Platform water and hazardous liquid drainage - The example of the Mont Cenis Base Tunnel

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ABSTRACT: Like for the other big railway tunnels under the Alps, the water drainage system of the Mont Cenis Base Tunnel provides 2 recovery systems: - one for the mountain waters considered clean; - one for the platform waters, whose potential hazardous liquids - from a possible leak on a wagon or lorry on a rolling highway train - require treatment before being returned to the river.
This paper will outline the story of the design of this very specific system.

KEYWORDS: Safety, hazardous liquids, design, project evolution

1. INTRODUCTION

After a brief presentation of the cross-border section of the new Lyon-Turin railway line, the paper will present the design evolution of the platform water and hazardous liquid drainage system.

Like for the other major railway tunnels under the Alps, the water drainage system of the Mont Cenis Base Tunnel provides 2 recovery systems:

- one for the mountain waters considered clean;

- one for the platform waters, whose potential hazardous liquids - from a possible leak on a wagon or lorry on a rolling highway train - require treatment before being returned to the river.

Since the preliminary project studies carried out in 2002 and through the validation of the preliminary safety file in 2018 by the EPSF with the consultation of the ANSF, the design of the platform water drainage system has undergone several changes, until the last one after the design-level studies.

This paper will outline:

- the various system dimensioning hypotheses depending on the fire management strategy;

- the technical choices regarding the siphon types and the opportunity of underground storage tanks and of a continuous water flow;

- the solutions chosen in the end.

2. THE NEW LYON-TURIN RAILWAY LINE

2.1 The Trans-European Network for Trains

The Mont Cenis Base Tunnel is a part of the New Lyon-Turin railway Line (NLTL). The NLTL is an integral part of the "Mediterranean Corridor" which is, in turn, part of the European project known as the TEN-T (Trans-European Transport Network).

The TEN-T is a new European policy designed to encourage the movement of people and goods via rail, the most environmentally friendly mode of transportation. The goal is to decrease the use of road transport, which contributes to pollution and to greenhouse gas emissions. Within this network, the new Turin-Lyon rail connection is located at the crossroads of two large European communication axes, between north and south and between east and west.

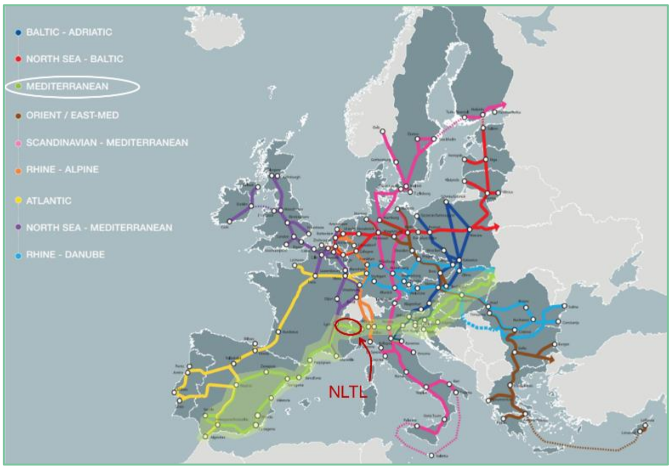

Figure 1 : TEN-T Networks

The New Lyon-Turin railway Line consists of three parts: the French part (under SNCF-Reseau management), the joint Italian-French part (international section) and the Italian part (under RFI management).

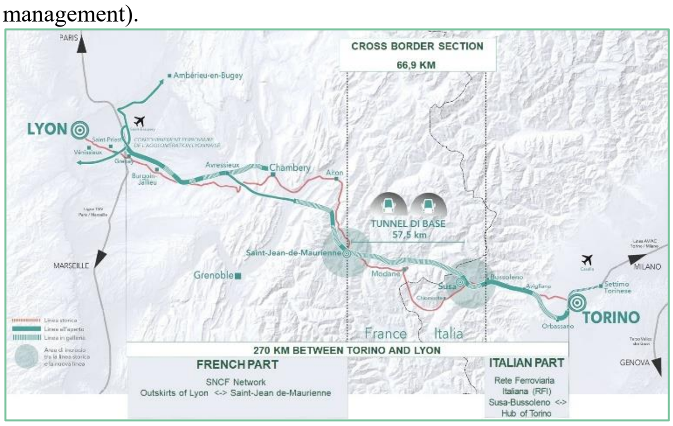

Figure 2: The New Lyon-Turin railway Line

2.2 The cross-border section

As shown in Figure 2, the international section includes the cross-border section that spans from St-Jean-de-Maurienne (France) to Susa/Bussoleno (Italy) and whose design/construction/management is under the responsibility of the Italian-French company TELT[1].
This section consists of:

[1] In accordance with Directive 2001/14/EC which provides for a specific infrastructure manager for the cross-border section, the "Public Sponsor" was officially created on 23/02/2015 and is called 'Tunnel Euralpin Lyon Turin (TELT) SAS

- an open-air area in St.-Jean-de-Maurienne (3.7 km) that includes the new passenger station of St.-Jean-de-Maurienne, the safety site and interconnection with the existing French line;
- the Montcenis base tunnel (57.5 km);
- an open-air area in the Susa Valley (2.7 km), which includes the new international passenger station and the Susa safety site;
- the interconnection tunnel (2.1 km) to the existing Bussoleno railway track;
- an open-air area for interconnection with the existing line in Bussoleno (0.9 km).

The cross-border section is therefore 66.9 km long in total and includes: 2 outside safety sites (Saint-Jean-de-Maurienne and Susa); 3 underground safety sites (La Praz, Modane and Clarea, accessible from the outside via access tunnels) and an additional tunnel for access to rescue services in Saint Martin la Porte. The two railway tunnels (base and interconnection) consist of two single-track tubes connected via bypasses built every 333 m (reduced to 50 m in the underground safety sites of the base tunnel). Along both tunnels, the cross-section of the current section consists of a service and evacuation walkway (no more than 1.20 m wide – from the side of the second tube), a rail traffic track, and a maintenance walkway on the outer side (see Figure 3).

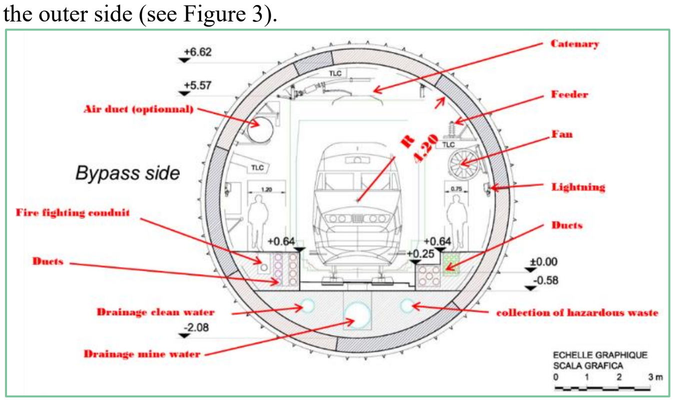

Figure 3 : Tunnel typological cross-section

In particular, the base tunnel has a lighting system and smoke extraction systems to be activated in the event of an accident, detectors, a liquid collection system and a fire protection network. The New Turin-Lyon Line will be a mixed passenger and freight traffic line designed with a nominal track speed of 250 km/h. The following train categories will be able to run on the line:

- High-speed passenger trains (HS): maximum operating speed 220 km/h on the Saint-Jean-de-Maurienne–Susa section
- High-profile Railway Trains (AFGG) and Modalohr Railway Trains (AFM): maximum operating speed 120 km/h
- Conventional freight trains (M), maximum length of each train 750 m. Maximum operating speed: 100 or 120 km/h depending on the category

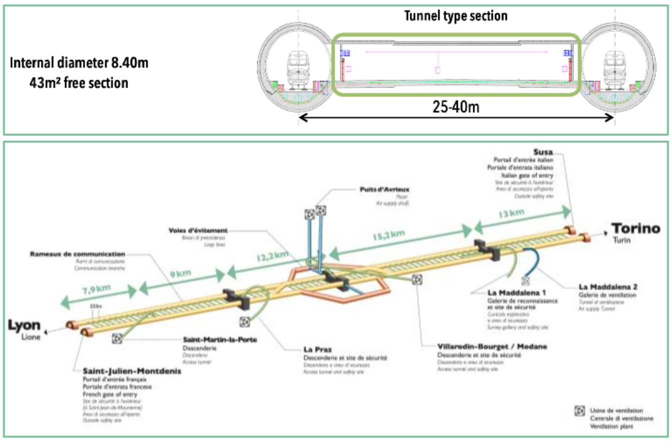

Figure 4 : 57.5 km Mont Cenis Base Tunnel diagram and main connected works

3. THE BODIES INVOLVED IN RAILWAY SAFETY

The Intergovernmental Committee, created from an Italian-French agreement of 15 January 1996, in particular, is in charge of approving the project and proposing to the two governments the specifications for the final works, the methods of construction and their financing as well as the conditions of operation.

To accomplish these tasks assigned by the aforementioned agreement, the Intergovernmental Committee has decided to set up a Safety Committee to assist it in the decisions concerning the technical safety of the work in the design, construction and management stages.

This Safety Committee, in fact, consists of experts in the following sectors:

- infrastructure safety and traffic in the railway sector,
- civil safety and rescue.

The National Safety Authorities for railways (NSA) of the two countries are also represented in the Safety Committee.

4. THE PLATFORM WATER AND HAZARDOUS LIQUID DRAINAGE SYSTEM

4.1 Changes to the design and regulatory context

The base tunnel has been the subject of various studies and validations since 1992. The system for collecting and draining platform water and hazardous materials has therefore also undergone design changes over time.

4.1.1 Preliminary design

At the preliminary design stage in 2002, the design involved a system for collecting platform water and hazardous liquids consisting of:

- A 2% transverse slope of the concrete track slab;
- A gutter on one side of the track;
- Drains every 50 m;
- Longitudinal fire break siphons alternating with the drains every 50 m;
- A concrete collector installed under the Ø 400 track.

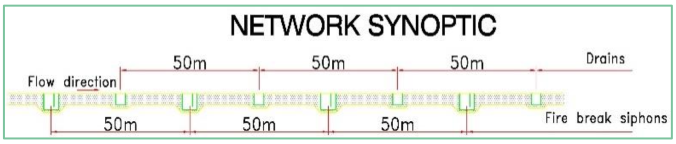

Figure 5: Schematic drawing of the platform water drainage network at the preliminary design stage (2002)

This definition of a hazardous material collection system meets the requirements of ITI 98-300[2]. It is also based on the design

[2] Interministerial Technical Instruction relating to safety in railway tunnels (no. 98-300) of 8 July 1998

which was validated in 2001 by the Franco-Italian Inter-Governmental Committee for the improvement of safety in the Fréjus road tunnel.

4.1.2 Changes leading to the Final Reference Project

The additional studies, carried out until validation by the Intergovernmental Committee in 2017 of the Final Reference Project (FRP), clarified the design of the hazardous materials collection system. Many other changes were also introduced, such as for example the number of and distance between safety sites in tunnels because updates to the Technical Specifications for Interoperability were issued by the European Commission.

Thus, at the FRP stage, the hazardous materials recovery system is based on:

- A 1% transverse slope of the concrete track slab;
- a longitudinal gutter on one side of the track;
- transverse gutters spaced 12m apart;
- longitudinal fire-break siphons spaced 48m apart;
- a variable diameter collector (between 500 and 710 mm depending on the slope) made of HDPE (High-Density Polyethylene).
- 42 x 120m^3 drain ways every 2500m along the length of the tunnel;
- drain ways downstream of the safety sites and at the portals with a minimum volume of 760m^3.

The transverse gutters spaced 12m apart serve to limit the surface area of a hydrocarbon puddle to 50m² in order to contain the power of a possible fire to approximately 100MW.

The drain ways that may be required to contain hazardous liquids mixed with fire extinguishing water are designed as follows:

- a coating of the drain way walls resistant to acidic or alkaline liquids and to mineral oils.
- an inlet fire valve;
- drain way access through explosion-proof doors;
- a tube for taking samples with the possibility of sending products to inert or quench the hazardous materials in the drain way;
- predispositions to be able to remove hazardous liquids using a mobile pump.

Moreover, the drain way volumes were adapted to the volume of liquid to be stored. Indeed, the flow rates for dimensioning the systems are different at the safety sites and in the standard sections. At the safety sites, as soon as the train has been evacuated, the procedures provide for the start-up of a fire attenuation system by sprinkling with a flow rate of 153 l/s, for 2 hours. To this flow is added the leakage flow rate of a wagon, estimated at 100 l/s. Once the fire-fighting teams arrive, they use nozzles with a total flow rate of 33 l/s.

In the standard sections, only the fire-fighters respond to extinguish the fire. Consequently, only the leakage rate of a wagon (100 l/s) is dimensioning for the networks.

Note that in 2018, the National Rail Safety Agencies validated the Preliminary Safety File relating to the Civil Engineering of the base tunnel. This decision, based on the design of the FRP, allowed the definitive base tunnel work to be initiated.

4.1.3 PRO design by the project managers - 2018

As part of the project studies (PRO), the project managers of the base tunnel on the French side proposed to make new changes to the design of the hazardous materials recovery and drainage system to simplify it, make it safer and more efficient.

The proposals, inspired by the solutions implemented in the Swiss Lötschberg and Gothard tunnels, were as follows:

- Increase the height of the plunging walls of the fire-break siphons - this increase limits siphon emptying due to the piston effect as the trains pass;
- Install transverse rather than longitudinal fire-break siphons;
- Implement a continuous flow of water in the collector - this flow of water allows permanent cleaning of the collector and ensures the correct filling level of the fire - break siphons;
- Eliminate the 42 intermediate drain ways - for the project managers, the intermediate drain ways constituted a hazard given the lack of ventilation and consequently the high risk of explosion in the event of an accumulation of explosive liquids. Moreover, drain way maintenance is a constraint vis-à-vis the operation.
- Keep the drain ways downstream of the safety sites because they can be more easily ventilated. They are easier to maintain because they are accessible from the safety sites and limit pollution of the platform water recovery network over a shorter length.

4.2 System continuity and homogeneity throughout the base tunnel

This proposal from the Project Management constitutes the last possible design change before the work is carried out. A complete overhaul of the system was carried out in 2019-2020 because the hazardous materials collection and drainage system is installed along the entire length of the tunnel.

The six operational base tunnel excavation sites (no. 3 to 8) in Figure 6 below are affected by the changes. Moreover, there is also a strong interface between the civil engineering works and the equipment works of the cross-border section (operational construction site 12).

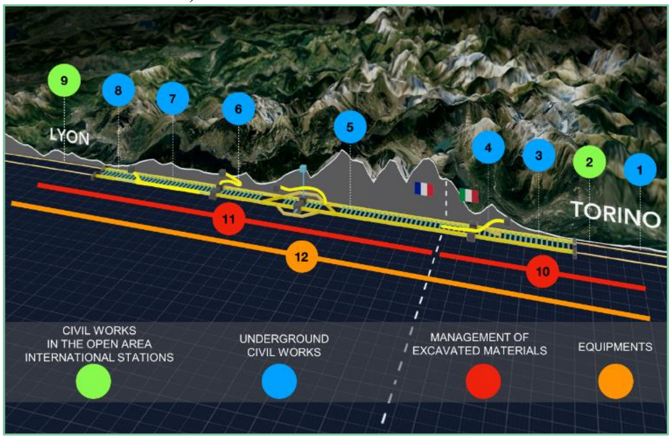

Figure 6: Operational construction sites of the Mont-Cenis base tunnel

At the same time, TELT presented these changes to the National Railway Safety Agencies because they constitute a "non-substantial" change of the Preliminary Civil Engineering Safety File. Thus, TELT had to provide an exhaustive file explaining the changes envisaged, specifying that they do not alter the level of safety of the structure, as it was validated in 2018. The National Rail Safety Agencies validated this change in November 2020.

4.3 Final design and special points of interest

4.3.1 Continuous flow supply

The origin of the continuous flow is in the Villarodin/Bourget-Modane access adit. More precisely, the water will be taken from a reservoir which collects the infiltration water from the access adit, which to date is pumped out. A dedicated pipe, equipped with valves and flow meters, will allow water to be conveyed from the niche (altitude 870m) to the high point of the tunnel (altitude 747m) ensuring a continuous flow of 5 litres per second in each of the 4 collectors (2 towards France: even and odd tubes; 2 towards Italy: even and odd tubes).

This pump-free system will be relatively robust since little equipment is required for flow regulation.

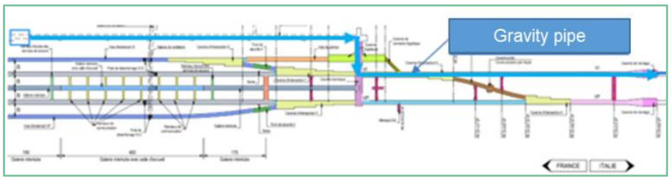

Figure 7: Continuous flow gravity pipe routing

4.3.2 The transverse siphon manholes

The geometry of the siphon manholes has been optimised in order to make them as compact as possible and to limit the impact on the civil engineering of the base tunnel. Indeed, the geometry of the manholes is adapted according to the space available in terms of the tunnel excavation methods.

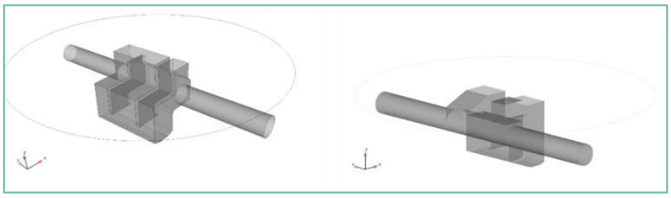

Figure 8: 3D view of the geometry of the siphon manholes (on the left the longitudinal siphon, on the right the transverse siphon)

Furthermore, a Computational Fluid Dynamics (CFD) analysis of the effect of the pressure wave generated by a train passing on the water level in the transverse siphon manhole showed that the maximum pressure is captured by the compressibility of the water.

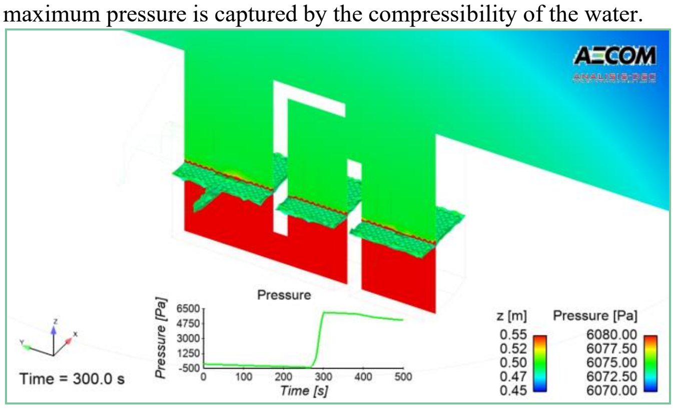

Figure 9: CFD analysis of the piston effect of trains on water height in the siphon manhole

4.3.3 Drain ways

The number of drain ways is now 6 in the base tunnel, plus the two reservoirs on either side of the base tunnel. Thus, downstream from each of the 3 safety sites, there is a drain way for each tube of the base tunnel.

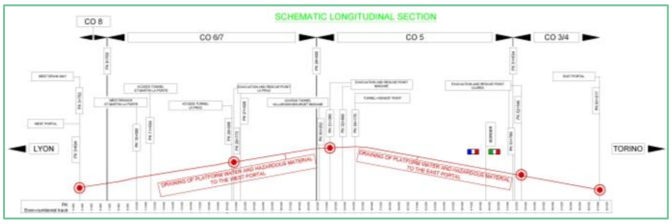

Figure 10: Diagram of the hazardous materials drainage system

The implementation of continuous water flow in the hazardous materials collector leads to a slight increase in the volume of the drain ways downstream from the safety sites. For example, the drain way at the La Praz safety site increases from 760m3 to 868m3 as it must now be able to store hazardous liquids, extinguishing water and all the water from the flow in the collector between the top point of the tunnel and the drain way.

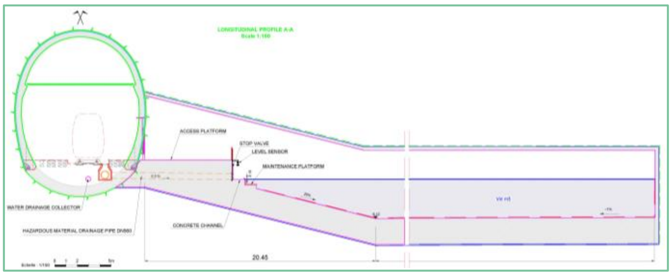

Figure 11: Cross-section of a drain way

The storage of liquids and hazardous materials in drain ways in the event of spillage or fire relies on a series of sensors and valves. In normal operation, the continuous flow enters the drain way, then emerges from it. If the system detects a sudden increase in flow or a hazardous gas or liquid, a valve closes and allows storage in the drain way.

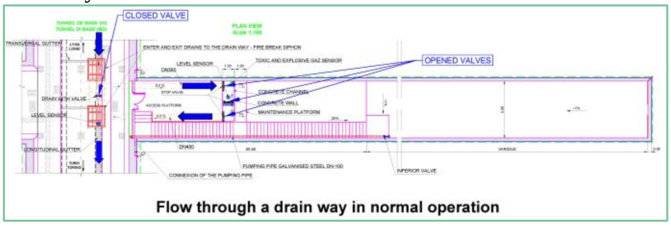

Figure 12: Diagrammatic representation of flow through the drain ways in normal operation

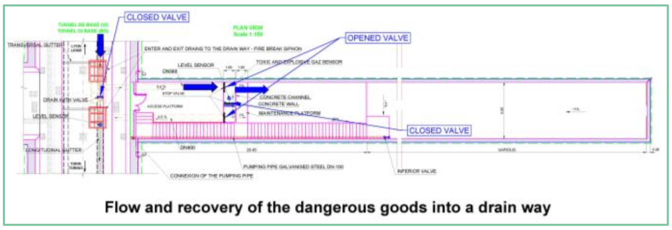

Figure 13: Diagrammatic representation of flow through the drain ways in case of detection of dangerous goods

4.3.4 A strong interface with equipment work

The division between the operational base tunnel construction sites leads to a number of interfaces between the various Civil Engineering lots, but there is also a strong interface with operational site no. 12 " Installations and technical buildings" (CO12).

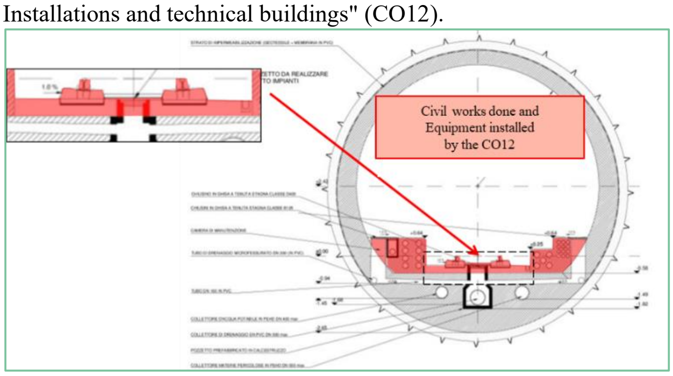

Figure 14: Work covered by CO12

Indeed, the base tunnel track slab and the hazardous materials drainage system are interfaced at the transverse and longitudinal gutters and at each siphon manhole. Moreover, the continuous flow control, toxic gas detection and drain way equipment will be installed by lot CO12.

All of these interfaces will require increased vigilance throughout the work.

5. CONCLUSION

As regulatory developments and design changes have occurred, the platform water and hazardous materials recovery system has been clarified based on devices already tested in other long and deep tunnels.

The design of this system, intimately linked to the safety management concepts of the Mont Cenis base tunnel, requires special attention in order to obtain an effective system in the event of an incident, guaranteeing robust operation and easy maintenance.

During the construction studies phase, it will be necessary to ensure the proper integration of the provisions provided by all operational civil engineering projects by ensuring that an optimal solution to interfaces, including equipment works, is possible.

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