World Tunnel Congress

Meet you
in NAPLES

WTC 2019

ITA - AITES General Assembly and World Tunnel Congress

TUNNELS AND UNDERGROUND CITIES:
ENGINEERING AND INNOVATION
MEET ARCHAEOLOGY, ARCHITECTURE AND ART

MAY
3|9
MOSTRA D'OLTREMARE
NAPLES 2019

EXHIBITION BROCHURE
SPONSORSHIP OPPORTUNITIES

www.wtc2019.com

Società Italiana Gallerie
Italian Tunnelling Society

ITA
AITES

Tunnels and Underground Cities: Engineering and Innovation meet Archaeology, Architecture and Art – Peila, Viggiani & Celestino (Eds)
© 2019 Taylor & Francis Group, London, ISBN 978-1-138-38865-9

The hugest and more complex belt conveyor system in the longest tunnel under construction in the world: Brenner Base Tunnel

M. Bringiotti
GeoTunnel S.r.l., Genoa, Italy

S. Portner & V. Grasso
Marti Technik AG, Moosseedorf, Switzerland

E.R. Vitale
Ghella S.p.A., Roma, Italy

ABSTRACT: Marti has been working on the Italian side of the Brenner Base Tunnel project since the beginning, starting not only with the bridge which overtakes the Highway, the Isarco river, a National Road, and the Railway line, but also with the supply of the long belt for the Aica-Mules pilot bore. These structures have been designed for those preliminary tunnels as well as for an extensive use in the ongoing project, which is related to the excavation of the main Brenner lines on the Italian side. The operative job sites which the system involves are Mules 1, Genauen 2, Unterplattern and Hinterrigger. These are linked to the already existing plants The system is able to handle contemporarily excavated material produced by n. 3 TBMs and various D&B tunnels (ca. 2.100 t/h capacity) and also brings crushed material to the batching plant installed in the logistic knot cavern, in an Industry 4.0 full integrated optic.

1 INTRODUCTION

Since the beginning of 2017 the BTC consortium, formed by Companies Astaldi, Ghella, PAC, Cogeis and Oberosler, has been involved in the construction of the longest underground railway link in the world: the Brenner Base Tunnel, which forms the central part of the Munich-Verona railway corridor.

The whole project consists of a straight railway tunnel, which reaches a length of about 55 km and connects Fortezza (Italy) to Innsbruck (Austria); next to Innsbruck, the tunnel will interconnect with the existing railway bypass and will therefore reach a total extension of about 64 km.

The tunnel configuration includes two main single-track tubes, which run parallel with a 70m span between each other through most of the track, and linked every 333 m by cross passages (Figure 1).

Between the two main tunnels and driven 12 meters below, an exploratory tunnel will be excavated first. Its main purpose during the construction phase is to provide detailed information about the rock mass Furthermore, its location allows important logistic support during the construction of the main tunnel, for transportation of excavated material as well as that of construction material. During the operations, it will be essentially used for the drainage of the main tunnel.

The excavation process is divided into 2 blocks; the first one will be bored by n. 3 TBMs (n. 2 for the main tunnels and n. 1 for the exploratory tunnel, toward North). The second one will be bored with traditional method, including mainly drill & blast in the competent material and special drilling techniques in the faulty zones, toward South and in some areas toward North.

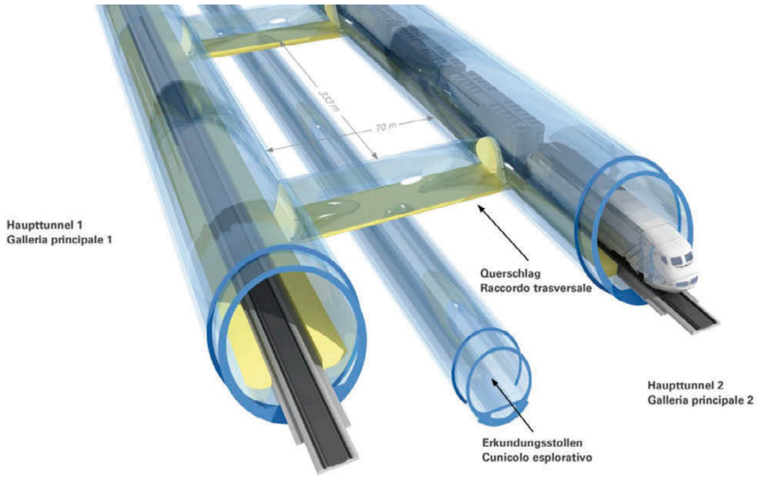

Figure 1. Brenner Basis Tunnel scheme.

The Company CIPA S.p.A. is currently handling most of the tunnel excavations activities in the lot named “Mules 2–3” with the French drilling partner Robodrill SA These mainly consist of:

- Excavation and lining of the ADIT Tunnel at the Trens Emergency Stop and the Central Tunnel, with a total length of approx. 4,500 m;
- Excavation and lining of the Exploratory Tunnel by traditional method, with a total length of approx. 830 m;
- Excavation and lining of the Main Tunnel toward South, East tube and West tube in single track section, with a total length of approx. 7,320 m;
- Excavation and lining of the Main Tunnel toward South East tube and West tube in double track section, with a total length of approx. 2,590 m;
- Excavation and lining of 19 Connecting Side Tunnels linking the two main tubes, with a total length of approx. 900 m.

All the material excavated in traditional method by the subcontractors Cipa, Europea92 and LSI, runs from the central cavern up to the surface, and sized by crusher, by means of MT belt conveyors. The material is also divided in 3 different geological classes and moved according to needs in 2 different depony areas.

2 GEOLOGICAL CONDITIONS

As anticipated, the Brenner Base Tunnel is the high-speed rail link between Italy and Austria and therefore establishes a connection with North East Europe. It consists in a system of tunnels, which include two single-track tunnels, a service/exploratory tunnel that runs 12 m below them and mostly parallel to the two main tunnels, bypasses between the two main tunnels placed every 333 m, and 3 emergency stop stations located roughly 20 km apart from each other. The bypasses and the emergency stops are the heart of the safety system for the operational phase of this line.

Average Overburden is, between 900 and 1.000 m, with the highest one about 1.800 m at the border between Italy and Austria.

The excavation will be driven through various geological formations forming the eastern Alpine Area. Most of these are metamorphic rocks, consisting of Phyllites (22%), Schist (Carbonate Schist and Phyllite Schist, 41%) and Gneiss of various origin (14%). In addition, there are important amounts of plutonic rock (Brixen Granite and Tonalite, 14%) and rocks with various degrees of metamorphism, such as marble (9%).

Among the tectonic structures in Italy, we find the above mentioned Periadriatic Fault. As mentioned, the unknown characteristics of the rock masses along this stretch determined the

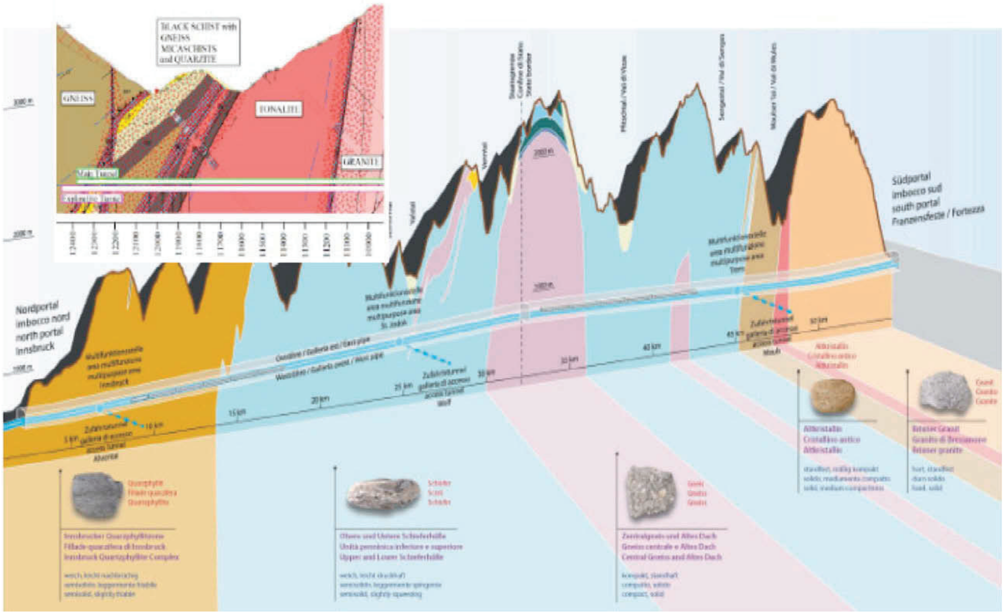

Figure 2. Geological distribution.

necessity of excavating the exploratory tunnel long before the main tunnels, in order to allow the identification of lithological sequences of the various types of rock mass within this heavily tectonized area, as well as a detailed study of their responses to excavation. These analysis were subsequently used to adjust the consolidation and support measures both for the exploratory and for the main tunnels. The excavation of the exploratory tunnel inside the Periadriatic Faults allowed to determine the actual sequence of lithologies within this area.

A geological description is necessary in order to understand the chosen excavation process., This is divided in mechanized tunnelling for the good and competent rock types along the exploratory and the main tunnels toward North, D&B for a limited distance toward South (2–3 km) and in some minor short tunnels as well as several bypasses, and traditional method in the faulty areas. It is also important to understand difficulties related to the excavation in the hard granite as well the related problems linked to the abnormal wear and tear due to high abrasivity.

A summary of the encountered rock sequences is illustrated with Figure 2.

3 THE IDEA

The conveyor belt system allows a straightforward and efficient mean of transportation for material going both in and out from the underground rock crusher, and in and out from the underground concrete batching plants. It evolves while the project is carrying out, and is gradually implemented in accordance to the work's progress.

The conveyor system has been rationalized during the tender phase maintaining its high potential, flexibility and capacity. The differentiation of the two belts in Aica (belt 1 and belt 2) allow each single band to be allocated with a certain type of material; therefore belt 1 is for material A (good material for concrete) and belt 2 is for material B+C (semi-good and not concrete-accepted material). The differentiated configuration avoids alternating different material types with temporary stocking buffer on the same conveyor. However, the system provides the possibility to switch the material types in Aica according to necessities. This kind of realization allows an easier management of the whole system.

Such works may be identified in three major phases. This report is aimed to describe the choices taken within the Construction Project and to list them congruently to the time-related phases.

Without taking into consideration the specific calculations regarding the Executive Work Program's Space-Time Diagram, the 4 major phases may be described as follows:

- Phase 1: excavation of the Exploratory Tunnel (CE) with the conventional excavation method and the TBM assembly chamber; realization of the excavation of the first part of the North Line Tunnels (GLN) by traditional system and excavation of the South Line Tunnels always by traditional method (done by Cipa S.p.A. with its Drilling Partner Robodrill SA);
- Phase 2: continuation of the activities following the previous phase; realization of “in cavern” assembly areas for the two TBMs, which will excavate the Line Tunnels (toward North), excavation prosecution of the South Line Tunnels with drill & blast system (GLS) and realization of the mechanized excavation of the CE Northwards.
- Phase 3: prosecution of the precedent activities, excavation of the North Line by mechanized tunneling (GLN) and subsequent finishing job site works.
- Phase 4: main TBM tunnels secondary final lining. This also represents a complex activity, which will take more than 1 year. A part of this job will be anticipated during TBM excavation, deviating logistic and traffic from one tube to the parallel one.

The phases are integrated and shown in the complex lay out indicated in Figure 3.

All belts generally are connected to the five excavation fronts with the Logistic Knot (N). The system is flexible, but actually in the current phase belts are directly used only for the North bound tunnels (3 TBMs). South bound (conventional excavation) the material is transported by dump truck up to the logistic Knot, where after resizing (by the crushing plant housed underground within the cavern) it is transferred and transported by belt conveyor system.

After that, from Knot N:

- Material type A is carried towards the jobsites Mules and Genauen 2 (depony area reached by a 180m long bridge belt conveyor – 300 ton/h – which crosses the A22 highway, the Isarco river, the National road S.S. 12 and the existing railway line, Figure 4), it is stocked and/or crushed outside and/or transported back to the underground batching plant, in order to provide DB tunnels’ primary and secondary lining.

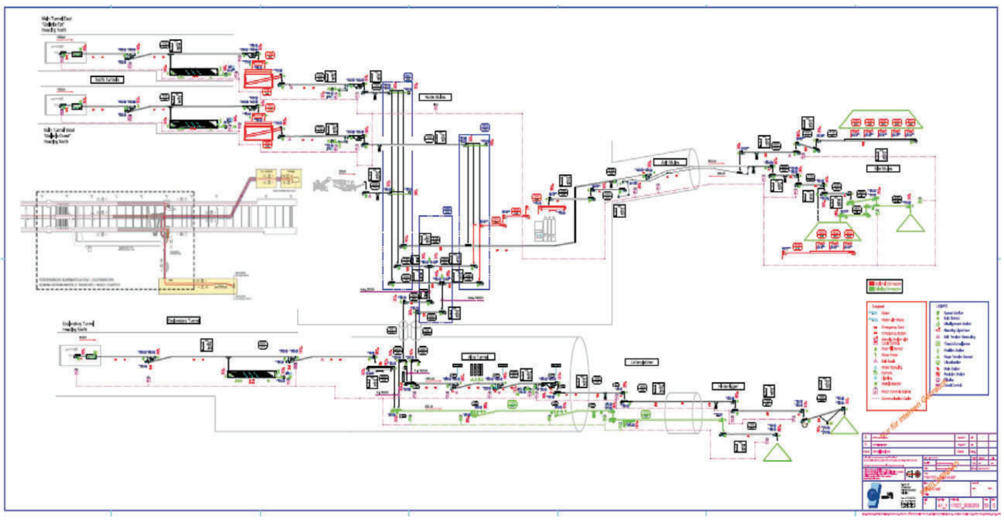

Figure 3. Belt lay out with cavern zoom (center left).

Figure 4. Highway A22 transfer belt to Genauen 2 intermediate waste dump.

- Material type A/B+C is transported to Hinterrigger jobsite and is used to produce the precast elements and as pea-gravel for the TBM's back filling. Concrete segments and pea gravel will be then transported back into the tunnel with a dedicated rolling stock through the AICA Tunnel.

4 BELT CONVEYOR SYSTEM DESCRIPTION

Up next is a description of the whole belt conveyor system taking into consideration the three main project's phases thus in order to provide detailed information about each specific installation. In particular it may be detailed by material class handled by each system (specifically type A in case material is high quality, and types B+C when material quality is poorest, material type A may be used to produce "working concrete" and sprayed concrete), its origin and destination, its potential and capacity in ton/h

4.1 *Phase 1*

During Phase 1, the system includes:

- Existing belt no. 1, located at Mules – Aica stretch, with a 500 ton/h capacity.
- Belt no. 2, which has been be implemented on the same stretch and juxtaposed to belt no. 1, thus resulting in a total capacity of 2.100 ton/h, having a capacity of 1600 ton/h.

Figure 5 shows the existing tunnel section and the related clearances of the two belts, as well as the rail system with the booster section where the two runaways become one.

The new conveyor belt system planned for the Aica Tunnel has been designed in order to allow transportation of material toward Hinterrigger in accordance the tunnel's geometries. These geometries grant a tunnel alignment with a reduced curve radius along the initial part of the tunnel. During the tender phase, changes in the tunnel geometries were explicitly forbidden, disqualification being the penalty.

This has been quite an important technical constraint; having the already existing Aica tunnel a very restricted section, contractually forbidden to provide suitable enlargements (niches) in order to host the necessary booster stations, it hasn't been possible to apply standard solutions. MT and BTC designed compact sized boosters in order to fit in the limited spaces available, leaving a sufficient train runaway.

Therefore, the two belts (no. 1 and no. 2) start at the Exploratory Tunnel chamber, arrive at the Aica – Unterplattner jobsite and continue on the outside. Belt no. 2 is designed to transport the incoming material from all excavation fronts (Main Line Tunnels, Exploratory Tunnel, Trens Emergency Stop, FdE Access Tunnel and new Logistic Knot) from the chamber's Exploratory Tunnel toward Aica.

Already existing belt no. 3 connects the Unterplattner jobsite with Hinterrigger, and has a capacity of 500 ton/h. Transition between belt no. 1 and belt no. 3 occurs through an existing transfer chute located in the Unterplattner jobsite.

Belt no. 4 is built in juxtaposition to belt no. 3; its capacity is 1.600 ton/h. Belt no. 4 will be of the same type as belt no. 2 is therefore an extension. The new belt is located on surface

Figure 5. Belts assembly in the Aica-Mules exploratory tunnel with the booster assembly details.

from the Aica portal to the entrance of the Unterplattner tunnel, a part being on an elevated structure and the other sitting on the ground.

The Figure 6 shows the belt conveyor portion standing in front of the Aica-Mules Exploratory Tunnel, together with its general layout out applied in the Unterplattner area.

Figure 7 shows the general layout out applied in the Hinterrigger area with the various distribution points.

During the excavation of the remaining tunnel stretches excavated with conventional method in the Exploratory Tunnel up until the assembly chamber of the TBM, the transportation of the muck is carried by dump trucks until the TBM dismantling chamber. From the existing chamber, material will be loaded on belt conveyors no. 1 and no. 2. Within said tunnel, later belt no. 7 will be assembled.

Belt no. 8 runs through the whole Mules Adit tunnel toward Mules, as mentioned, with a capacity of 600 ton/h. Just a note on CE material; muck coming from the excavation activities within the Exploratory Tunnel will be transported to Hinterrigger by means of conveyor belt system. The plant is able to separate CE material from A and B+C, but it will be moved only to Hinterrigger

4.2 *Aggregate handling within the Logistic Knot*

All belts coming from the GL tunnel discharge material onto the 3 conveyor belts available at the Logistic Knot; which are:

- One for material A towards Mules
- One for material A towards Hinterrigger
- One for material B+C towards Hinterrigger

The two belts towards Hinterrigger merge in order to transport material into the shaft that connects GL and GE tunnels.

The related material will go down from the upper level, and will be unloaded either on belt no. 1 or on belt no. 2, according to its classification and quantity.

Figure 8 (top right) are a close-up representation of belt no. 10 (the picture may be also referred to belt no. 9), which unload on a lower level through the vertical shaft (on the left).

Belt no. 11 connects belt no. 13 with belt no. 8b. related to the transport of material type A, this belt allows to carry material outwards, thanks to a belt plow switch, supplying the Mules jobsite with good quality material thus in order to mix fresh concrete. Belt capacity is about 1.600 ton/h.

Figure 6. Unterplattern general lay out.

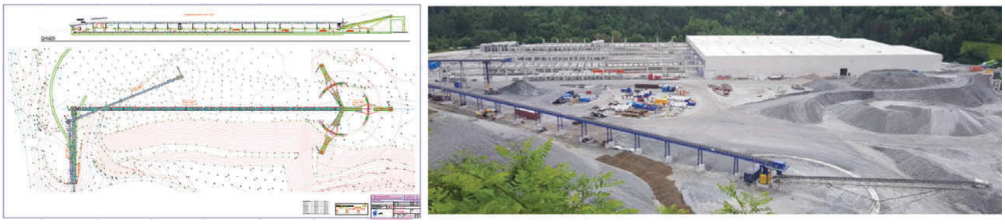

Figure 7. Hinterrigger general lay out.

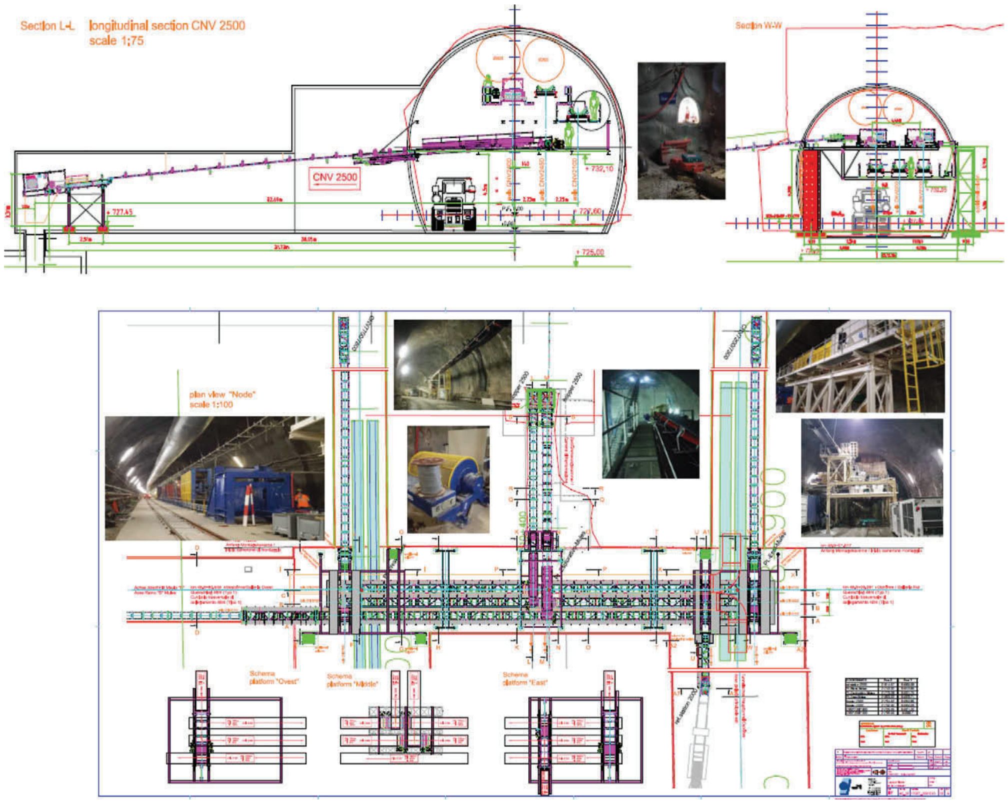

Figure 8. General logistic knot plan view lay out and details.

Figure 8 shows the general layout out of the logistic knot.

As previously reported, in the caverns, transferring devices are provided for each belt; this is the so-called Switch system. It consists of a belt plow system, transferring material on different belts according to classification. One belt is dedicated to material type A and one to material type B+C. These cross the tunnel connecting the two chambers, reaching the connecting pit area down to the Exploratory Tunnel chamber (km 10+4).

Belt no. 12 connects the East bound Tunnel with the Logistic Knot. In this phase the material can be handled in the Movable Crusher located in the GLE assembling chamber. This material converges in the Logistic Knot and heads to jobsites Hinterrigger or Mules. It comes from the GLE, the GLO and the CE excavations. The belt's capacity is 1.000 ton/h.

Belt no. 13 connects the West bound Tunnel with the Logistic Knot and is implemented during this phase. Its capacity is 1.000 ton/h.

Belt no. 23 allows the handled material (crushed and screened in Mules) to return through the Mules Adit. This material is used to produce concrete with the batching plant available in the Logistic Chamber. This belt's capacity is 350 ton/h. Figure 9 shows the related installation.

Belt no. 24 carries material handled by the Movable Crushing Plant to be transferred on belt no. 12. The material then reaches the Logistic Knot. The belt's capacity is 200 ton/h; during this phase, it receives the excavated material of the GLE, GLO and CE. From there,

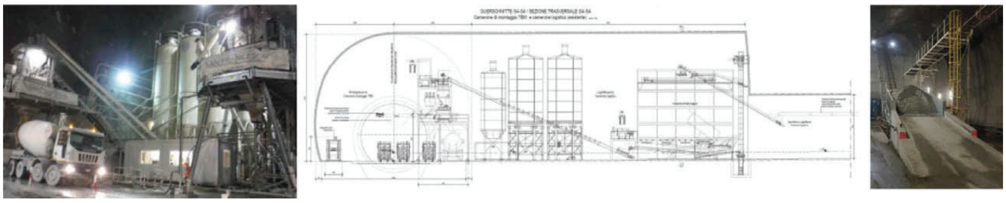

Figure 9. Batching plant installed in cavern.

material reaches the connecting shaft, goes down to the chamber in the Exploratory Tunnel (km 10+4), and then transported to Hinterrigger (classes A and B + C) or in Mules (class A).

Belt no. 25; as previously mentioned, handles the outgoing material from Mules Adit to the surface. The exiting belt no. 25 reaches the south part of the jobsite area, next to the first transfer chute. Through a specific Switch, from there, the muck can either be discharged on ground, on a temporary stock pile, or it can befurtherly transported by the secondary belts (i.e. branch 1 and branch 0) to a second transfer chute toward Genauen 2. Belt no. 25 has a capacity of 600 ton/h.

The peculiarity of this system is the 2 level belt; in which the upper part is able to move material from the cavern, through Mules Adit to the surface, and the lower part handles crushed and sized aggregates (from the surface close to Mules Adit) to the underground batching plant. It has been specially designed in order to handle the various and different demands, in terms of aggregate size and mucking capacity).

Belt no. 26 handles material to Belt no. 23, allowing material handling back to the underground batching plant. The belt's capacity is about 350 ton/h. It handles the crushed material resized in the crushing plant by means of vibrating dosing transfer chutes.

Figure 10 shows the general plant layout in the Mules site.

Belts no. 27 and no. 28 are in the Hinterrigger jobsite, down from Belt no. 4. They are meant to handle material types B+C; Belt no. 28 is a slewing conveyor, suitably designed for stock piling. The capacity of both is 1.600 ton/h each.

Belt no. 29 handles material from Belt no. 3 and serves, as the mentioned, for type A material stock piling. Belt no. 29 has a maximum capacity of 500 ton/h.

4.3 *Phase 2*

All of the mentioned belts are installed during Phase 2.

The excavation of the Exploratory Tunnel with conventional method up to the TBM dismantling chamber is conducted during phase 1. Transportation of muck is preferably handled with conveyor belts when the supply time is favorable. In case of delay, the material is handled by means of dump truck. During said phase Belt no. 7 handles the mechanized excavation material to the Logistic Knot, from where it is transported to Hinterrigger as material type A or B+C. Belt no. 7 has a capacity of 500 ton/h.

All the material excavated by D&B is moved to the underground crushing plant, and then transported via belt conveyor on surface (Hinterrigger or Mules).

4.4 *Phase 3*

In main phase 3 the previously installed belts are continuously extended in accordance to the mechanized excavation advancement rate. together with the belts for the mechanized excavation towards North.

Belt no. 7 is extended consequently to the advancement of the mechanized excavation in the Exploratory Tunnel. The extension belt station is located within the TBM launch chamber (km 1+29). From there, the excavation material is carried to the chamber at km 10+47 with a fixed belt. Muck is transported from the TBM belts in the GLN to 100mc transfer chutes in order to manage potential minor stops without interrupting the excavation activities as well as to level off the flow of material coming from the node.

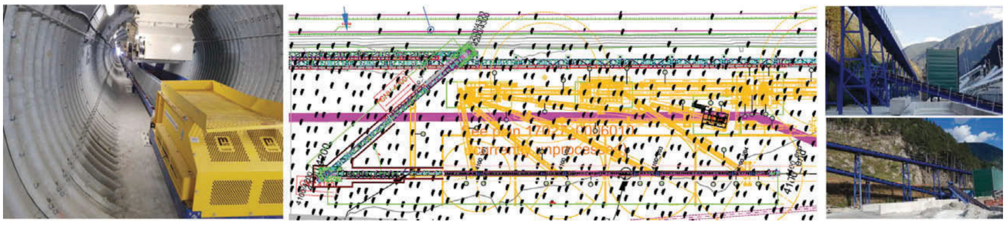

Figure 10. General plan overview site Mules with external crushing plant and extraction pits.

Belts no. 19 and 20 allow transportation of the excavation material coming from the mechanized excavation of the North-East Tunnels to the Logistic Knot. Material is crushed within the TBM and transported on conveyor belts toward the east TBM assembly chamber (km 49+0) first, and to the Logistic Knot through Belt no. 12 after. An independent system of conveyor belts is planned, and it gradually extendes as the job progresses. Afterwards, from the Logistic Knot it is transferred to Hinterrigger or Genauen 2, according to the material quality and the stock capacity. Both belts have a 1.000 ton/h capability.

Belts no. 20 and 21 allow transportation of excavation material coming from the mechanized excavation of the North-West Tunnels to the Logistic Knot. Material is crushed within the TBM and transported on the conveyor belts toward the East TBM assembly chamber (km 49+0) first, and to the Logistic Knot through belt no. 13 next. An independent system of conveyor belts is planned, and it is gradually extended as the job progresses. Further, from the Logistic Knot it is then transferred to Hinterrigger or Genauen 2, according to the material quality and the stock capacity. Both belts have a 1.000 ton/h capability.

5 THE SYSTEM IN NUMBERS

At the end, the approx. 80 km long system will be installed (integrated with the already existing one, ca. 14 km), with a total installed power of more than 10 MW, which is a really huge number, taking into consideration the complexity of the working sites; see summary table in Table 1.

6 THE SYSTEM'S BRAIN

The various MCCs (Motor Control Centres) are installed in a special container equipped with a suitably dimensioned air conditioning system, which is able to safely handle high working temperatures and potentially dusty atmosphere.

The belt conveyor system in its complexity is equipped with a PLC system, which is able to manage all the functions provided with HDMI design for easy and friendly interface.

Safety devices have been installed in all critical points in order to detect any critical occurrence in advance, and to keep the system working safely in accordance with its quite long working life (at least 4 years).

Table 1. General design data in items [n], length [m] and power [kW].

Areas	Items	N.	Length [m]	Power [kW]
Mules logistic knot	Belts	6	211	206
	Chutes	2		
	Dosing units	2		
	Service platforms	3		
Tunnel North	Belt explorative tunnel	1	16.763	
	N-E belt	2	7.195	
	Main tunnel N-E	1	13.182	
	Main tunnel N-W	1	13.223	
			50.363	5.981
Tunnel South	Belt	1	50	22
Aica - Unterplattner - Hinterrigger	Aica belt	2	10.761	
	Unterplattner - Hinterrigger	1	1.169	
	Hinterrigger	2	499	
	Movable stacker	1	48	
			12.477	2.778
Adit Mules	Belts	3	1.979	673
Site Mules	Belts	6	831	213
TOTAL - new installation			65.911	9.873

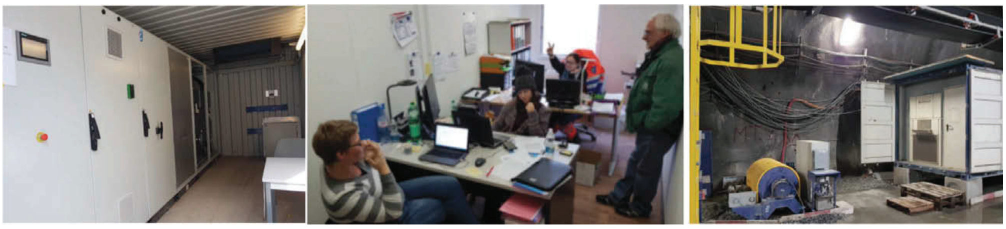

Figure 11. Control rooms and MT's Team in Mules.

Since the handled material is highly wearing, due to the extreme quartz content in the excavated rock (mainly granite), ordinary and extraordinary maintenance is planned according to the various usage coefficients managed by a specifically designed algorithm.

No. 3 control rooms have been foreseen in the critical areas. They are all interconnected between each other. From the job site MT Technicians can control easily the full system (Figure 11).

24/7 Tele-Assistance is granted by Marti Technik with a simple Wi-Fi connection, which link directly to Marti offices in Switzerland.

7 CONCLUSION

Handling such a complex project, is a matter of Team work between highly professionals; in no way can it be considered as simple "procurement and supply" activities. Main target has been the complex design considering the already existing systems within the jobsite. The challenge to ease the work flow of 6 excavation fronts, selecting and conveying muck into classes and needing to feed the underground batching plant with suitable aggregates as well. Partnership between the Main Contractor and the Supplier is the key to success.

ACKNOWLEDGMENT

All the BTC Team must be acknowledged for the hard and professional work done together, starting from feasibility study to the contractual and supply set-up; C. Bernardini, G. Frattini, S. Citarei, M. Ferroni, M. Secondulfo, A. Caffaro, R. Paolini, G. Vozza, A. Cicolani. In MT: R. Damaris, H.J. Meier, P. Rufer and the CEO W. Aebersold!

REFERENCES

Bringiotti, M. 2002. *Frantoi & Vagli: trattato sulla tecnologia delle macchine per la riduzione e classificazione delle rocce*, Febbraio, Edizioni PEI.

Bringiotti, M., Duchateau, JB, Nicastro, D. & Scherwey, P.A. 2009. *Sistemi di smarino via nastro trasportatore - La Marti Technik in Italia e nel progetto del Brennero* Convegno "Le gallerie stradali ed autostradali - Innovazione e tradizione", SIG, Società Italiana Gallerie, Bolzano, Viatec.

Bringiotti, M., Parodi, G.P. & Nicastro D. 2010 *Sistemi di smarino via nastro trasportatore*, Strade & Autostrade, Edicem, Milano, Febbraio.

Fuoco, S., Zurlo R. & Lanconelli M. 2017. *Tunnel deformation limits and interaction with cavity support: The experience inside the exploratory tunnel of the Brenner Base Tunnel*, Proceedings of the World Tunnel Congress – Surface challenges – Underground solutions. Bergen, Norway.

Rehbock, M., Radončić, N., Crapp, R. & Insam, R. 2017. *The Brenner Base Tunnel, Overview and TBM Specifications at the Austrian Side*, Proceedings of the World Tunnel Congress– Surface challenges – Underground solutions. Bergen, Norway.