Management for material recovery in the context of SMP4 reconnaissance work

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ABSTRACT: The “exploratory works” activity of the Lyon-Turin cross-border section will end with the completion of the SMP4 works, allowing the start of the actual excavation of the Mont-Cenis Base Tunnel structures. In parallel to the excavation construction sites of the Base Tunnel, the operational construction site for the reuse of excavated materials will be a challenge, both from the point of view of the supply of recovered materials to the sites and from the point of view of TELT's Sustainable Development Goals. During the SMP4 exploratory work, the implementation of recovery of the excavated materials served to generate feedback that will be used for the operational digging sites to come. This paper explains these methods of recovery and the ways in which the recovery of excavated materials can be improved.

KEYWORDS: Recovery, excavated materials, Sustainable Development

1. INTRODUCTION

Tunnel Euralpin Lyon Turin (TELT) is the binational public promoter, owned in equal parts by the French State and the Italian State and in charge of the construction and operation of the cross-border section of the mixed rail line, whose main underground structure, the Base Tunnel, is 57.5 km long.

The cross-border section aims to replace the historic rail tunnel between Lyon and Turin, with a route adapted to efficient rail transport, in compliance with current environmental and safety standards.

This section is part of a new connection representing one of the links in the trans-European transport network (TEN-T) and which will eventually allow communication and facilitated exchanges from North to South and from West to East, in Europe. The cross-border section between Lyon and Turin is shown in figure 1:

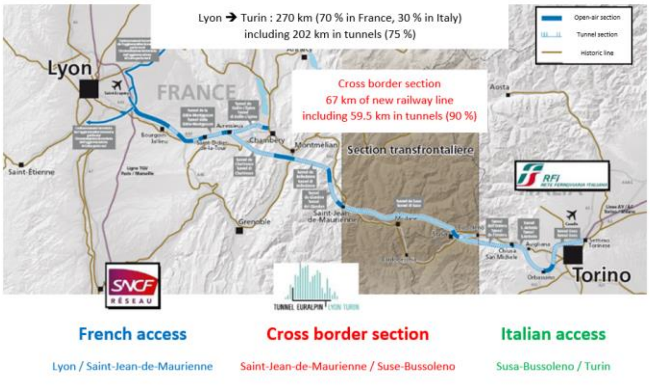

Figure 1 Location of the cross-border section on the Lyon-Turin line

2. LYON-TURIN LINE CROSS-BORDER SECTION

2.1 Presentation of the project

The European project of the Lyon-Turin cross-border section is located between Saint-Jean-de Maurienne, in France and Susa, in Italy, on a mainly underground route with a twin-tube Base Tunnel 57.5 km in length.

The Base Tunnel work is based on the Final Reference Project (FRP), which defines in particular a functional programme, a schedule with commissioning in 2030, and a certified cost of the work. This work, which is starting, is organised on the French side into 3 operational construction sites (CO 5, 6-7 and 8) and 1 transverse and strategic operational construction site (CO11) responsible for the recovery of the excavation materials of the Base Tunnel. Figure 2 shows the operational construction sites:

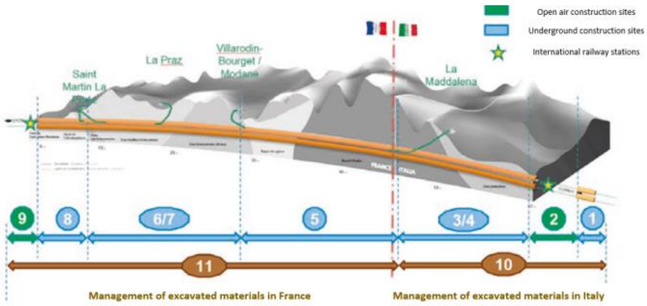

Figure 2 Breakdown of work into 12 operational construction sites

In geological terms (broad sense), the exploratory and study phases followed one another in order to acquire sufficient input data to allow the construction of a geological model at the project scale and to reduce geological risks during construction.

Among these exploratory phases, access tunnels were dug in Saint-Martin-La-Porte, La Praz, Villarodin-Bourget-Modane and La Maddalena to, in particular:

- complete the geological model of the project,
- allow the multiplication of excavation approaches with these accesses,
- be able to provide safety / ventilation / maintenance for the Base Tunnel during the operating phase.

Figure 3 shows the route of the cross-border section, along with a schematic representation of the two tubes of the Base Tunnel, its associated structures and its accesses.

The Saint-Martin-La-Porte access tunnel also served to access the SMP4 works in the axis of the southern tube of the Base Tunnel for the exploration of the Coal face and the Briançon Coal area, between the Saint-Martin-La Porte and La Praz access tunnels. This exploratory work also aimed to implement the management of excavated materials.

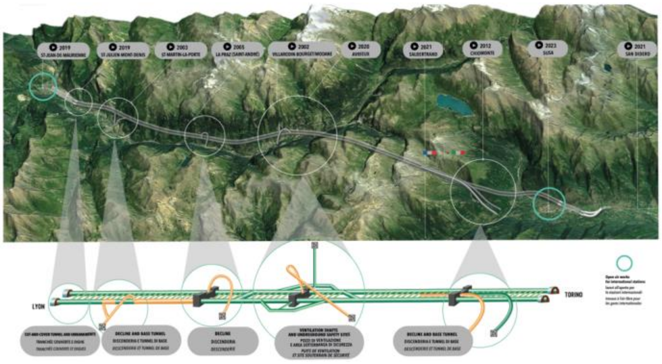

Figure 3 Representation of the Base Tunnel and its accesses

The purpose of this paper is to present the implementation of the recovery of excavated materials, as part of the excavation of the SMP4 exploratory tunnel, in the axis of the South tube.

2.2 Project recovery stakes

As part of the Lyon-Turin project, TELT is building the Base Tunnel with a sustainable strategy for the management of excavated materials. These materials will be extracted over a period of approximately 6 years and used in large part for the construction of the tunnel: the objective is to reuse more than 50% of these materials for the construction of concrete structures and railway embankments. The fraction that cannot be reused for the needs of the site will be permanently deposited on sites dedicated to the project or used outside in site restoration operations.

As pointed out in the introduction, the work of the Base Tunnel is divided, on the French side, into three underground operational construction sites (CO 5, 6-7 and 8) identified according to the geographical sectors of the route. To meet the objective of recovering excavated materials, these operational construction sites are supplemented by a transverse and strategic operational construction site in charge of the management and recovery of all the excavation materials generated on the French side: CO11. The Italian part of the route includes a mirror organisation to the one set up on the French side.

Figure 4 details the provisional balance sheet for the management of excavated materials (GEME) as defined in the Final Reference Project of 2017.

Global production: 37.2 Mt			
29.9 Mt		7.3 Mt	
Needs: 14.1 Mt		Needs: 5.7 Mt	
Aggregates: 8.6 Mt	Backfills: 5.5 Mt	Aggregates: 2.6 Mt	Backfills: 2.9 Mt
Construction site production (Aggregates+backfills):			
13.2 Mt		4.6 Mt	
Balance – deficit:			
Aggregates: - 0.9 Mt		Backfills: - 1.1 Mt	

Figure 4 Provisional Balance Sheet of excavated materials management and use, in Millions of tonnes (Mt)

3. SMP4 EXPLORATORY SITES

3.1 Presentation of the work

The Saint-Martin-La-Porte (SMP4) exploratory site was started in 2015, with in particular the excavation of parts 3b and 2, in the axis of the South tube of the Base Tunnel, between the Saint-Martin-La-Porte and La Praz access tunnels. The objective of this work was to cross the Coal face and the Briançon Coal area underground to:

- complete the geological, geomechanical and hydrogeological model of the project,
- test the excavation, support and lining techniques,
- optimise and adapt the excavation to the tunnel boring machine,
- in view of the excavation of the North Tube between the Saint-Martin-La-Porte and La Praz access tunnels.

The exploratory tunnelt, in the axis of the South Tube, consisted of creating:

- part 3b, over a distance of approximately 1.4 km, using the traditional method, between the foot of the 3a access tunnel and that of the SMP access tunnel, to identify the Coal deposit land in the area of direct influence of the Coal face,
- part 2, over a distance of 9.0 km, using the mechanised method (with the Federica tunnel boring machine), between the base of the SMP access tunnel and that of the La Praz access tunnel, to identify the Briançon Coal deposit land.

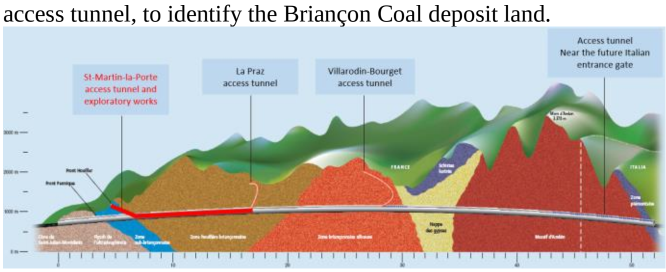

Figure 5 Position of the SMP4 sites on a schematic geological cross section

The different areas of the SMP4 site can be found in figure 6:

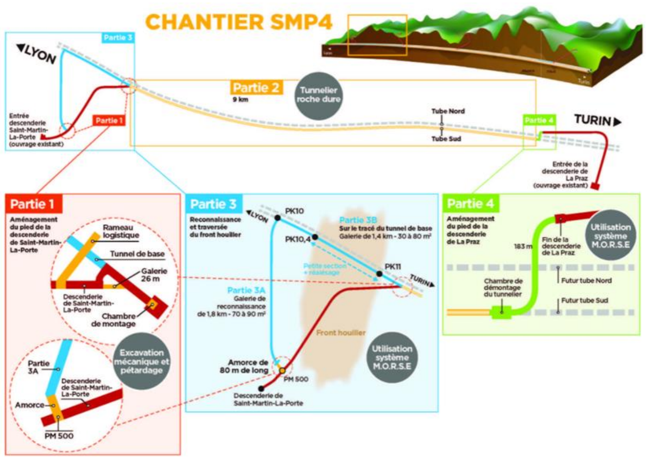

Figure 6 Description of the sections of the SMP4 construction site

The main geological formations concerned by the SMP4 work, along the South Tube axis, are listed in Table 1:

Table 1 Geological formations of the route

Parts 3b - Traditional method (explosives, hydraulic rock breaker and milling cutter)		
Pk 10+140 to 10+270	Sub-Briançon area - Upper Triassic anhydrites and gypsum	tGsb
Coal Face		
Pk 10+270 to 10+850	Briançon Coal face - Encombres Unit: dominant black shale, coal, sandstone and conglomerates (Wesphalian C or D to Permian)	hE
Pk 10+850 to 11+469	Briançonnaise Coal Zone - Brequin-Orelle Unit: sandstone, micro-conglomerates, shale and coal	hBO

	(lower Wesphalian C-D stage)	
Part 2: Mechanised method (hard rock tunnel boring machine)		
Pk 11+797 to 18+950	Briançonnaise Coal Zone - Brequin-Orelle Unit: sandstone, micro-conglomerates, shale and coal (lower Wesphalian C-D stage)	hBO
Pk 18+950 to 20+500	Briançon Coal Area - La Praz Unit: sandstones and conglomerates, rare shale. La Praz sandstone unit or "sterile coal deposit" (Namurian-Westphalian?)	hLP

Figure 7 shows the two Saint-Martin-La-Porte and La Praz access tunnels, along with Parts 2 and 3b in their geological context:

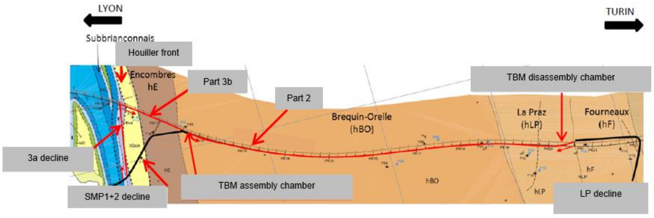

Figure 7 Position of the SMP4 sites on a provisional schematic geological cross section

The distribution of these units is shown on the forecast geological profile, in figure 8, with the SMP4 works, in the axis of the South Tube (in red):

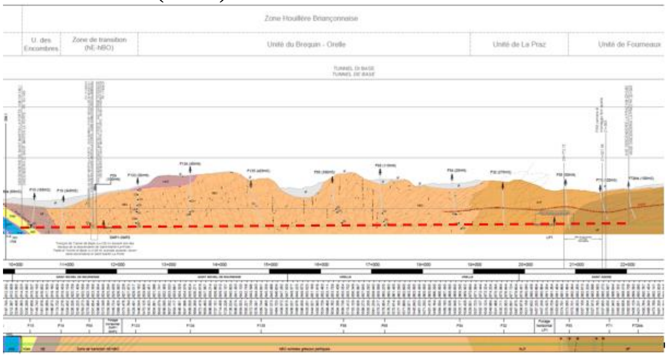

Figure 8 SMP4 works on the PRO geological profile of the Base Tunnel

The stakeholders of this construction site were as follows (figure 9):

Figure 9 Stakeholders of the SMP4 construction site

3.2 Recovery targets set

Pursuant to TELT's environmental policy, a target for the recovery of excavated material has been set for the SMP4 construction site stakeholders. The objective to achieve, within the framework of the works contract, was the separation of recoverable materials (CL1/2) and non-recoverable materials (CL3) according to the criteria defined by WG 35 of AFTES, given in table 2:

Table 2 Details of the material classes according to AFTES GT35

Class	Quality	Use
1	good	concrete and road aggregates
2 / 2a	moderate	noble / common backfill
3a	poor	chemical treatment or definitive disposal
3b	non-inert or with hazardous products	specialised disposal

The criterion for placing the materials in class 3 was among others the presence of a mixed face with coal.

The total material excavated for SMP4 corresponds to 1.3 million m^3 of excavated material in place with 450,000 m^3, for the part excavated using conventional methods, and 850,000 m^3, for part 2, excavated with a tunnel boring machine.

Depending on their classification, these materials were either disposed of definitively for class Cl3 materials, or placed in a temporary deposit, or used for class Cl1/2 materials, pending their recovery in the context of the SMP4 contract or of future work on the Base Tunnel. The excavated materials were transported by conveyor belts and for recovery, by truck, to temporary or final storage sites.

Four depots, near the works, were used, two of which were dedicated to recoverable materials with a storage capacity of approximately 300,000 m3 and two others of 100,000 m^3 and 1,500,000 m^3 were dedicated to the final storage of Cl3 materials.

4. MATERIAL RECOVERY METHODS AND EXPERIENCE FEEDBACK

4.1 Mechanised method

Part 2 was excavated with a hard rock TBM, the Federica TBM. The muck was transported to the open air by a conveyor belt.

The principle of recovery, in the context of part 2, consisted in classifying sandstones and shales as potentially recoverable materials (Cl1/Cl2). Depending on the degree of cleavage, these could possess good geotechnical properties. Coal, an evolving organic rock, has poor geotechnical properties. Coal, or other coal-containing materials were placed in definitive disposal (Cl3).

The geological forecasts (presence of mixed sandstone / shale / coal faces and decrease in the percentage of coal from Saint Martin la Porte to La Praz) suggested more favourable conditions for the recovery of materials when approaching La Praz, which led to favour, on this last section, more precise sorting operations with a view to better recovery of the excavated materials and their temporary storage. This strategy was established on the basis of the limited capacity of sites dedicated to the sorting and temporary storage of materials.

The process of identifying and sorting excavated materials was mainly based on the implementation of the following in-line techniques:

- visual identification of lithological distributions in external stocks,
- test-based characterisation,
- in-line colorimetry for the identification of carbonaceous materials,
- particle size analysis for the identification of materials with too large a fine fraction.

The sorting methodology changed during the work to adapt to the expected lithology and that actually encountered. Table 3 traces the evolution of this methodology:

Table 3 Changes in materials identification methodology

Dates	Section	Typology
Sept. 2016 to June 2017	11,800 to 12,500	Visual evaluation of the % coal in deposit (CL3 if the % coal >3%) + PLT
June 2017 to January	12,500 to	In-line colorimetric + particle size sorting

2018	14,100	
February 2018 to May 2018	14,100 to 15,150	In-line colorimetric + particle size sorting + PLT
June 2018 to Sept. 2019	15,150 to 20,500	In-line colorimetric + particle size sorting + PLT + lab tests

To prepare the materials for analysis, a scalper (grizzly) was present in the assembly chamber in order to skim materials with particle size greater than 300 mm before passing through the buffer hoppers. Between May 2017 and September 2018, approximately 2.2% of blocks greater than 300 mm in size were sorted by the grizzly scalper.

The materials skimmed after passing through the grizzly were brought outside by the belt conveyor and directed to the in-line analysis devices located at the access tunnel entrance. These materials were subjected to in-line colorimetric and particle size analysis at a speed of approximately 3m/s. The apparatus controlled a conveyor belt exchanger to classify the rocks as Cl1/2 on the one hand and Cl3 on the other hand.

The two in-line analysis techniques are detailed below:

- In-line colorimetry: the equipment was a fully automatic analyser used to measure the colour (intensity) of a product on any type of conveyor in an industrial environment. The threshold used for sorting carbonaceous materials was a percentage of coal greater than 3%.

Figure 10 shows the colorimetric tests of July 2018 with the potential Cl1/2 materials placed at the top left.

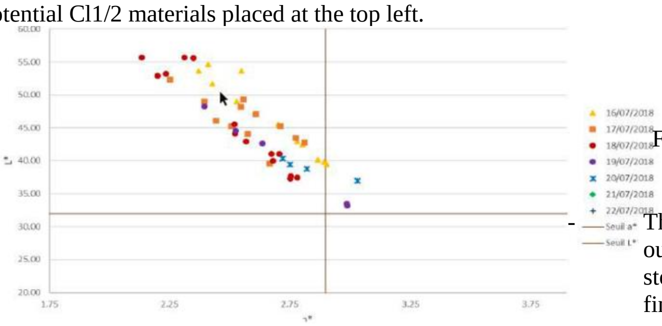

Figure 10 Example of colorimetric analysis results

- In-line particle size analysis: the aim of the in-line analyser was to characterise the materials from a statistical model according to the size, arrangement and movements of aggregates. The device did not detect materials below 5 mm. At the outfeed, the materials were characterised by a particle size curve bounded between two standards (regularity zone).

Figure 11 corresponds to the median curve between the 1866-2565 rings (max, median and min values) for a 5 mm/300 mm mesh size.

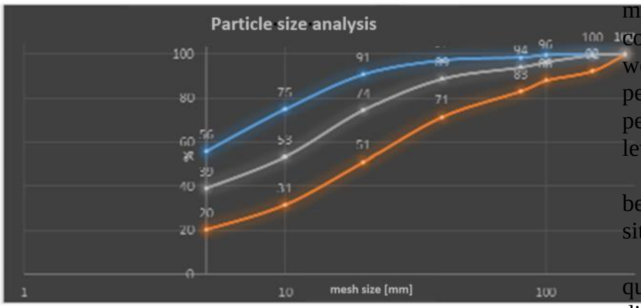

Figure 11 Example of colorimetric analysis results

The feedback from the recovery of excavated materials in Part 2 are as follows:

- The identification of the materials gave results allowing discrimination of unusable Cl3 materials and was conclusive in the heterogeneous geology of the project.

Based on the face surveys and the reconnaissance drilling carried out, the percentages of dominant lithologies at the scale of the face are indicated in table 4 in percentage of the excavated distance:

Table 4: Lithology distribution Part 2

Lithology	**Distribution (%)**
dominant sandstone/pelitic sandstone	69.8
mixed fronts sandstone/pelitic sandstone, pelites, black shales, and coal in low proportion	17.5
dominant pelites and black shales	10.8
coal in high proportion, with black shales and pelites	1.4
quartz-sericite shales	0.5

Figure 12 shows the expected geological profile along with the frieze of lithologies encountered during excavation:

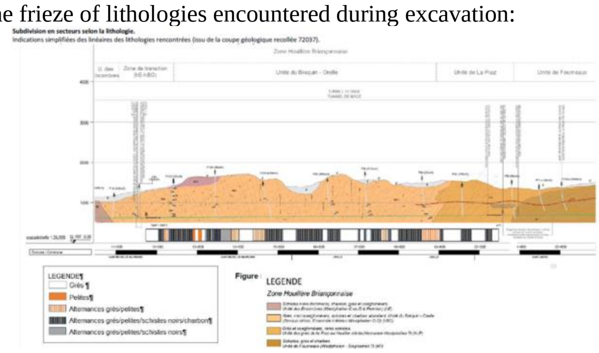

Figure 12 Expected geological profile with lithologies encountered during excavation

The automatic pre-classification of materials at the belt conveyor outfeed served to identify the materials to be placed in definitive storage due to their evolving nature or their excessive proportion of fines.

- Sorting the materials serves to guide the choice of the operators, but does not allow a fine classification of the excavated materials, the particle size curve being generated out once a day, making it possible to obtain a weekly average, either a reference curve for approximately 100 lm or approximately 40,000 tonnes of 10-ring material/day.
- Compared to the forecasts of the preliminary design, a high percentage of fine materials (greater than 50%) was observed, even in land with good mechanical characteristics. This level of fines is linked to the action of the tunnel boring machine in slightly fractured ground (self-crushing at the front of the excavated material) in connection with the adopted TBM cutting head configuration. Discussions from the cutting head design phase would allow the development of an adaptable cutting head (opening percentage in particular) without prolonged and production-penalising down time, in order to limit this effect generating a high level of fines.
- the main problems encountered since the beginning of this work have been the calibration of the devices on site and the drift of results during periods of strong water inflow.

First of all, during the implementation of the devices, the question of the representativeness of the sampling arose due to the diversity of materials and to a broad range of granular particle sizes. A large amount of materials and several tests on various rocks were required.

- the presence of heavy groundwater inflow, or the need to add water to the cutting face or muck to reduce dust, affected the colorimeter measurements, requiring digital data processing for the removal of these areas. Improvements could be considered to optimise the amount of water used for dust control in the shaft and to improve the reliability of the colorimeter.

- the transport and deposit logistics conditions should be anticipated as much as possible in order to provide the necessary areas and facilities to maximise the reusability of materials.

In summary, compared to the market forecasts, the objectives in terms of production of Cl1 materials were not reached due to:

- the behaviour of the Praz sandstones and the presence of mixed cutting faces, with very rapid changes in the lithological nature of the cutting face (sandstone/shale),
- the production of a significant proportion of fines,
- the presence of water inflows, disrupting identification operations.

4.2 Traditional Method

For Part 3b, excavated using conventional methods, recoverable materials were identified from geological surveys carried out at the cutting face, combined with laboratory tests (Point Load Strength Test). Reconnaissance survey data were also taken into account for the anticipation of choices.

Excavated material identification sheets were drafted from the geologist's observations on the excavated rocks, their geotechnical quality, the presence (or absence) of evolving materials (coal or anhydrite) and the Is value (Is50) determined with the Point Load Test. An evolving materials content greater than 3% or an Is value less than 1 predetermine Cl3 materials.

From early 2020, additional tests were carried out on pre-class Cl1/Cl2 materials every 15m for the materials of Part 3b (Table 5):

Table 5 tests carried out from the beginning of 2020 on LC1/LC2

Tests	Standards
Density	NF P 94-054
Particle size on 0/60 materials	NF P94-056
Methylene Blue value (VBS)	NF P94-068
Sulphate content	EN 1744-1
Micro Deval (MDE)	NF P18-572
Los Angeles (LA)	NF P18-573
Abrasiveness Grindability	NF P18-579
Fragmentability (FR)	NF P94-066
Degradability (DG)	NF P94-067
Assays for active alkali	XP P18-544
MicroBar test	NF P94-594

The samples were collected during excavation or, failing that, from the external sites.

During the first part of excavation and up to approximately 11+270 section, the materials of Part 3b were mostly anhydrites, considered evolutionary and classified in Cl3.

In the subsequent excavation, the lithology of the excavated materials corresponded to shales and sandstones, in varying proportions, in the form of mixed faces, with a marked coal presence and were classified as non-recoverable and placed in definitive disposal due to the presence of the evolving materials.

Figure 13 shows an example of mixed cutting face:

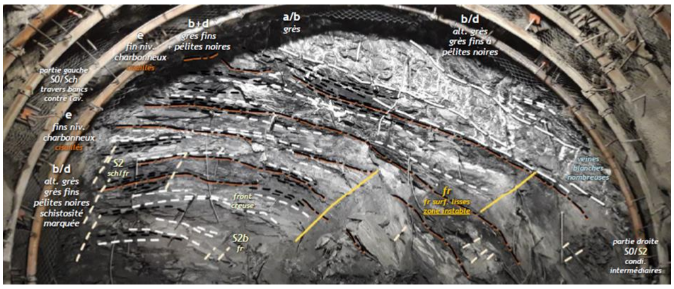

Figure 13 Photograph of a cutting face profile at metric point 11113.8 of Part 3b, with materials classification as LC3

In summary, the heterogeneity of the materials (presence of mixed faces with recoverable and non-recoverable materials) thus limited the possibilities of recovery.

5. CONCLUSIONS

The recovery balance of the materials of parts 2 and 3b of the SMP4 works made it possible to produce Cl1/Cl2 materials representing 25% of the excavated materials, including 137,000 m^3 used to date in the context of the creation of the structures.

The SMP4 reconnaissance work in parts 2 and 3b served to implement and test a materials recovery methodology, the main points of which were:

- Need to precisely define the materials recovery objectives from the works tendering procedure,

Importance of setting up upstream of the recovery organisation work and means,

- Need to choose relevant recovery criteria according to available knowledge,
- Importance of the quality of cutting face pre-sorting, based on a recovery plan relying on progress reconnaissance,
- Importance of carrying out characterisation tests according to the excavation method used to validate the sorting and classification of materials, with a view to their reuse or final storage,
- Need to be able to influence the settings of the TBM cutting wheel (opening rate, wheel pressures, etc.) in order to optimise the quality of the excavated materials so that they can be more readily recovered and in greater quantity (by seeking to limit self-crushing at the cutting face to reduce the proportion of fines in the muck).

The experience feedback from SMP4 works in terms of recovery methodology serve to validate the arrangements taken into account in the consultations for the Base Tunnel works as well as in the PRO/Tendering studies of operational construction site n. 11 dedicated to the recovery of materials.

6. REFERENCES

P. Schriqui, C. Salot, E. Hugot, J. Burdin, La gestion et l'emploi des matériaux excavés du tunnel de base du Mont-Cenis du projet TELT, Tunnels et Espace Souterrain N°266 – Octobre/Novembre/Décembre 2018

J. Burdin, X. Darmendrail, E. Cesolini, L. Brino, La raccomandazione del gruppo di lavoro GT 35 dell'AFTES su La gestione e l'impiego dei materiali scavati, Gallerie e Grandi Opere Sotterranee, settembre 2019, n. 131, pp. 65-67 e inserto pp. 1-50, Pàtron EditoreSETRA LCPC, Guide Technique Réalisation des remblais et des couches de forme Fascicules 1 & 2, Juillet 2000

X. Darmendrail, L. Brino, J. Burdin, Bilan et résultats des études sur la gestion et la valorisation des déblais du tunnel de base de la nouvelle liaison ferroviaire Lyon- Turin, AFTES 2008

X. Darmendrail, J. Rimey, L. Brino, J. Burdin, Nouvelle liaison ferroviaire Lyon-Turin – Une approche d'étude originale pour la valorisation des déblais des tunnels, Tunnel et Ouvrages Souterrains, mars/avril 2003, n. 176, pp. 55-61

C. Thalmann, C. Carron, L. Brino, J. Burdin, Gestion et valorisation des matériaux d'excavation de tunnels – Analyse comparative de trois grands projets, St. Gothard, Loetschberg, Maurienne-Ambin, Congrès International AFTES 2005, Chambéry, 10-12 ottobre 2005, pp. 237-248, Edition Spécifique

X. Darmendrail, L. Brino, J. Burdin, Bilancio e risultati degli studi sulla gestione e valorizzazione dei materiali di scavo del Tunnel di Base della Nuova Linea Torino Lione, Convegno SIG 2011, Verona, 2-3 marzo 2011, pp. 47-55, Editore SIG srl

C. Thalmann, J. Burdin, L. Brino, M. Petitat, Fabrication de bétons de grande qualité à partir de sable riche en mica – Expérience sur les grands chantiers de construction, Congrès International AFTES 2014, Lyon, 13-15 ottobre 2014

Recommandation de l'AFTES n° GT35R1F2, La Gestion et l'Emploi des matériaux excavés, Janvier 2019

Recommandations de l'AFTES GT1R1F1 relatives à la caractérisation des massifs rocheux utile à l'étude et à la réalisation des ouvrages souterrains, 29/04/2003