Information Management and Time & Cost Control of Underground Projects; Lessons learned from the Transalpine Tunnels in Switzerland

The construction sites for the Lötschberg and Gotthard Base Tunnels are so complex they require decisions to be made constantly. During planning and building, these decisions are based on predictions, but in tunnel operation and maintenance they are based on the experience gained in the project, drawn in particular from the careful documentation of the construction work.

Matthias Neuenschwander, *Civil eng. ETHZ/SIA, Lombardi Engineering Ltd., CH-6648 Minusio*
Chief supervisor Engineering J.V. AlpTransit Gotthard Base Tunnel South

Benoît Stempfel, *Civil eng. ETHZ/SIA, PERSS Consulting engineers Ltd., CH-1709 Fribourg*
Main chief supervisor of the section Steg/Raron, AlpTransit Lötschberg Base Tunnel

Matteo Bianchi, *Civil eng. ETHZ/SIA, SISO Ltd., CH-6648 Minusio*
CEO

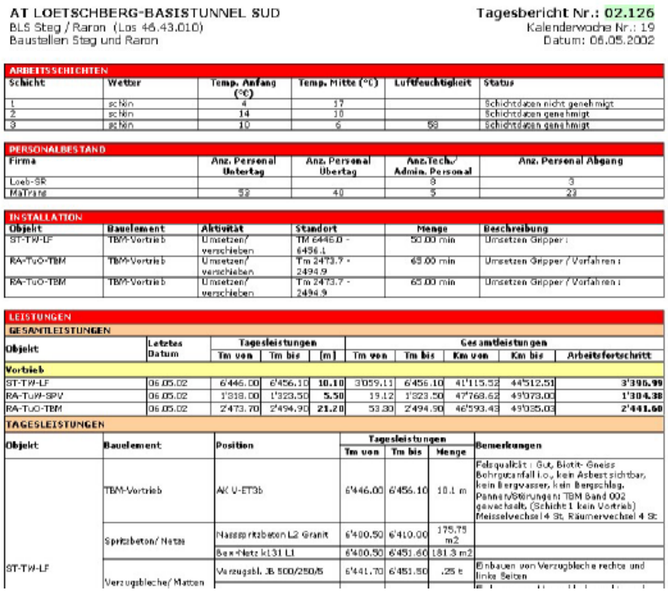
▲ Introduction

The control of costs, of deadlines and of quality, the data processing and the storage and sharing of information are all essential requirements in guaranteeing the control and management of any project. These activities require a large investment of time and money from all parties involved in a project. All data acquired must be available to the owner in due time, condensation and form: information is crucial to keep up project support at all stages and at all levels.

The complexity of an underground project depends on the number of component parts, on the number of stakeholders involved, on the financial planning, on the project management and on the project realization. The success of the project depends directly on the co-ordination and close collaboration which exists between all parties. The risk of changes increases with an increase in the number of parties involved or with an increase in the length of the project. Currently every party leaves at the end of a project with only a fraction of the total information generated.

While these points are true for the construction phase, they are even more so for the operation and maintenance phase, which will be at least ten times as long as the construction phase. It is extremely important to maintain all the original information and acquired experience from the construction stage.

Such requirements can only be guaranteed with the help



AT LOETSCHBERG-BASISTUNNEL SUD
BLS Steg / Raron (Los 46.43.010)
Baustellen Steg und Raron

Tagesbericht Nr.: 02.126
Kalenderwoche Nr.: 19
Datum: 06.05.2002

ARBEITSSCHICHTEN

Schicht	Wetter	Temp. Anfang (°C)	Temp. Mitte (°C)	Luftfeuchtigkeit	Status
1	schön	4	17		Schichtdaten nicht genehmigt
2	schön	14	10		Schichtdaten genehmigt
3	schön	10	6	59	Schichtdaten genehmigt

PERSONALBESTAND

Firma	Anz. Personal Untertag	Anz. Personal Übertag	Anz.Tech./ Admin. Personal	Anz. Personal Abgang
Loeb-SR			8	3
MaTrans	53	40	5	23

INSTALLATION

Objekt	Bauelement	Aktivität	Standort	Menge	Beschreibung
ST-TW-LF	TBM-Vortrieb	Umsetzen/ verschieben	TM 6446.0 - 6456.1	50.00 min	Umsetzen Gripper :
RA-TuO-TBM	TBM-Vortrieb	Umsetzen/ verschieben	Tm 2473.7 - 2494.9	65.00 min	Umsetzen Gripper / Vorfahren :
RA-TuO-TBM	TBM-Vortrieb	Umsetzen/ verschieben	Tm 2473.7 - 2494.9	65.00 min	Umsetzen Gripper / Vorfahren :

LEISTUNGEN

GESAMTLEISTUNGEN

Objekt	Letztes Datum	Tagesleistungen			Gesamtleistungen				
		Tm von	Tm bis	[m]	Tm von	Tm bis	Km von	Km bis	Arbeitsfortschritt
Vortrieb									
ST-TW-LF	06.05.02	6'446.00	6'456.10	**10.10**	3'059.11	6'456.10	41'115.52	44'512.51	**3'396.99**
RA-TuW-SPV	06.05.02	1'318.00	1'323.50	**5.50**	19.12	1'323.50	47'768.62	49'073.00	**1'304.38**
RA-TuO-TBM	06.05.02	2'473.70	2'494.90	**21.20**	53.30	2'494.90	46'593.43	49'035.03	**2'441.60**

TAGESLEISTUNGEN

Objekt	Bauelement	Position	Tagesleistungen			Bemerkungen
			Tm von	Tm bis	Menge	
ST-TW-LF	TBM-Vortrieb	AK U-ET3b	6'446.00	6'456.10	10.1 m	Felsqualität : Gut, Biotit- Gneiss Bohrgutanfall i.o., kein Asbest sichtbar, kein Bergwasser, kein Bergschlag. Pannen/Störungen: TBM Band 002 gewechselt. (Schicht 1 kein Vortrieb) Meisselwechsel 4 St, Räumerwechsel 4 St
	Spritzbeton/ Netze	Nassspritzbeton L2 Granit	6'400.50	6'410.00	175.75 m2	
		Bew-Netz k131 L1	6'400.50	6'451.60	181.3 m2	
	Verzugsbleche/ Matten	Verzugsbl. JB 500/250/5	6'441.70	6'451.50	.25 t	Einbauen von Verzugbleche rechts und links Seiten

Fig. 1: The daily report with all major activities from the previous day is sent every day to a predefined list of individuals.

of a computerized database which, during the entire construction phase, gathers and keeps track of all the project information, being the information exchange hub for all parties. This software has to be an analytical center for statistical requirements, for comparisons and correlations and especially has to provide a tool for decision making, for filing, and for the evaluation of cost forecasts and deadlines. This database has moreover to be totally integrated in the operation and maintenance database, so that the operator has direct access to all the information.

In the projects of the Alptransit Lötschberg and Gotthard Base Tunnels an innovative concept has been adopted by the owners BLS Alptransit Ltd. and Alptransit Gotthard Ltd., which opens a new dimension in the simultaneous treatment and sharing of information and offers a graphical database for the project, which in turn allows complete real-time control of costs, deadlines and quality.

This concept is based on the internet-supported platform '**SISO**' (Site Information Software), which is accessed daily by nearly 200 users and serves as the hub of construction site communication and controlling.

▲ What kind of documentation for what kind of decisions?

The contract for services between the owners and their contractors is the basis of project execution. This contract contains primarily the cost schedules, geological predictions, project plans, the technical requirements as well as the schedule of construction operations. Put simply, this contract requires among other features the comprehensive monitoring of construction to assure compliance with **deadlines, costs** and **quality**. It is therefore crucial that **all knowledge and all experience gained during construction be compiled and archived** from the outset.

In other words, the usual static data management at a construction site must be converted into a **dynamic compilation of data and information**. In the process, self-serving individualism must be eliminated in favour of a **collective and rational use of data**.

The only way to accomplish this task is with the help of a computerized database that collects data throughout the construction period. This database must represent the total knowledge gained in the project and serve as a communication and information platform for all stakeholders. The data being recorded cover mainly *the heading operation data, the geological data, the financial data from the contract of services, the monitoring and inspections, the performance data, the events, orders, and decisions, photos and diagrams,* as well as *the contractual documents*.

Of course, the data only have to be collected once and then processed so that they are available for any kind of reporting required. The factors that apply during construction become all the more important during the operation period, which lasts at least ten times as long as the construction phase.

▲ Heading and quantities

The first question asked every morning is: "How far along are we now?"

The question is easy to answer but the consequences can run the entire gamut: in the interest of dynamic data management, the project team must be disciplined about daily inputs. There are two indispensable prerequisites for meeting this goal:

- **Availability of a synthesis tool**;
- **Daily recording of the most important quantities (heading data)**

the various works. For instance, one can compare the average performances of the two parallel tubes or the contractual data with the actual progress made in heading operations.

The as-built drawings of mining and rock support are also generated automatically to the extent that all important contractual items in production at the construction site are recorded daily.

The data pertain primarily to *rock bolts, ring beams, wire mesh and shotcrete* for rock support. The project engineer also depends on this information to make decisions on adaptations while the tunnel is being driven.

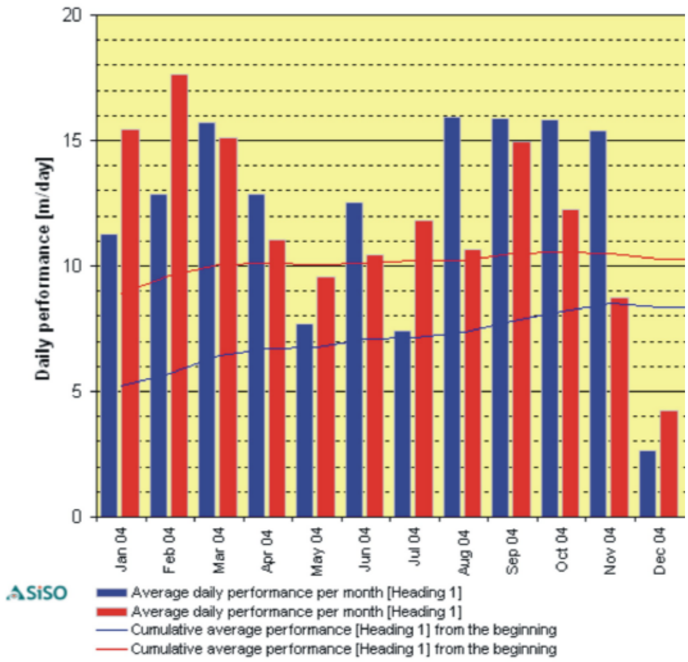


Fig. 2: Performance rate comparison between two parallel TBM headings.

This simple procedure triggers a whole range of automatic mechanisms:

- The database portal of the overall project management is updated with the latest information.
- A report on driving data is compiled.
- The construction costs and schedule are updated.
- Due time for construction and deadlines are each updated with the latest information.
- Average performances are calculated.
- The information is sent to a predefined list of individuals.

This flow of data, in turn, allows a large amount of production statistics to be generated for

▲ Site diary, QA/QC and reporting

The second question that is always asked is: "Why were the expected production rates not achieved in the heading operations?" The site diary allows these questions to be answered. In reports, it directly synthesizes the events and information for the given day or week.

The site diary is the **heart of the works documentation**. It allows all comments, documents and photos to be linked to the recorded data. It also allows all decisions and orders to be passed on promptly and task lists to be kept and monitored.

The quality assurance and quality control (QA/QC) procedures are part of the daily work saved in the database structure. With this information, the results of special studies, such as the sampling of a concrete section or the position for taking a drill core, can be found quickly based on date and location.

▲ Geology

All technical and contractual aspects of excavation work depend on the ground conditions. The essential geological information such as the rock and rock mass properties (petrography, structures, physical properties) and their effects on the structure (geotechnical and hydro-geological aspects) must be recorded in a non-redundant structure.

Comparison between prediction and reality is an important instrument for ongoing adaptation of costs and schedules. To understand the relationship between difficulties arising in heading operations and encountered geology, it is useful to record the main geological parameters systematically and to automatically generate **synthesis plans** that fully take into account the driving and machine parameters (e.g. TBM).

It is crucial to involve the geologist in this work so that the observations made can be correctly interpreted and then cloaked in geological terms. With this central recording and storage of data, the stakeholders can make more objective assessments.

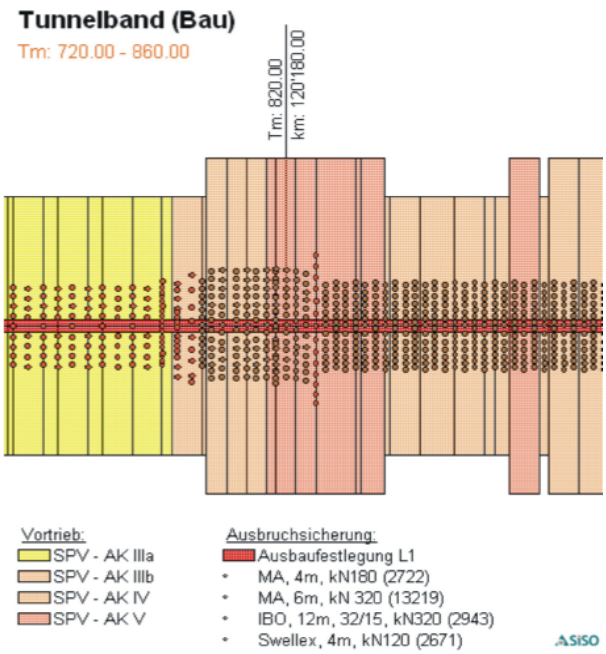


Fig. 3: The main quantities are graphically recorded in the as-built drawings.

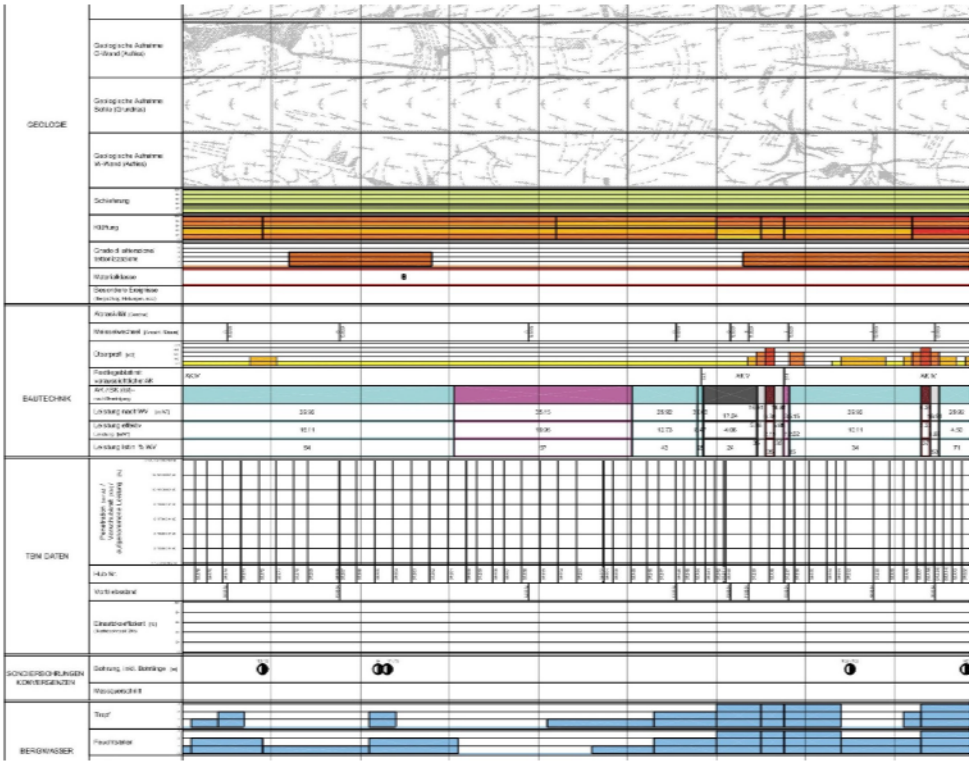


Fig. 4: The synthesis plans are a site management tool and part of tunnel final documentation.

If synthesis plans are generated and tracked on a regular basis and observations and drawings are analyzed, necessary interventions can be made more quickly and any contractual difficulties that may arise can be better estimated.

▲ Performance monitoring

The main indicator for understanding performances is the daily synthesis of the shift report or, to put it another way, the **time analysis of the individual work processes**.

With suitable statistical formulae in hand, the project team can evaluate heading operations for a given geological formation or a certain class of excavation on the basis of the following factors: time lost in breakdowns and interruptions, delays caused by difficulties that arise, maintenance times and the time required to carry out each work process. This evaluation, in turn, allows the project team to find solutions to technical and contractual issues.

Although the **parameters of tunnel boring machines (TBMs)** are also key indicators, they are unfortunately rarely used. The main reason is a lack of correlation with other information, especially the progress being made in advance work. **Juxtaposing a wide variety of data from various sources** allows the team to obtain a more objective picture of the difficulties encountered and often provides an answer to recurring anomalies in heading operations.

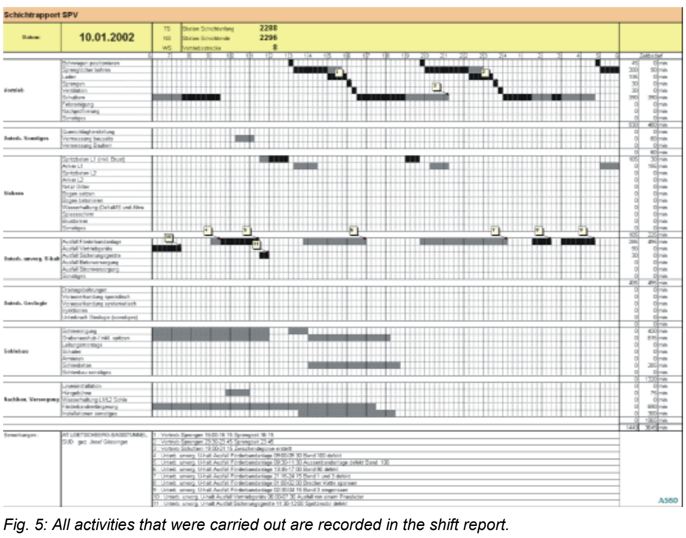


Fig. 5: All activities that were carried out are recorded in the shift report.

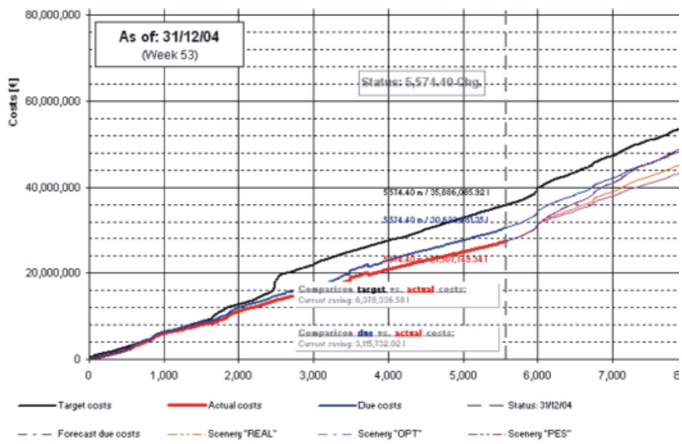


Fig. 6: Costs are monitored in real time throughout the construction period (final forecasts included).

▲ Cost and schedule controlling

The cost of a structure is the element most closely monitored in site management. To assure that everything is under control, the project team has to work with linear meter costs wherever possible. In other words, the main items in the contract for services must be expressible in tunnel meters to assure credible cost controls.

Cost credibility is achieved only through **a constantly updated comparison between target and actual costs.** Once an integrated structure is in place – as it is in this case –, the contract becomes a readable and interactive tool. Yet in construction work which is as important as that for the Lötschberg and Gotthard base tunnels, the number of parameters to monitor is daunting (mainly due to the large number of sites where advance work is underway and their interconnection). These parameters cannot be managed unless they are systematically processed.

With heading data recorded and entered daily, the updated costs are calculated automatically. They are then compared immediately and in real time with the contractual costs and deadlines (list of target construction time and the period relevant to billed construction time). The same is true for **the drawing up forecasts on final costs and final schedules in real time**. The resident engineers then have the necessary resources for detecting contractual divergences. Where necessary, they can clarify the details in order to determine the cause and arrive at suggestions for improvement.

▲ Lessons learned in 5 years of work

The experience gained in five years of work at the construction sites of the Lötschberg and Gotthard Base Tunnels can not be summarized in a few sentences. To maximize the effectiveness of the management system, the detailed project requirements must be clarified in advance. This, in turn, requires a painstaking analysis of all documents pertaining to the project and the contract for services and ultimately results in the determination of all data which are to be recorded.

Construction sites of the kind described here, i.e. which are

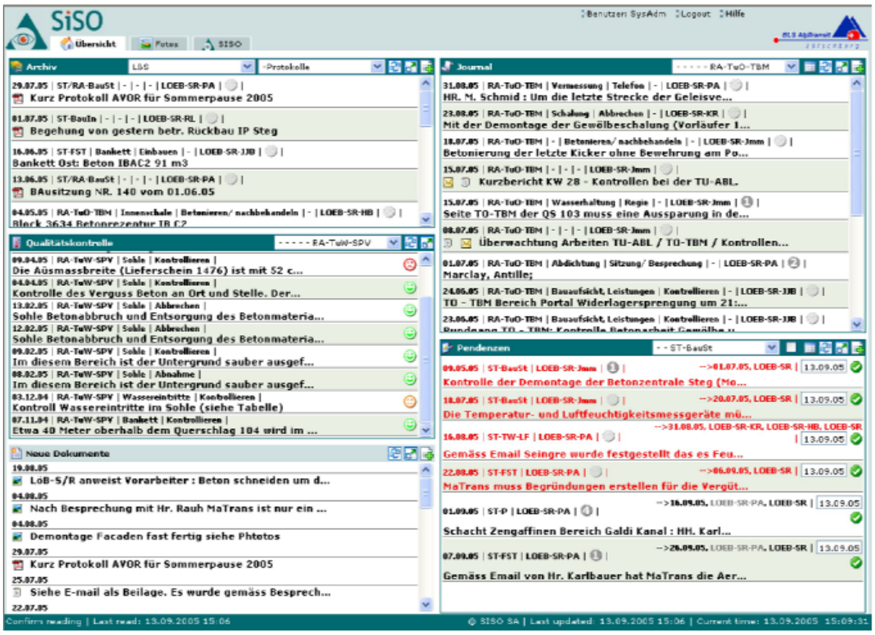


Fig. 7: The database portal at Section Steg/Raron in the Lötschberg Base Tunnel.

in place for several years and where the size of the crews vary constantly, can only be successfully managed if the **interaction of the essential data for the contract of services is assured**.

The one-time recording of data in SISO takes an enormous burden off the shoulders of all workers and project staff on a daily basis. The **standard processing of documentation and especially the data relevant to costs and scheduling,** as well as the quality of these data offer a major advantage to the owner and the contractor. A further advantage to be taken into account is the **availability of information** that can be referred to at any time to make research easier.

The biggest difficulty for construction site managers has been to shift the site staff from an individual to a collective approach. In the meantime, this change has come to be accepted by the majority. The advantages are also becoming increasingly evident, so that the database system is now largely accepted.

The database portal simplifies daily work and provides direct access to an information exchange platform based on collaboration. **The quick access to important data and information** promotes **work discipline,** which is crucial for construction projects of this kind.

▲ Return flow of experience and knowledge management

Up to this point, this article has focused on the short and medium term. The main point of interest in a project over the long term is whether one can **tap into the experience gained** from it. The experience and lessons from a project should continue to be available and possible incorrect decisions must be avoided in comparable situations. This is true for the client, the project engineer and the contractors.

On the subject of **knowledge management**, it is important to note that the **integrated structure** of the database is crucial in allowing this source of knowledge to be fully tapped. People carrying out current projects can draw on the experiences gained by predecessors at any time without having been directly involved in those earlier projects.

▲ Conclusion

Knowledge, direct and immediate access to information and data, and the ability to assess the consequences of new situations and circumstances are all factors that determine the success of a project and a construction site. **Documentation and traceability within a geographic reference system**, for their part, are crucial factors for the future operation and maintenance of a structure. In a sense, the database is the "**genetic code**" of the structure and will be an extremely useful tool for operations and maintenance once construction is completed.

On examining our revered ancestors' depiction of construction progress and predictions for the Gotthard and Lötschberg base tunnels some 130 years later, we recognize that it is indeed time for an integrated synthesis and information system that allows us to utilize this knowledge, these insights and this experience in the short, medium and long term.

The owners of the Lötschberg and Gotthard base tunnels have put just such a system in place. We are grateful to them and are convinced that the management system used for these tunnels is a one-of-a-kind system worldwide.

Fig. 8: Graphical depiction of the progress of work on the Gotthard Tunnel in 1876