The Montcenis base tunnel: how to turn project environmental constraints into opportunities

S. Lione, L. Brino, P. Grieco & L. Pinchiaroglio
TELT sas, Turin, Italy

A. Mordasini
LOMBARDI SA, Minusio (TI), Switzerland

ABSTRACT: Security and safety concerns, mainly due to grassroots opposition in Italy, have led to the need to implement drastic changes in the Final Design for the construction phase of the new Turin-Lyon rail line. Alternative solutions in the design of the Montcenis Base tun-nel have in-cluded a reversal of the mechanized excavation direction in favour of a downhill path; a reduction of the space available for the main construction site, and a particularly com-plex logistical setup. Faced with these challenges, the classic design approach has been over-turned in order to convert constrains into opportunities for the project, especially for the local regions and the environment. These opportunities include a reduction in the use of soil, an in-crease in the proportion of the excavation conducted with mechanized means, and a wholly underground handling of “green” (asbestos-containing) rocks.

1 INTRODUCTION

The new Turin-Lyon Railway Line (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. It is the central ring of the Mediterranean Corridor, serving 18% of the EU’s population, in regions that produce about 17% of European GDP. The work will contribute to a necessary shift in transport habits, particularly in the sensitive Alpine region.

Completion of this line is therefore part of a development strategy that goes beyond the national interests of Italy and France to establish roots in the concertation between Alpine countries aimed at encouraging economic and social development in these areas, making sure that undesired traffic jams or transfers cannot threaten the economic feasibility of some routes.

Within the NLTL, the cross-border section extending from Bussoleno/Susa in Italy to Saint Jean de Maurienne in France, for an overall length of about 65km (57.5km of which are the Montcenis Base tunnel) has been the subject of studies and approval procedures since 1992.

The “Comitato Interministeriale per la Programmazione Economica” (CIPE) with resolution n. 19 dated 20 February 2015 declared the Public Utility of the cross-border section and approved the Definitive Design for the Italian side.

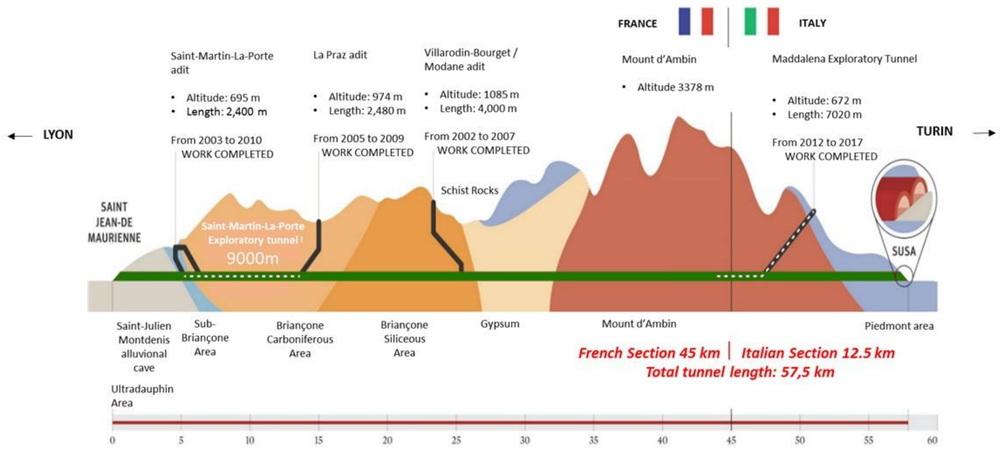

Figure 1.The Turin-Lyon base tunnel

The prescriptive framework of resolution 19/2015, with provision n. 235, "*Construction site optimisation study*", reads: "*During the executive construction design, an alternative placement of the construction sites must be studied according to the security needs of the public and with respect to the operational needs of the project... This study should also evaluate and quantify the resulting cost of classifying the aforementioned construction sites as strategic interest sites...*"

Faced with this provision, TELT (Tunnel Euralpin Lyon Turin), the Public Promoter responsible for the creation and management of the international section of the NLTL, has entrusted a specialised consortium with the task of creating a study aimed at fully responding to the above-mentioned provision. The result of this study has led to the need to draft a variation of the approved Definitive Design that involves the entirety of the project's construction site set-up.

This article, describing the Definitive Design as approved by CIPE in February 2015 and highlighting its strengths in relation to the application of the project's best practices, illustrates the approach followed to transform the constraints deriving from the new prescriptive framework into an opportunity for the local territory and the environment.

The usual and consolidated design approaches, adopted in the absence of constraints and public order requirements, have been completely revised. The result has led to the creation of an alternative Definitive Design, the so-called "Security Alternative" approved by CIPE with resolution n. 30 dated 21 March 2018, with innovative construction solutions that, with the same costs envisaged for the previous version, have further improved the environmental aspects without negatively impacting the efficiency of the industrial process used to carry out the works.

2 THE DEFINITIVE DESIGN

The original NLTL Definitive Design is the result of a decision-making process open to the territory and enriched by the contributions of interested parties and stakeholders that have actively collaborated in the works of the Observatory for the Turin-Lyon Railway.

That approach has been quite beneficial in guiding the planning of construction sites that, in addition to the criteria of consolidated organization and shared use for the creation of large works, has adopted the most advanced principles of innovation, sustainability and respect for the territory.

The environmental mitigation measures were intended to be works of sustainability, i.e. "planning actions" resulting from a set of inseparable best practices, respect for regulations, guidelines, and opportunities provided by the territory and its socio-economic context.

The general criteria for the choice and organization of the construction sites were based mainly on the following key points:

- a reduction of the size of the construction areas, optimizing their functions;
- occupation of already-used areas and poor quality soils in order to reduce land consumption;

- elimination of temporary base camps for the workers in favour of lodging in hotels or similar structures already available in the area;
- transport of excavation materials using the railway as much as possible;
- completion of the main work processes in closed environments (to contain dust and noise), transforming work sites into true industrial establishments;
- use of the best technologies available (with the goal of optimum technical and energy efficiency), i.e., the adoption of recently applied or currently-being-applied best practices and best technologies at large alpine excavation work sites;
- earlier completion, i.e. already in the construction phase, of definitive measures-aimed at environmental mitigation;
- optimization of the economic and occupational impact on the region, exploiting the opportunities provided by Piedmont regional law n. 4 of April 2011.

The main industrial area for the excavation of the Italian tract of the Montcenis Base Tunnel was located in Susa and it was to occupy a surface area of 12 hectares. It was designed to provide support to the outdoor construction sites and to the work areas, being the site of necessary supply plants (e.g. temporary muck deposits, a plant for the selection and valorisation of the excavation materials, a concrete batching plant, the precast concrete plan for segmental liners production, etc.). From this framework, the strategic nature of the Susa area in the original design of the industrial construction site, heart of the entire organization for the completion of the work on the Italian side, was clear.

The railway plant for the evacuation of the surplus excavation material was to be located in the same Susa area and it was designed to manage the railway equipment and systems after completion of the civil works.

Essentially, one might say that the industrial construction site of the Definitive Design was conceived as a linear construction site with a layout designed according to the production sequence.

1. Conveyor belt
2. Building materials storage
3. Concrete aggregates storage
4. Plant for the valorisation of excavated materials
5. Concrete batching plant
6. Covered areas for temporary muck deposit
7. Precast segmental lining plant
8. Temporary deposit
9. Workshop + oil storage
10. Helipad
11. Offices
12. Visitor Building

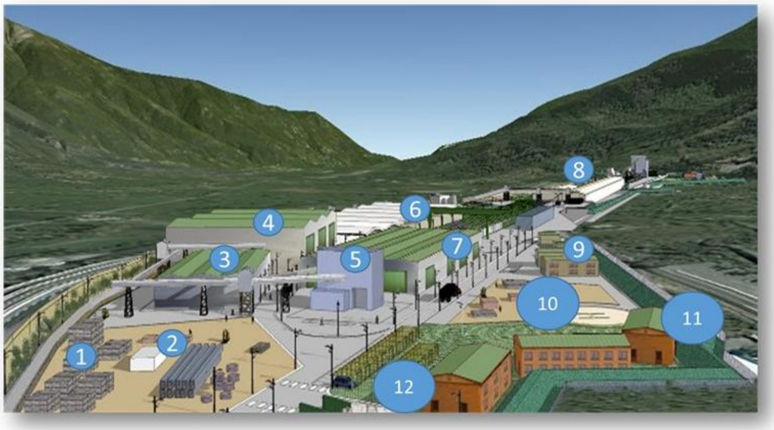

Figure 2. A rendering of the truck terminal

3 THE WORK SITES SECURITY STUDY

In order to comply with the provisions of CIPE resolutions concerning the optimization of the construction site to ensure people’s security, a study was drawn up by the National Inter-university Consortium for Transport and Logistics (NITEL); a Consortium of 19 prestigious Italian universities.

This study is based on a risk analysis of the different hypothetical ways the construction sites could be configured. The location of some work processes on different sites with respect to those established in the Definitive Design implied a different use of the individual areas, with their subsequent greater and/or lesser exposure to safety and security risks. Hence the need to carry out cumulative analyses of the various hypothetical solutions.

The level of risk exposure associated to each site was determined according to the relative level of sensitivity and impact. “Sensitivity” measures the degree to which a site may be subject to malicious action carried out by opponents, while “impact” is the measure of potential consequences that a malicious action carried out against a site may generate, assessed according to four points: impact on the population, on the workers, on work continuity and financial losses.

Therefore, the developers of the study, in close collaboration with the design team, have analysed the various technically possible options for construction site locations and, more specifically, have considered the different options for excavation sites: for the Base tunnel, muck evaluation and train loading, the ventilation central and the deposit sites.

Considering the technical restraints, it was possible to identify various configuration hypotheses, subsequently reduced to four, eliminating those with clear functional and/or security issues.

Once the risk associated with each of the four configurations had been analysed, in relation to the main Susa valley area, the security study then compared the exposure to the risk itself. The conclusion of the study led to the identification of the best solution, characterized by a rather different layout of the construction sites than in the previous plan.

Introducing a variable not traditionally considered in construction site design, the Security Study thus led to a change in terms of the organisational choices that are far from standard. The priorities and the design choices were dictated mainly by security requirements, which influenced the technical assessments. Except for the unchanged rail alignment, the construction site of the Base tunnel has been completely revised.

The designers thus had to grapple with new territorial, hydraulic and environmental constraints and they had to adapt the entire construction site system, which, like many work sites, is particularly complex, to the context identified due to security reasons.

4 CONSTRAINTS BECOME OPPORTUNITIES

The results of the construction site Security Study and the constraints imposed by the need to protect and ensure the security of the workers and the public have affected both the logistics of the construction phase and the changes to some final works.

The experience of the Maddalena exploration tunnel, a site already protected by law enforcement, has made it possible to identify the area as the best suited to host the main base tunnel boring construction site between the underground safety area of Clarea and Susa. Given the scarcity of available surfaces, at the confluence of the Clarea Stream and the Dora River, it was not possible to maintain the concept of an in-line unique construction site. Rather, it was necessary to identify other locations to contain all the necessary operations. For example, the evaluation and use of muck and its loading on trains for transport to deposit sites was located in Salbertrand, a new municipality that wasn’t part of the Definitive Design, about a dozen km from the boring site. In order to carry out other logistical activities, other areas were identified adjacent to the existing construction site on the opposite side of the Clarea stream.

The identified layout also implies a revision of the tunnel advancement faces and the excavation methods for some types of lithology, leading to the better use of the TBM, as explained further in the following paragraph. The reversal of the boring direction from Chiomonte to Susa has greatly simplified the construction activities in the Susa area, with a reduction of environmental pressure factors, thanks to a simplification of the activities while work is under way. The shifting of the main Base tunnel boring activities from the Susa area to the area of the current construction site of Chiomonte has made it possible to predict the environmental impact, based on the environmental monitoring of excavation activities of the exploration tunnel in the last 5 years. In addition, in summer 2017, the Environment Minister, after having analysed the feedback from the exploration tunnel construction site, stated that “*the impact created on the environment by the construction site did not produce significant irreversible changes nor effects on any monitored environmental component*” and that “*we consider all the possible impact and effects on the environment of reference as tested, both in terms of the environment and management*”. Operating in a context proven in its transformations, makes a work site with lower environmental risks possible, where further techniques to control and reduce the impact on environmental components can be applied.

The relocation of the industrial construction site, originally located in the Susa area, has taken place in an environmentally degraded zone of the Salbertrand municipality, but close to other zones of great ecological importance. This location has led to the study and proposal of a "restoration ecology" design that aims to achieve more important objectives than simply restoring the sites to their original condition. The new design in fact allows for the ecological upgrading and recovery of the area involved, including a portion that has been heavily damaged from a natural and environmental point of view.

Figure 3. The Maddalena reconnaissance tunnel construction site

The new Maddalena underground interchange has created an important opportunity, making it possible to store underground green rocks that potentially contain asbestos. This green rocks storage method will better adhere to the principle of caution in the management of such materials, as it eliminates the risk of the fibres being dispersed into the environment. The material is managed entirely underground, in a tunnel section in confined environment conditions, without the need for open-air transport and handling.

One other positive direct consequence of the new construction complex was the elimination of the ventilation well and ventilation plant in the Clarea valley. The elimination of this final work thereby removes the effects generated by the plant's construction and operation, in a valley that is quite valuable environmentally, as well as in terms of its landscape.

Another important aspect was the chance to limit the underground 132 kV Susa-Venaus cable duct, with its environmental threats, to the land covering three municipalities. Thanks to the reversal of the excavation direction of the boring machines and the fact that their power supply will therefore come directly from Chiomonte instead of Susa, it will no longer be necessary to build the definitive connection as soon as possible in order to power the construction site. The overall length of the cable duct alignment after this modification will remain largely unchanged in respect to that of the approved Definitive Design (about 7.8 km). However, the most important thing to note is that only 1.4 km will still need to be buried near the surface, while the remaining tract will become part of the Base tunnel. This makes it possible to simplify the construction site and to significantly reduce the effects generated by drilling associated to the laying of cables, as well as the interference with local roads and public services, thereby also reducing completion times.

4.1 *The Maddalena underground excavation site*

The Montcenis Base Tunnel excavation site on the Italian side has been entirely revised. The excavation direction of the two tubes from Susa towards France, established in the Definitive Design as uphill, has been reversed completely, assuming a downhill approach. This choice, which is not standard in terms of normal excavation operations, has resulted in notable advantages in terms of the general layout.

The introduction of the Maddalena-2 tunnel has made it possible to bring the Base tunnel's advancement attack underground instead of out in the open, thereby greatly reducing potential environmental impact.

Below is a description of the plan for the new Maddalena excavation site, illustrated in Figure 4.

The Maddalena-1 tunnel coincides with the exploration tunnel, which has already been completed in order to gain a better understanding of the geology, geomechanics, and hydrogeology of the rock mass. From the portal, the tunnel leads to the Base tunnel, placed between its two tubes, in an overlying position, running parallel to them for about 4 km.

During the operational phase, this tunnel will be accessible to emergency vehicles for about the first 2.2 km, from the entrance to the starting point of connecting tunnel 1, along which they will proceed until the safety area/Base tunnel. The remaining portion of the Maddalena 1 tunnel will be completely closed in order to store the “green rocks”, as described below.

Connecting tunnel 1, along with the first tract of the Maddalena-1 tunnel, will be the access way to the Base Tunnel for emergency vehicles. The considerable reduction of the route with respect to the approved Definitive Design will facilitate the timely access of vehicles during an emergency response.

The Maddalena 2 tunnel will be built to allow, as work in progress, the entry of the TBMs to be used to excavate towards Susa. Thanks to this tunnel, it will be possible to eliminate the works for the ventilation plant in the Clarea valley and its related shaft. The junction with Connection tunnel 2 will therefore have the function of ventilation in the safety area and of smoke extraction from the Base Tunnel in case of fire. Access will be limited exclusively to maintenance vehicles. The remaining portion of Maddalena-2 will be closed and it will also be used to store all the green rocks.

With the “Security Alternative”, the new underground Maddalena construction site will thus become the main hub for underground boring management on all advancement faces of the tunnels excavated on the Italian side, helping to free the Susa Valley from the construction activities

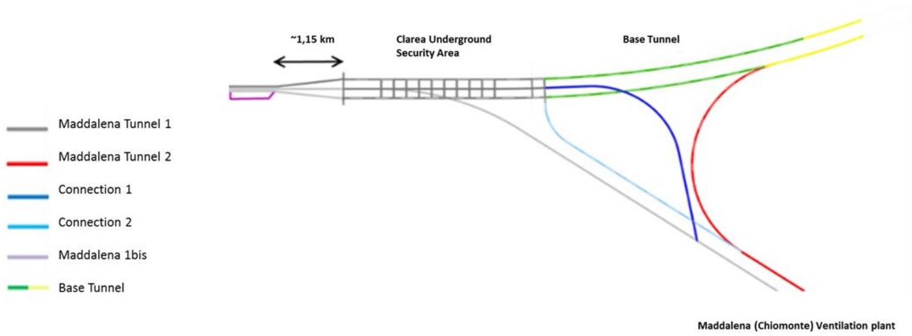

Figure 4. Tunnel layout in the Maddalena interchange

related to the execution of underground operations.

The eastern portal of the Base Tunnel in the Susa area will become active only several years after the beginning of the works. It will be used only for the construction of the artificial tunnel and during the dismantling of the TBM, occupying a very small space and for only a short duration. Its function as a construction site for technological installations will, however, continue.

4.2 *The Salbertrand industrial area*

The new location for the temporary construction site, identified by the Security Study, is in an area suited to host the various features necessary for the operation of the construction site, including the transport of surplus excavation material by train, as it is adjacent to the existing railway line. It is located in the Municipality of Salbertrand, on the left bank of the Dora Riparia River, in an area that is currently subject to intense environmental pressure. Close to the Natura 2000 Site of the Gran Bosco di Salbertrand, the area is currently used for industrial activities and it is mainly occupied by soil piles and small contaminated areas.

The industrial construction site covers about 11 hectares.

The industrial area serving the underground construction sites has taken over the activities and

Figure 5. The Salbertrand Industrial Construction Site

functions originally planned for the Susa area: temporary muck deposits, a plant for the selection and valorisation of the excavation materials, a concrete batching plant, the precast concrete plant for segmental lining production and storage, a rail yard for transporting muck to final deposits, etc.

The zone where the new construction yard will be located is an area with hydraulic restrictions and constraints for construction works.

The limitations imposed by law to set up construction works in the aforementioned area and the constraints deriving from the unavailability of alternative locations (as declared by the Government Commissioner for the Turin-Lyon Railway) have forced the commissioning of a detailed hydraulic study finalised to ensure that site installations and the expected temporary activities do not affect the water tables (upstream and downstream) or other characteristics of particular importance for the natural ecosystem of the Dora Baltea River.

The permanence of the construction site for many years and the value of the landscape of the surrounding areas have led to the choice of a final restoration with nature as a priority, to allow for a marked improvement compared to current conditions.

The project includes the creation of wooded or shrub-covered areas, alternating with open spaces to improve environmental complexity and create diversified habitats for fauna and flora. A portion of the mitigation interventions will be carried out already during the construction phase, in order to make it possible to have meaningful clusters of native vegetation already established at the time of final restoration in the implementation phase. These cluster will be especially useful to accelerate the spontaneous recolonization of the industrial area used during the construction phase.

The wooded and bushes communities will be heterogeneous, made up of native species with a local origin certificate. In particular, the restoration of wooded areas will take place through the use of species that form already part of the area's plant communities (phytocoenosis), alternating pioneering species with entities typical to more mature, stable developments.

In addition, restoration interventions will include the maintenance of broad grasslands, thereby facilitating their use by wildlife.

The environmental recovery design also proposes experimental interventions against invasive alien species such as *Buddleja davidii*, aimed at improving the ecological conditions of the pebble tracks along the Dora.

The field studies carried out for the project in this river area have produced a snapshot of an area of significant interest because of its ecosystems and of the presence of rare botanic species thanks to a very wide river bank freely shaped by the morphogenesis of the river.
Among the many plant communities surveyed in the study, there are single species of extreme interest for conservation, such as the *Carex alba* and the *Typha minima*. The project is a great opportunity for "ecological restoration" that, once the tunnel is completed, will allow the involved areas to move beyond their current degraded status, activating a process of natural restoration and ensuring a greater presence of wild fauna and reducing the current risk of damages to wildlife.

4.3 *The underground deposit of green rocks*

The area relative to the Mompantero zone, where the Base Tunnel portal for the Italian side is

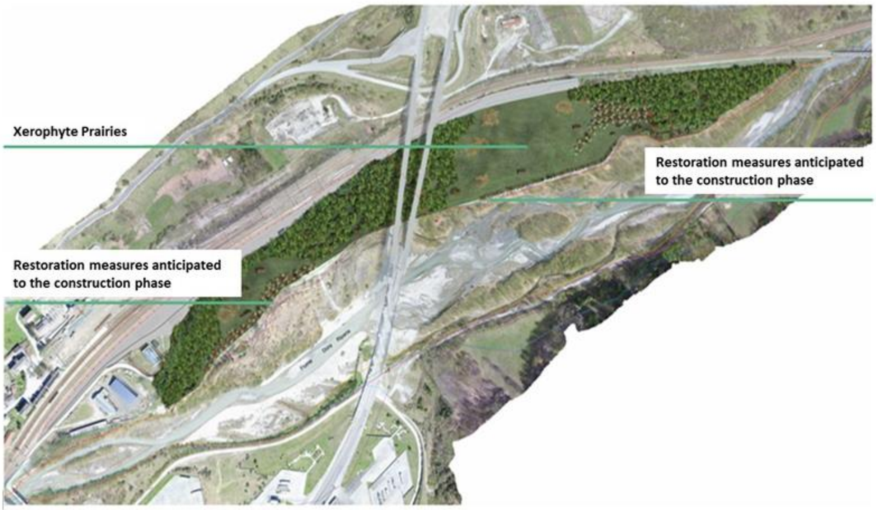

Figure 6. Restoration activities and final development of the Salbertrand construction site

expected to be located, is characterised by the presence of ophiolitic rocks (basic and ultra-basic rocks) belonging to the tectono-metamorphic set of the Piedmont zone.

For a section of about 300-350 m up to the eastern portal of the Base Tunnel, the tunnel will be excavated through ophiolite, which are potentially asbestiform lithotypes part of the "green rocks" group.

Based on the available direct data and current knowledge, it is possible to estimate that the volume to be excavated in "green rocks" is about 80,000 m3. Of this volume, however, only a limited portion could potentially contain asbestos and, in any case, only a small fraction will presumably be characterized by concentrations of asbestos over 1,000 mg/kg, which is the limit to distinguish a material as either:

- not dangerous, and potentially usable in construction works, according to art. 184 bis of Italian Legislative Decree 152/06 and subsequent amendments and additions, or
- dangerous waste, according to "CER code n. 17 05 03*", requiring permanent storage.

The passage from the calcareous schist formation to the ophiolite formation is not cut and dry and the available soil investigations in ophiolite formations show a scenario with a high variation of asbestos concentrations. An accurate estimate of the volume of material that might contain asbestos and, even more, a detailed evaluation of the volume of material classified as "dangerous waste" will become available only during the Construction Design phase. According to this approach, the Design has prescribed additional soil investigations and laboratory tests to be carried out during the excavation phase. The new data collection will increase the knowledge and will allow to determine the actual degree of presence of asbestiform rocks.

Currently, the “Security Alternative”, inverting the Base Tunnel excavation direction from the Italian to the French side, as described above, will make it possible to excavate the section in “green rocks” entirely from within the mountain and not from outside. It also offers the opportunity to create an underground deposit in already-excavated temporary tunnels, as they will have no purpose once the railway begins operations.

Based on what has already been completed, an adapted version of the storage project for the ANAS underground deposit in Cesana Torinese (TO), this layout has been adopted for storing in an underground space all the 80,000 m^3 of “green rocks”. The underground

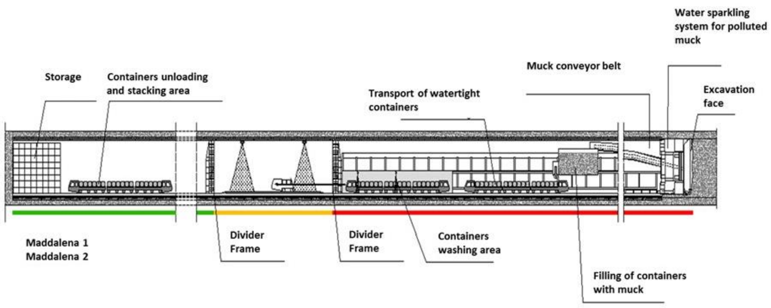

Figure 7. Diagram of the green rocks excavation and the underground deposit

deposit design includes the burial of the “green rocks”, the complete filling of the tunnel with cement mortar, and the sealing and waterproofing of the access closure with a reinforced concrete wall. This practice is borrowed from ancient techniques used in the industrial mining, such as the cultivation of the Fontane talc mine in Germanasca Valley, not far from Turin.

The project thereby provides for the material first to be packed into high-density polyethylene (HDPE) containers, and then to be transported and permanently stored in the underground deposit site.

The solution identified allows for the “green rocks” to be stored underground without any handling in open air. They will always remain within underground spaces, and no transport and disposal in other locations outside the site, with their related environmental impact, will be necessary.

The disposal methods and criteria, the provision of suitable equipment and of personnel and personal protective measures will be handled according to Italian Legislative Decree 36/2003 and to Italian Decree 27/09/2010.

It should be emphasized how the change in the excavation works makes it possible to tackle the excavation of the section in “green rocks” with a TBM instead of conventional excavation methods, leading to considerable protective benefits. The TBM can be considered a “travelling factory”. It allows to mechanize and automate all the various operations, such as boring, clearing out, transport, and storage of the muck, reducing both the excavation time and the number of workers necessary to manage the excavation phase, avoiding the creation of dust and the release of fibres in the environment.

The design choices have made it possible to optimize the reutilisation in totally safety conditions, both for the workers and for the environmental surroundings, of tunnels already excavated, as well as to achieve lower costs for the management of material that sees the presence of “green rocks”.

5 CONCLUSIONS

The most important infrastructure projects, especially if in international scenarios, derive from the willingness to make plans with horizons of at least ten years. From the first feasibility studies

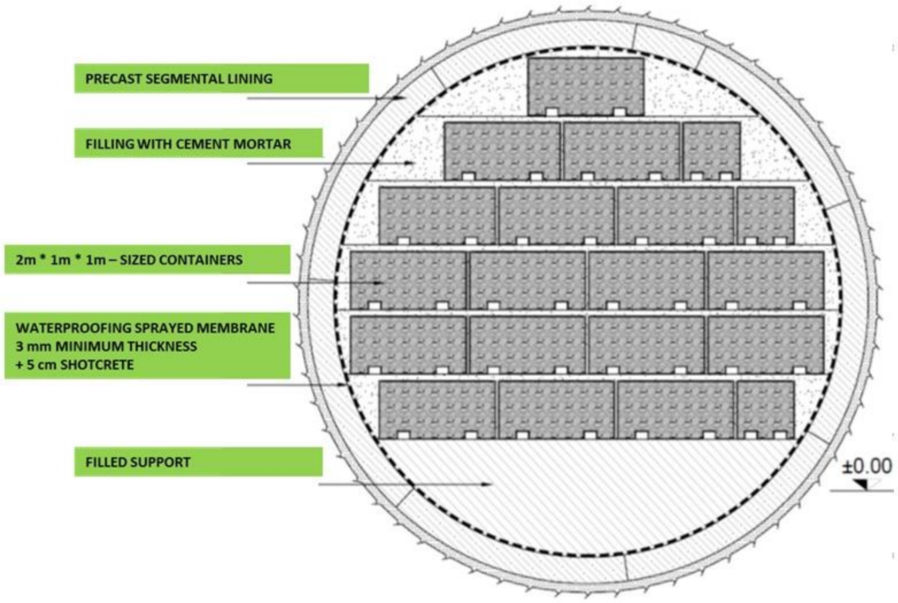

Figure 8. Storage of green rocks in the underground deposit (e.g., the Maddalena 2 tunnel)

to the completion of the project, through the authorization practices and necessary procedures, relatively long periods may pass, during which it is often possible to have important changes in social and political contexts, on local or international scale.

The true challenge is to create opportunities for the territory and the environment where these projects are implemented, subverting if necessary the usual design approaches and insisting, more and more, on sustainable designs, so that these projects can be seen and appreciated as a positive vehicle for change.

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