All tests show that a gasoline fire in the slot gutter is little violent and does not produce much smoke. In a tunnel the generated opacity will therefore be lower than that could be expected in such an event. This is therefore a rather favourable situation.

Various observations show that two respiration modes are in rivalry:

- a transverse mode in which fresh air flow and burnt gases flow must cross in the slot thickness (6 cm);
- a longitudinal mode which supposes that no combustion exists in a zone near the flame (figure 6).

A number of tests with blocked longitudinal respiration movement (small gutter length, or flame on the whole slot length) lead to self-extinction. They tend to demonstrate that the transverse respiration mode is very fragile.

These tests generally correspond to very particular experimental protocoles. The other tests show that the maintained combustion remains the most probable hypothesis. In other words the fire self-extinction in the gutter, although possible, does not appear as a probable phenomenon in a realistic scenario.

4.3.2. Siphon

a) Firebreak role of the siphon

In presence of a hydraulic isolation – even gasoline – the siphon ensures its firebreak role. Tests show that the flame never succeeds in reaching the downstream compartment.

b) Respiration mode in normal operation

The tests which imply a siphon fire show that the combustion process is being maintained there provided that the longitudinal respiration mode has already settled in the gutter (figure 7). The second condition supposes that the fresh air flow and the burnt gas flow cross in the entrance hole. This movement can be easily disturbed and several cases of self-extinction have been observed. In the general case, where fire lasts, the combustion process is low.

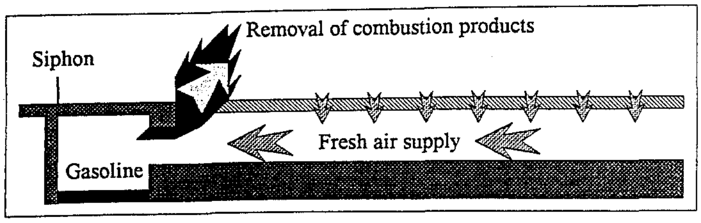

Fig. 7: Diagram of flows between the gutter and the siphon

c) Dysfunction situations

The hydraulic isolation divides the siphon – and more generally the drainage system – into two distinct volumes with respect to the gaseous phase. As soon as this separating role is altered the system enters a disfunction regime. Several plausible situations have been tested:

- If the isolation is composed of gasoline its level decreases when combustion is being maintained in the upstream 1–2 compartment. In a test where this isolation has become insufficient to preserve its separating role, it has been observed that the explosible atmosphere developed in the downstream 3–4 compartment was sucked then burnt by the flame, without any explosion phenomenon. This test was conducted in siphon B where the head loss in the collector is low (figure 5).
- For comparable tests conducted in siphon A, the head loss in the collector was higher, and it has been demonstrated that the flame had been able to extend in the counter-direction from the upstream 1–2 compartment to the downstream 3–4 compartment, following the free space under the blade. In the most disadvantageous case an explosion was initialized in volume 4. In the other cases this compartment was the seat of a well-marked flash.
- If placed in situation of double dysfunction (no hydraulic isolation and cover open on the downstream 3–4 side) the siphon does not play any more its role of firebreak protection towards a burning leakage. In return if the hydraulic isolation is absent, but the downstream compartment still airtight, the absence of standing flame in the downstream part of the facility is guaranteed, although some ignition has been established during the very first instants during the tests. The contest between the speed of self-extinction and the raise of the liquid which arrives into the retention pool can explain that, before the overflowing, the flame has not found the conditions required for existing and has extinguished. In the inverse case it is not irrealistic to suppose a collector fire. The firebreak role of the siphon is then limited to maintaining conditions unproper to combustion in the downstream compartment.

d) Layering of gasoline vapours

After spillage, layering of vapours can induce a rapid variation in explosibility conditions in the same volume and completely change the assessment of risk for the same type of experience. Several tests show that this gravitational movement is relatively quick in the siphon, although it appears necessary to relate it to volatility of gasoline which is likely to vary according to the product manufacture (this depends on the period in the year).

e) Effects of explosion

In the most violent cases of explosion the concrete plates covering the siphons are slightly displaced under the effect of overpressures. The cast-iron covers are thrown up and a short flame appears. In the other situations only the metal covers are ejected. When the phenomenon is limited to a flash, this generally goes with a small jump of covers which fall again in their seats (clang). The airtightness of the siphon is then maintained.

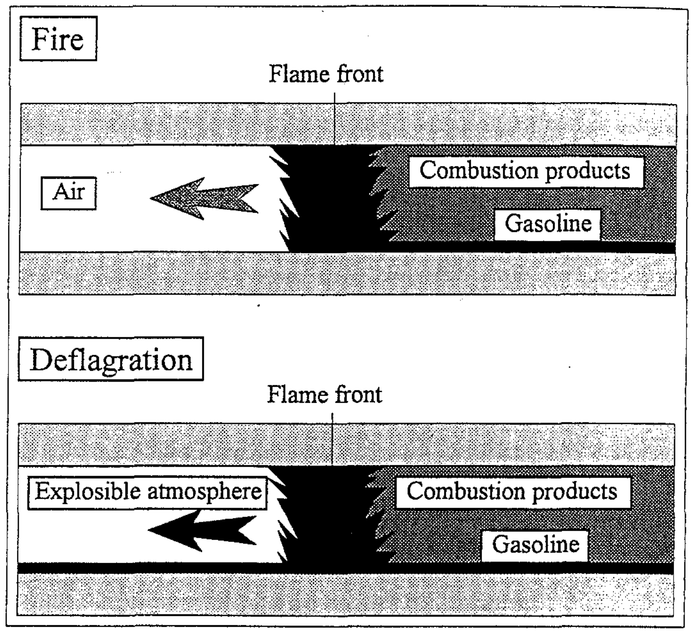

Fig. 8: Combustion process in the collector

4.3.3. Collector

a) Fire

The experimental configuration selected for the collector may seem particular, since due to its small length this duct cannot be considered as representative of an actual facility (especially the aeraulic head losses are underevaluated).

In the absence of inflammable vapours already present in the collector the fire can last there only under the form of a front flame which follows the progression of a gasoline runnel. Behind this front extinction is imposed by the concentration of combustion products (figure 8).

The speed of this displacement depends on the speed of the gasoline runnel at the collector bottom. The existence of the flame therefore depends on the competition between this speed, the collector cross section and the production of burnt gases. Unbalance in these parameters can lead to self-extinction.

The inside surface of the collector – a PVC pipe in the experimental facility – warped on the occasion of a temporarily stationary fire. This incident resulted in the complete sealing of the duct and the outage of the whole drainage system, which can hardly be repaired. Obviously such a material must be avoided, even as a lost formwork.

b) Explosion

This phenomenon is expressed by a deflagration along the collector. It supposes that explosible conditions first grow up, as those generated by the presence before the ignition of a gasoline runnel at the collector bottom. The demonstrated propagation speeds are higher than in the previous case and reach several metres per second (figure 8).

Although the explosion regime never exceeded that of deflagration, the collector is an element in which the flame front speed is likely to speed up, not at the scale of a collector section but rather at the scale of a complete facility. This risk remains at the state of assumptions, but it shows that it is wishable to break the continuity of this duct on the total length of the system.

5. Analysis of the risks raised by the collecting system

The previous experimental results allowed a comprehensive analysis of risks that may raise in the investigated facility, for all assumable scenarios. It appears from this assessment that a very high safety level is brought in case of accidental spillage of an inflammable liquid:

- The vertical slot gutter allows the very quick removal of the hydrocarbon sheet and therefore reduces the potential fire to a gutter fire, often little violent and which – in addition – does not produce much smoke.
- Very quickly, maximum after several tens metres, the hydrocarbon flow, burning or not, reaches the siphon. In presence of a hydraulic isolation the siphon proves to be an essential safety factor by stopping the possible flame, also by isolating the flow from the tunnel environment, as the hydrocarbon pursues its way in the collector. In some cases a little violent fire characterized by a low combustion speed may settle down in the upstream part of the siphon. Its effects remain small during several hours and extinction with foam is easy.

The study of risks also considered the dysfunction situations of the system, such as partially damaged siphon covers, or the absence of hydraulic isolation. Most of time the effects are limited in their gravity. The most severe scenario occurs in case of hydrocarbon and inflammable vapours associated in the collector. The starting and propagation of an explosion in this part of the facility can lead to projected covers and flames coming out. These effects will then regard the immediate environment of the siphons, and their gravity will depend on the collector length affected by the explosion development.

Such dysfunctions must be prevented by adapted supervision and maintenance, in order not to affect the safety potential provided by the system.

6. Conclusion

The experimental results summarized above are closely related to the geometry peculiar to the tested system, and extrapolating them to other layouts requires a lot of precautions.

Reflections are still necessary for drawing maximal advantage from the experimentation and optimizing the drainage systems. Among the items to be examined, one can mention the design of siphons in order to reduce their volume (nearly 2 m³ at present) without altering their qualities, their installation so that they can "break" the way of a possible explosion in the collector, the minimal inside diameter for the slot gutters, the design of vertically opened slots consistent with low sidewalk edges, etc.

This work is in process and will result in guidelines to be applied to French tunnels. It already becomes obvious that these guidelines lead to generalize the use of slot gutters and siphons for all tunnels of a certain length permitted to the transport of dangerous substances. A special care must be brought to the maintenance of these systems, which have an essential role in case of severe accident.

Summary

Tests in six road tunnels have permitted to compare the hydraulic efficiency of several systems planned to drain possible burning liquids spilled on the pavement after an accident. Moreover an experimental, full size facility of 50 m in length including slot gutters, gully holes with siphons and a collector has been subjected to twenty-five fire and explosion tests. Lessons are drawn on the interest and safety of such a system.

Kurzfassungen / Abstracts / Résumés

Versuche im Maßstab 1 : 1 mit Ableitsystemen für brennende Flüssigkeiten in Straßentunneln

Eine zunehmende Zahl von französischen Strassentunneln genehmigen den Transit von gefährlichen Gütern. Diese betreffen hauptsächlich flüssige Kohlenwasserstoffe in Tanklastwagen. Im Fall eines Unfalles mit Leckage muss unbedingt das Abwassersystem die rasche Ableitung dieser Flüssigkeiten erlauben, um die Entwicklung eines möglichen Feuers zu vermindern und seine Ausbreitung zu vermeiden.

Verschiedene Ableitungssysteme wurden seit mehreren Jahren in Frankreich in neueren Strassentunneln installiert und untersucht: Sie sind entweder klassische Wasserrinnen den Gehweg entlang mit Sinkkästen in geringem Abstand, oder kontinuierliche Schlitzrinnen, die von den Sammlern durch Siphons getrennt sind, um die Übertragung von Bränden zu verhindern. Bevor solche Systeme zu verallgemeinern sind, schien es notwendig, die Wirksamkeit jeder Lösung experimentell zu vergleichen und die Feuer- und Explosionsrisiken, die von der Einrichtung ausgehen konnten, zu analysieren.

Eine erste Versuchsreihe betraf die hydraulische Wirksamkeit der Sammlungssysteme. In sechs betriebenen Strassentunneln wurden Versuche mit einer kontinuierlichen Strömung von reduzierter Leistung (20 bis 30 l/s) und raschen Freigaben von 5 und 10 m³ durchgeführt. Wasser wurde verwendet, um den gefährlichen Stoff zu simulieren.

Ein zweiter Versuchstyp betraf eine experimentelle, mehr als 50 m lange Einrichtung in natürlicher Grösse, die mit einer kontinuierlichen Schlitzrinne, Sinkkasten und einem Sammler versehen wurde. Bleifreier Superkraftstoff wurde verwendet, um die verschiedenen Feuer- und Explosions-Ausbreitungsphänomene in der Einrichtung zu analysieren. Zahlreiche Versuche wurden durchgeführt, u.a. auch unter Bedingungen, für welche das Ableitungssystem fehlerhaft war. Die Ergebnisse wurden verwendet, um die Risiken der Einrichtung zu analysieren, und daher die Betrachtung aller möglichen Betriebsfälle des Ableitungssystems zu erlauben.

Der Vortrag stellt die Resultate dieser Untersuchungen vor und die Schlußfolgerungen, die für Tunnelprojekte über die Rinnengestaltung, die Knienutzbarkeit und -gestaltung, die Sammler, Einrichtungsunterhaltung, usw. gezogen werden können.

Full Size Testing of Drainage Systems for Burning Liquids in Road Tunnels

The transit of dangerous goods is permitted in an increasing number of French road tunnels. Most of these substances are liquid hydrocarbons in bulk. In case of spillage, the drainage system must discharge these liquids very quickly, in order to reduce the severity of a possible fire and prevent its propagation.

This is the reason why various drainage systems have been studied for several years and applied in recently built tunnels in France: they are either conventional water gutters along the sidewalk, provided with gully holes at short intervals, or continuous slot gullies separated from the collectors by siphons aimed at extinguishing the burning liquids. Before generalizing such systems it appeared necessary to make an experimental comparison of the efficiency of the various solutions and to examine the fire and explosion risks that may be generated by the facility.

A first testing programme concerned the hydraulic efficiency of the drainage systems. In six road tunnels under operation, tests have been performed with a continuous limited flow (from 20 to 30 l/s) and a sudden release of 5 and 10 m^3. Water was used to simulate the dangerous goods.

A second series of tests was conducted on an experimental full size facility exceeding 50 m in length, provided with a continuous slot gully, gully holes with siphons and collector. Unleaded super fuel was used to study the various phenomena of fire propagation and explosion risk in the facility. Numerous situations were tested, including malfunctioning of the drainage system. The gathered data have been used to analyze the risks of the facility, allowing the consideration of all possible scenarios for operating of the drainage system.

The paper presents the results of all these studies and draws conclusions for tunnel projects, regarding the design of gullies, the usefulness and design of siphons, the collectors, the maintenance of the facility, etc.

Essais en vraie grandeur de systemes de recueil des liquides enflammés en tunnel routier

Un nombre croissant de tunnels routiers français est autorisé au passage des matières dangereuses. Celles-ci sont majoritairement constituées d'hydrocarbures liquides en citerne. En cas de déversement accidentel, il est indispensable que la système d'assainissement puisse évacuer très rapidement ces liquides, afin de réduire l'importance d'un éventuel incendie et d'éviter sa propagation.

C'est pourquoi depuis plusieurs années différents systèmes d'évacuation ont été étudiées et mis en oeuvre dans les tunnels récents en France : il s'agit soit de fils d'eau classiques en bordure de trottoir, comportant des regards avaloirs à intervalles rapprochés, soit de caniveaux à fente continue, séparés des collecteurs par des siphons destinés à éteindre les matières enflammées. Avant de généraliser de tels systèmes, il a paru nécessaire de comparer expérimentalement l'efficacité de chaque solution et d'examiner les risques d'incendie et d'explosion que l'installation pouvait engendrer.

Une première campagne d'essais a concerné l'efficacité hydraulique des systèmes de recueil. Dans six tunnels routiers en exploitation, des essais ont été réalisés avec un écoulement continu de débit limité (de 20 à 30 l/s), et avec des relâchements brutaux de 5 et 10 m^3. De l'eau a été utilisée pour simuler la matière dangereuse.

Un deuxième type d'essais a été réalisé sur une installation expérimentale en vraie grandeur de plus de 50 m de longueur, comportant caniveau à fente continue, regards munis de siphons et collecteur. C'est du supercarburant sans plomb qui a été utilisé pour examiner les différents phénomènes de propagation d'incendie et de risque d'explosion dans l'installation. De nombreuses situations ont été testées, y compris des conditions où le système d'évacuation présentait des défauts. Les données ainsi obtenues ont été utilisées pour faire une analyse des risques de l'installation, permettant d'envisager tous les scénarios possibles de fonctionnement du système d'évacuation.

La communication présente les résultats de l'ensemble de ces études et les enseignements qu'on peut en tirer pour les projets de tunnels quant à la conception des caniveaux, l'utilité et la conception des siphons, les collecteurs, l'entretien de l'installation etc.