Emergency management during the construction of Moncenis base tunnel. Safety concept, applications, and first experience on site.

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ABSTRACT: The paper describes the principles that guided the design of emergency management in the construction of the Mont Cenis base tunnel, the main work of the new Turin - Lyon line, Corridor 5 of the TEN-T network. The revision of the final design concluded in 2017 allowed to redefine the safety concept of the construction phase of the tunnel, which, with its length of more than 56 km, represents the longest railway tunnel under construction. The access conditions, overburdens higher than 2000m and long distances between the excavation faces favored scenarios where self-rescue with workers staying in safe places is the optimal choice for emergency management and the recovery of all people underground. In parallel, the strengths of the emergency and rescue management system are the new technologies for monitoring presence and plant operation, and the involvement of the public rescue services from the planning stages and their participation in on-site training sessions with direct knowledge of the workplaces with dedicated rescue vehicles and equipment. Finally, the first real cases of intervention allowed the system to be tested and action to be taken to improve its performance.

1 INTRODUCTION

The new line between Turin (Italy) and Lyon (France) is the central and key part of the East-West "Mediterranean Corridor", one of three major rail lines passing south of the Alps planned by the European Union.

The bi-national border crossing between Italy and France includes a 57.5 km, 8.70 m diameter single-way twin-tube base tunnel, the longest in the world under construction, which crosses the Alps at an elevation of approximately 600 m, roughly 45 km in France and 12.5 km in Italy (see figure 2). As of June 2024, 10 construction sites are active, 35 km of tunnels have been excavated of the 165 planned, and the workforce is over 2,500.

The Mont-Cenis base tunnel is a complete geological section of the Western Alps, which are crossed from west to east with an overburden of over 2,000 meters. The excavations will face complex challenges due to the geotechnical and hydrogeological conditions, the nature of the rocks and the conditions of access to the workplaces, kilometers away from the entrances and under extreme microclimatic conditions.

For these reasons, emergency management has been an important topic from the development of the reference project in 2017, to the composition of the tender dossiers between 2018 and 2022, and finally to the drafting of the emergency plans developed during construction.

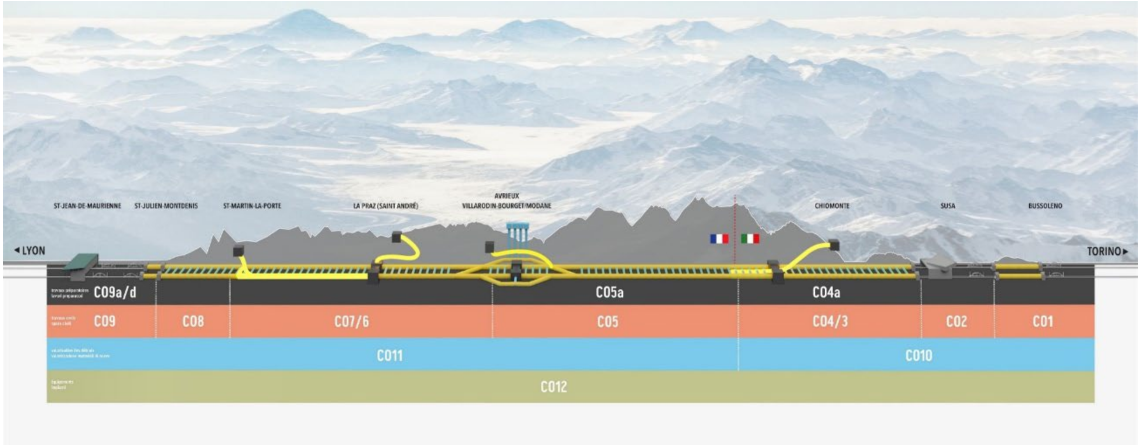

Figure 1. the base tunnel between France and Italy; in deep yellow the tunnels already completed by 2024.

2 EMERGENCY DESIGN

2.1 *Emergency design criteria*

The priority goal of correct emergency planning for underground scenarios is to allow that workers are able to exit safely from the tunnel and for this task, structural and technological choices of construction process and operation planning play a decisive role.

The major emergencies in workplaces underground consist of:

- events that prevent survival in the working environment; requiring total or partial underground evacuation, waiting for rescue in safe places or waiting for healthy conditions to leave the survival chambers;
- serious accidents requiring fast, advanced rescue of one or more persons, even on complex sites, far from the surface;
- possible combination of the first two points.

For the various scenarios of emergency, the designer must analyze the availability of the necessary escape routes to reach safe places within the same tunnel or other interconnected tunnels, if not directly to the surface. Similarly, safe access routes must be available for rescuers.

If the emergency is located at the front of the excavation, in some cases the use of the next safe room may not be the correct choice. It will therefore be necessary to leave the front more quickly and reach another safe place or the surface directly. For this reason, it is practical to have an equipped evacuation vehicle available at the front.

The scenario analyses can follow the indications of EU Regulation 1303/2014 (Commission Regulation (EU) No 1303/2014), which distinguishes between hot scenarios (fire, explosion, smoke or gas emission) and cold scenarios (collision between vehicles, etc.). These have to be analyzed following the time development of the construction site. Project and construction planning are therefore the first weapon for dealing with emergencies below ground.

2.2 *Safety concept*

When designing an emergency system in a complex underground, it is good practice to draw on the experience of the mining industry, which handles similar, if not more difficult scenarios.

The basis of any scenario must be that, under no circumstances, should rescuers endanger their own safety even if unfortunately, it is recognize this condition cannot be guaranteed. Therefore, the access route for search and rescue operations, aimed at reaching safe havens, must also be planned.

The following two actions are therefore to be developed:

<u>Self-rescue</u> - Today's complex construction sites rarely allow personnel to go outdoors immediately during an emergency. Rather than face long transfers, it is preferable to gather people in

well-equipped safe places, which allow for safe conditions while the system is restored, and they can be picked up by rescuers.

Search and Rescue - Outside rescuers must be able to access the underground without jeopardizing their own safety and have the means to find their way around, reaching shelters and collecting waiting personnel. It is essential to know the number and location of people underground with the utmost precision. Exercises carried out in conjunction with the local rescue services are essential.

2.3 *Design and construction management*

On the French side, the obligatory collaboration with the labor inspection and public rescue services made it possible to draw up a very advanced project on the needs of emergency management. Parts of the underground, work stages and the equipment and management systems were analyzed and sometimes modified.

In the tender phase, TELT asked the participants to detail the specifications in the tender dossiers, also supplementing them with their own improvement proposals. These parts of the bid were evaluated and given weight in the award phase.

2.3.1 *The agreement SDIS / TELT*

TELT's general management had to take account of emergencies from the first phases of design stage. The development of this approach began upstream: TELT and SDIS73 had been working together to develop an emergency management strategy (Design Emergency Management Unit / CGU in French)).

To guarantee this approach, an agreement was drawn up in 2017 for the SMP4 site. This initial agreement was repeated, and a new agreement was signed in 2021 for all TELT sites. The features of the Design Emergency Management Unit come from the AFTES recommendation of WG12, and the 'COMMON OPERATING RULES' of 02 May 2017, the bi-national health and safety regulations of the project.

2.3.2 *Tender Requirements*

The characteristics of the emergency management system was included in the contract requirements, which mention Emergency Management Unit, frequency of meetings and periodic verification visits. The unit is formed by the contractor, the construction management and the safety coordinator.

The main topics referred to in the contractual documents concern: Emergency Management Unit Conception; Operational emergency management unit; Emergency plan; Visits and exercises with external emergency services; Tunnel access control; Fire prevention; Vehicles and machinery with internal combustion engines; Battery-powered vehicles; Fire detection; Warning and evacuation / confinement of personnel; Survival shelters; Fire-fighting equipment; Staff training; Integrated emergency team; Specific resources dedicated to the fire and rescue services; Command post; Fire brigade communication system; Emergency vehicles; Specific measures and means concerning accidents in the workplace.

2.3.3 *The Emergency Management Unit (CGU)*

The Emergency Management Unit was activated during the project design and development phase in application of the AFTES GT12 recommendation. After the award of tenders, the Emergency Management Unit is made up of the contractor, the project manager, the safety coordinator, the project owner and the institutional bodies (Inspection du Travail and Firefighting and Rescue Service). The unit meets on average every three months, discussing the following topics: emergency organization and procedures; work and emergency equipment; prevention measures; exercise planning. In addition, SDIS carries out regular meeting directly with the contractor for adjustments about technical details or deeper reflections. Monthly are organized operational visits to sites to increase the knowledge of firefighters (crew members and officers)

3 MAIN SYSTEM ELEMENTS

3.1 *Underground design and construction phases*

The design of the work and the study of the construction phases were conducted in coordination with safety requirements with the objective of minimizing the length of the blind faces. The subsequent advancement phases of the main fronts intersected with the construction of the bypasses between the two line tunnels. In this way, the main tunnels are interconnected, providing a rapid escape route in the event of an emergency in one of the two. In this configuration the main difficulty is to maintain aeraulic or physical separation between the two galleries during the changing phases of the construction site.

3.2 *Ventilation design and management*

The design and implementation of the ventilation systems followed the French technical standards that favor mixed extraction/ventilation systems. Ventilation system is designed to maintain good health condition (sanitary ventilation) : the issue is to be able to manage this sanitary ventilation for not increasing disorder in case of fire and if it's possible in different case it could bring opportunities to help if it's really well managed.

Figure 2. Ventilation ducts in Modane underground station

3.3 *Parameter monitoring and plant operation*

Each section under construction is equipped with an extensive system for monitoring environmental parameters (temperature, humidity, presence of gases and fumes) and plant operating parameters (air flow rate and speed, fan operation, lighting, extracted water flow rate, operation of continuous transport systems, presence and location of people and vehicles underground, video images). The data is collected and managed by a single centralised system that allows remote monitoring and control.

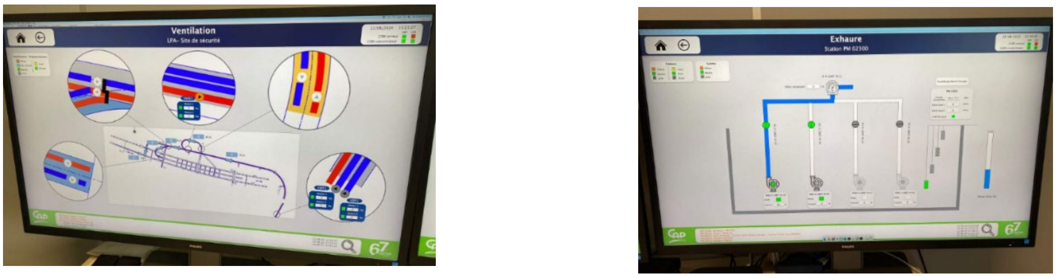

Figure 3. Screenshots from centralized monitoring system

3.4 *The crisis room*

The focal point of the Emergency Management System is the crisis room. At each entrance to the underground (4 in France and 1 in Italy) there is a room with up-to-date plans of the underground, a connection to the centralized data management system so that people's presence and location, and environmental conditions in the tunnel can be verified. In addition to this, portable radios and other emergency equipment. The room is the reference point for external emergency rescuers in the event of a major emergency and is manned by a member of the contractor's emergency team.

Figure 4. exercise in the crisis room.

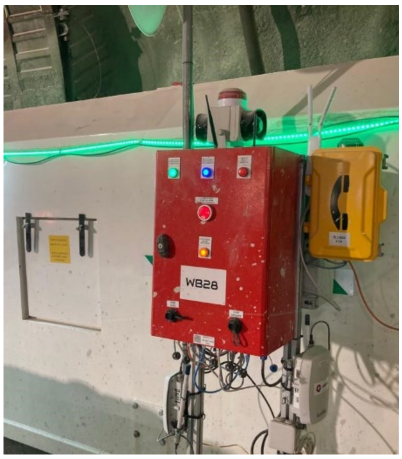

Figure 5. Monitoring and emergency station.

3.5 *Communications*

As already requested in the contract documents, each part of the tunnel must have two communication si-systems. The first is a system based on a wired connection in a protected location. The second connection is a radio system that must also be usable at every point in the tunnel. The radio system also operates on the rescue frequencies used by the SDIS in order to optimize communications in the event of an external intervention. In some areas and on the TBMs, connections to the WiFi network are also available, allowing the use of the cell-phone, which, however, does not replace the two previous systems.

3.6 *Access Control and Positioning*

In a complex underground, it is necessary to have an access control system that is able to count and locate people at the various sites. The more detailed the location of people, the more efficient the rescue interventions will be. The shelters must have their own access control system that allows, together with the communication system, knowledge of who has taken refuge inside them. The positioning of vehicles accessing the underground also allows for their monitoring, especially over long distances.

3.7 *Underground Safe Places*

Underground survival shelters are arranged to allow personnel to wait for rescue in a safe place. The shelters guarantee a survival time of at least 24 hours and are equipped with communication systems and autonomous power supply. They are positioned as close as possible to the excavation faces in D&B (approx. 200m); on the TBMs and every 1000m or so of tunnel in the sections already constructed. They comply the ITA-WG5 Report 14/2018 guidelines.

3.8 *Search and Rescue Vehicles*

Within the TELT - SDIS agreement, a budget was included for the purchase of special vehicles for Firefighting and Search and Rescue operations. The characteristics of these vehicles were provided by SDIS itself, as it is their personnel who use them. The vehicles can operate in low or no visibility thanks to infrared cameras; they provide a safe environment to accommodate people rescued from shelters and have the driver's cabs adapted to fire brigade equipment (self-breathing apparatus and masks).

Figure 6. Special Emergency Vehicle

3.9 *Formation, training and drills*

The training of the contractor's personnel is conducted together with SDIS personnel, who simultaneously become acquainted with the state of the plants and check the efficiency of the communication and fire-fighting systems. Three level of exercises are periodically realized:

- first level: internal exercise contractor with only an external observer (simulation of an emergency situation, real call to public fire and rescue services, internal first actions until time arriving fire and rescue service);
- second level: global simulation, idem first level but with intervention on site fire and rescue service for a simple emergency (example: one or two injuries underground in a traffic accident);

-third level: global simulation, idem second level, but for a complex emergency (exemple: underground fire).

Figure 7. Evacuation exercise

3.10 *Contractor Emergency Unit*

The contractor's emergency teams are defined as follows:

- The Prevention and Emergency Team: 3 members for any shift. They are in charge of checking safety installations. They lead ¼-hour safety sessions, and work with the Prevention Department to set up emergency drills. They therefore have a good knowledge of the site, current activities, the state of the premises and SDIS procedures. As a result, in the event of an emergency, they take over the duties of the posts in line with the emergency procedure;
- the Level 1 emergency contact. This person is in direct contact with the fire brigade, providing information about the emergency and helping to prepare the fire brigade's response.
- Level 2 emergency contact. This person has authority over the management of the facilities.

4 REAL EVENTS

4.1 *Forklift Fire in S. Martin La Porte*

On 19 May 2021 at 23:32, a Manitou forklift caught fire in the logistics branch of an underground construction site, near the TBM assembly cavern. The fire was extinguished by personnel with fire extinguishers by 00:34 on 20 May. The foreman initially experienced problems with the telephone line, but was later able to communicate the emergency via radio. The SDIS73 arrived in about 20 minutes, finding the fire already under control and securing the area. Two workers, slightly intoxicated by smoke, were discharged from the hospital after a few hours. The fire started in the electrical part below the dashboard of the forklift truck. The flames burnt all the electrical connections, part of the driver's seat and the cab lining, before being extinguished.

The analysis of the event revealed some elements that played in favour of its rapid resolution:

- The TELT - SDIS Convention paid off: the precise knowledge of the SDIS sub-terranean due to the numerous regular trainings with the GRPT per-mitted quick and effective access to the scene. (75% of the personnel on board the emergency vehicles had already been trained there);
- features and provision of the dual communication system (telephone and radio);
- ventilation duct decentralized to the fire;
- presence and training in the use of fire extinguishers;
- full accessibility of the site with emergency vehicles.

4.2 *Tunnel Accident Rescue*

Several hundred people worked together in those different big sites so the probability of minor or serious accident is important; for example in 2024, about two times per week, external rescue service is solicited: for each of them, even the accident is not important, a feedback is realized in the issue to confirm or adapt procedure.

5 CONCLUSION

The strategic choices made during the design phase were decisive in achieving the best infrastructural conditions for rescue and emergency management. Together with this, the strong points that ensured its functioning were the desire to introduce evaluation criteria for contractors on emergency response already in the tender phases, the cooperation agreements with the public rescue service SDIS73 and the dynamic site management through emergency management committees. In this type of long and deep tunnels, the main problem is fire. So, it's necessary a close collaboration of public and private stakeholders before calls for tenders and a permanent monitoring of the progress of the construction sites. Fire and rescue services need probably a bit of luck to manage a serious emergency, but it's sure that without good preparedness the result may be a disaster.

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