



MONT SION TUNNEL

1. Organisations involved

CARSAT Rhône-Alpes (Regional health insurance Fund)

Bouygues Construction

2. Description of the case

2.1. Introduction

On a construction site, and in particular a subterranean construction site, risk is ever present and comes in many forms. Fire, of course, can have particularly grave consequences in an enclosed space. The danger might also be mechanical, such as caves-in, falling bricks, crushing by machinery or the use of explosives, etc.

The risk might equally be chemical in nature, with noxious gas, such as vehicular exhaust, being potentially present, or radon emitted by granitic rock or firedamp. Indeed, dust particles are able to cause serious respiratory conditions such as silicosis. It may be that the symptoms of this insidious condition do not manifest until twenty or thirty years post-exposure.

2.2. Aims

The CARSAT (a social-security organism with regional competencies, hereinafter 'the CARSAT') of the Rhône-Alpes region was commissioned in advance of the plan to build the tunnel at Mont Sion on the A41 nord motorway, linking Annecy to Geneva. The originality of this project is that Bouygues Construction, in charge of drilling the tunnel, was involved in the designing of the tunnel boring machine (TBM) that would be used on site.

As such, the CARSAT was also able to provide, from the moment of this machine's conception, advice on improvements that might be made to ventilation in order to minimise risks related to dust inhalation. Bouygues construction and the TBM constructor were able to, subsequently, work with this in mind.

The CARSAT was also mindful to promote a general occupational risk prevention agenda, a key priority. The objectives of this agenda are numerous. It was important to profit from experience gained with this TBM as it could be of good use on other similar construction sites, such as the planned tunnel between Lyon and Turin.

Bouygues construction, who had won the tender, was already committed to safety on tunnel construction sites and its teams have worked closely with the CARSAT, respecting its agenda.

2.3. What was done, and how?

The Mont Sion tunnel comprises two tunnels, each 3100m in length, bored with an open type TBM. This machine, built in Germany by Herrenknecht, is the biggest actually in service in France, being 12m in diameter, 180m long and weighing 2 200 metric tonnes. Prior to its installation onsite and the start of the boring, considerable preparation was necessary.

Generally speaking, subterranean works present the same risks as surface works but with exacerbating factors, most notably those associated with confinement in a small space.

They also give rise to context-specific risks such as subsidence, cave-ins and falling material. The nature and the integrity of the terrain are of central importance in the organisation of a construction

site.

Principal risks include:

- Fires in construction equipment
- Ventilation
- The presence of large volumes of water – whether permeating through rock or sprayed in order to reduce levels of dust in the air – may create a serious impediment to the organisation of work by destabilising the terrain and increasing the risk of slipping or tripping over
- Lighting, which must be adapted to each work station
- Biological hazards due to the presence of animals or mould
- Noise,
- Co-ordination of workers from different fields and communication problems between workers of different nationalities

All of the foregoing risks have been taken into consideration by Bouygues Construction, with the help of the CARSAT.

Conception and construction of the tunnel boring machine

Regarding the conception of the TBM, Bouygues construction was mobilised well in advance, even before the signature of the tender, to put safety and ergonomical considerations to the fore for its construction. It consisted in meeting the standards set by French legislation which can sometimes be different to the legislation in force in Germany, and involved including the safety and ergonomical considerations regarding the TBM in the contract signed between Bouygues and the TBM constructor.

This was done because in such situations, the engineers sometimes tended to focus primarily on the result to be achieved, on the aptitude of the system to achieve the desired performance, ergonomics and safety being relegated to a second rung consideration. The upshot is that it is the men on the ground who have to adapt to work posts which are often badly designed. By looking at the project from a different angle, Bouygues has taken this into account by organising the machinery around ergonomical and safety considerations.

To be able to do that, Bouygues asked the machine operators how they work. Indeed, it was insufficient merely to give guidance for it to be followed. It has to be possible to follow that guidance given the working environment, the desired results and, simply put, human nature.

Then, the production, equipment, and ‘quality, environment, security’ teams worked for a year with Herrenknecht to guide its work, and to orient it towards risk prevention, in applying, for example, the ‘Fifth avenue concept’ whereas with conventional tunnelling equipment, the workmen are obliged to keep up with the progress of the work, in narrow and uncomfortable pathways, this time the tunnel boring machine involves a wide central alley, going from one end of the TBM to the other, with easy access to equipment scattered in various locations. In addition, virtually all ladders were replaced by steps.

Even the positioning of the toilets was thought through so as to minimise unnecessary displacement. Considerable effort was put into the most awkward work stations, notably that of the erector operator who fits the voussoirs (wedge shaped elements that form the tubing of the tunnel). It took several months to come up with a platform allowing the operator and his assistant to work with growing efficiency and precision.

Concerning risks of a chemical nature (dust particles and gas), the Bouygues team put in practice advice and knowledge received from the CARSAT on recommendation R352 concerning ventilation for subterranean excavations. From October 2005, twelve months before its activation, the conception of the TBM’s ventilation and dust extraction systems was tested by the CARSAT’s



laboratory.

In July 2006, the CARSAT went to Germany. This allowed it to fine-tune its prevention work and to bolster its collaboration with Bouygues construction and Herrenknecht prior to the onsite installation of the TBM.

Inter-service collaboration

The overall prevention plan promoted by the CARSAT Rhône-Alpes involved different aspects, in particular analyses of the ergonomical considerations applied by Bouygues construction to the tunnelling machinery (including analysing projected and realised objectives), work meetings with Bouygues, analyses of conformity with the EU 'Machines' Directive, onsite intervention to take dust, diesel-particle and analysis of the results.

The various service branches of the CARSAT also had to collaborate internally: the construction service, the research and development service and the laboratory. Considerable progress was made on dust capture: the 'spoil' (the materials that are extracted from the earth by the tunnelling machine's cutting wheel) is humidified in the extraction chamber. From the moment of escape, to the loading point on the transport belt, residual dust particles are caught and extracted towards repellent filters which are immune to clogging.

Start of the drilling

Assembled at its starting point at the end of the summer in 2006, the TBM was thus able to start work, reaching a rhythm of up to 40m per day within a few weeks. The TBM digs into the earth, removes spoil and puts in place the concrete that makes up the tubing of the tunnel (the 'voussoirs'). First, the cutting wheel extracts the waste earth while a metal shield temporarily supports the structure. This spoil is taken from the extraction chamber to the exterior by a conveyor belt. Behind the shield an 'erector' puts in place the 'voussoirs' (of which there are 18 000 in the two tunnels at Mont Sion, each weighing 15.5 tonnes) which are transported into place by specialised equipment. As they are put in place, the TBM levers itself onto the 'voussoirs' with jacks capable of exerting a total pressure of several thousand tonnes, thus allowing the cutting head to progress. The whole machine, including the shield, cutting wheel and erector, tows an assembly of equipment that is necessary for it to operate: power units, 'voussoir' unloaders, filtration units, control equipment, even workshop space – as such, it's truly a mobile factory that is responsible for constructing the tunnel, advancing with it.

As with all heavy construction sites, each member of personnel in the tunnel under construction received individual protection equipment: a helmet, protective boots, ear-protection, a reflective jacket. Moreover, no visitors were allowed into the tunnel without undergoing a thirty minute safety briefing which included instruction in the use of a breathing mask to facilitate an immediate evacuation of the site in the event of fire. Another precaution was that all who entered had to leave their ID tag on the board at the entrance of the tunnel, taking it back upon exit. As such, the number of persons in the tunnel, and their identity, were known at all times.

After eight months, at the start of June 2007, the TBM reached the other side, completing the first tunnel, and was replaced at its starting point to begin work on the second. The second tunnel was completed in March of 2008.

2.4. What was achieved?

The project was assessed positively and employees were largely satisfied with their working conditions.

Moreover, the risk-prevention built into the TBM also led to a gain in productivity, most notably because of better working conditions. An important aspect of this was the defining of workstations and maintenance stations.

The main risk factors – ventilation and noise – were properly taken into account, and certain improvements were made during the course of the construction work.



The CARSAT also wished to generalize this approach to prevention in the construction of tunnels (very active in the region) by creating a regional program of actions called "Tunnels" 2009-2012

Tunnels are becoming more and more complex: designed almost exclusively in two-tubes, they include security gates, equipment and underground facilities. It's more and more technical, with a multitude of risks. The CARSAT thus needs multiple skills, and to share knowledge and feedback. Through this regional program, which encourages meetings, the CARSAT capitalizes different skills: collaboration between its construction department and chemical department, but also with various actors of the Rhone-Alpes region.

With all these exchanges, the goal is not only to improve safety on construction sites but also to best take into account the protection worker's health.

2.5. Success factors

The collaboration between the different players (the CARSAT, constructor, TBM manufacturer and workers) was crucial for the success of the project, allowing to anticipate and combat potential risk at the stage where the TBM was conceived. Taking the views of those on the ground allowed for the reality of the job to be taken into account.

The success of the work also rests on the following considerations:

- ✧ At the design stage, the accessibility of workstations was a priority and allowed Bouygues to provide good working conditions, particularly with the 6th avenue, the main artery allowing access along the length of the tunnel. Staircases replaced ladders as the means of access to certain work zones.
- ✧ The period allowed for design work and manufacture of the TBM (July 2005 to July 2006) was appropriate; usually this period is around four months.
- ✧ The risk-prevention approach formed part of the contract with the manufacturer through an index of charges.
- ✧ The TBM should be considered not as a "hole-boring machine" but as a piece of construction equipment in its own.

2.6. Further information

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2.7. Transferability

This practice is transferable to other large machinery employed on heavy construction sites, and to other businesses.

Indeed, whichever company is charged with completing the works can, just as Bouygues has done, stipulate in its contract with the manufacturer of the machinery that the prevention of occupational risks are to be taken into account in the design of that machinery so that it is not the operator who has to adapt his behaviour to be able to work in safety.

This project was only a first step for Bouygues construction, who wishes to apply the same logic of



prevention and ergonomics to all of the business's activities.

3. References, resources:

[http://www.travail-et-securite.fr/ArchivesTS/archivests.nsf/\(allDocParRef\)/TS675page2_1/\\$File/TS675page2.pdf?OpenElement](http://www.travail-et-securite.fr/ArchivesTS/archivests.nsf/(allDocParRef)/TS675page2_1/$File/TS675page2.pdf?OpenElement)