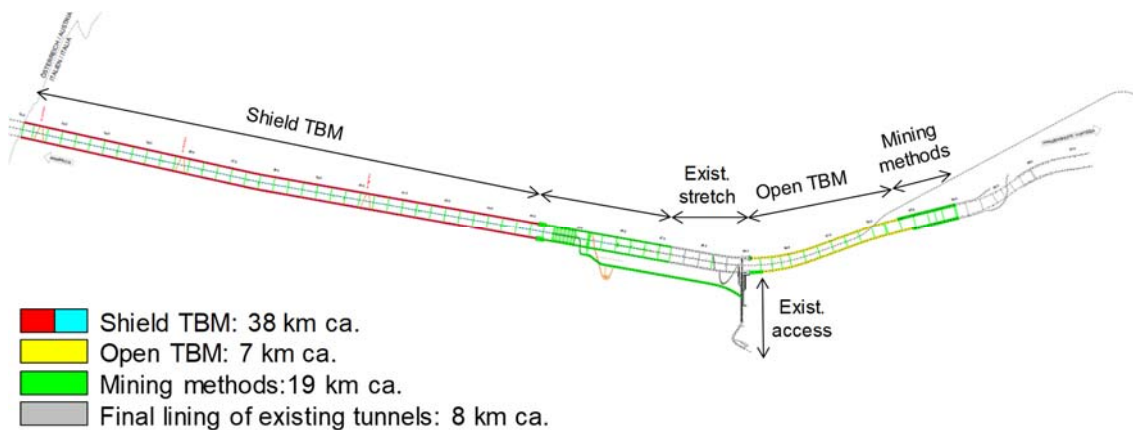


Brenner Base Tunnel, Italian Side: construction methods for a railway 22 km long tunnel

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Pro Iter, Milan, Italy

ABSTRACT: The Brenner Base Tunnel is mainly composed by two single track Railway Tunnels and an Exploratory Tunnel; Lots Mules 1 and 2-3 and previous Preparatory Lot concern a 22 km long stretch on the Italian side. They cross the South part of mountainous dorsal between Austria and Italy, under over-burdens up to 1850 m, consisting of rocks both of the Southalpine and Australpine domains, separated by the major Periadriatic Fault. More than 30 km of tunnels have to be carried out with dimensions ranging from 7 m (Exploratory Tunnel) to 20 m (Logistics Caverns). This results in an extremely hard logistic, geological and geomechanical challenge. During design, different construction options were evaluated, from all the technical, economic and schedule point of view, duly considering the construction risks. The paper explains the design choice of a mix of Mechanized (TBM) and Mining Methods excavation, identified as the most convenient solution.



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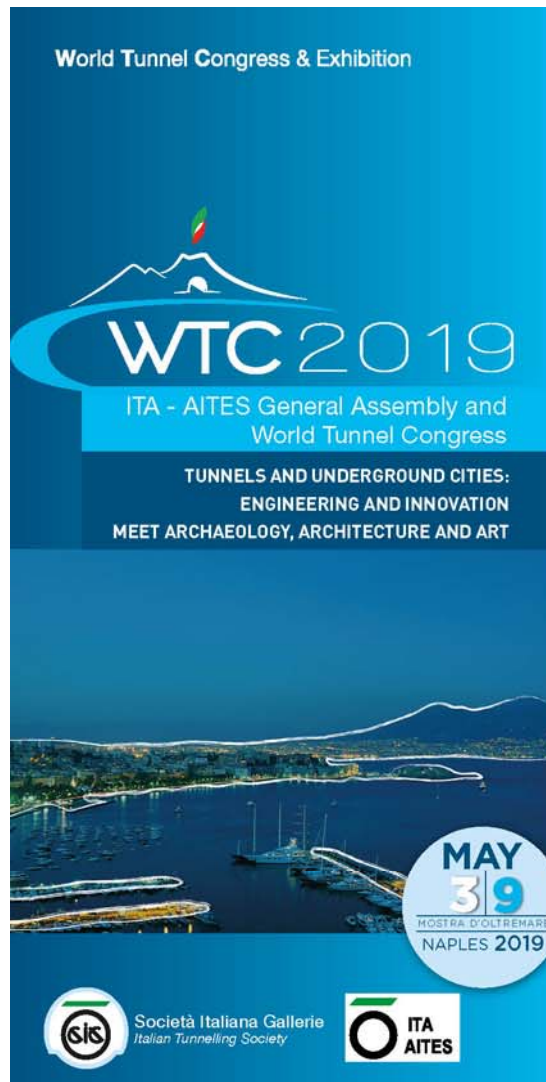


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Long and deep tunnels



BBT, ITALIAN SIDE: CONSTRUCTION METHODS FOR A RAILWAY 22 km LONG TUNNEL

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Introduction – Why BBT?

The Brenner Base Tunnel (BBT) is the heart of the **Scandinavia-Mediterranean TEN Corridor** from Helsinki to La Valletta.

from:
Fortezza (Bz – Italy)

to:
Innsbruck (Austria)

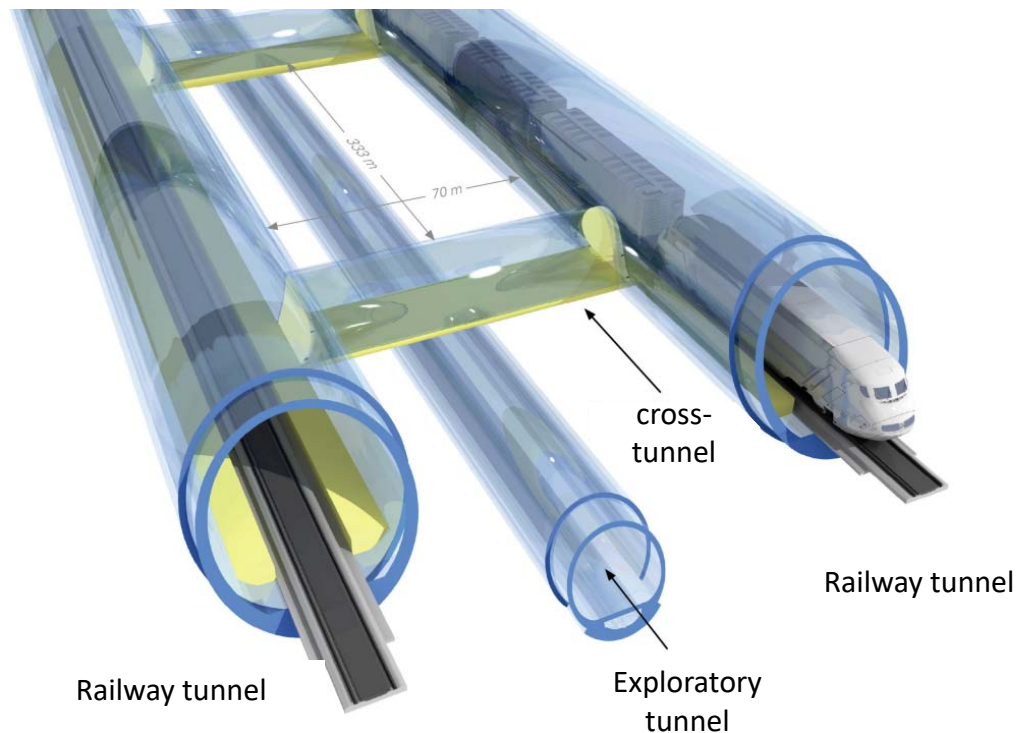


Main goals:

- Freight transport: modal shift from road to rail
- Passenger transport: reduce travel time



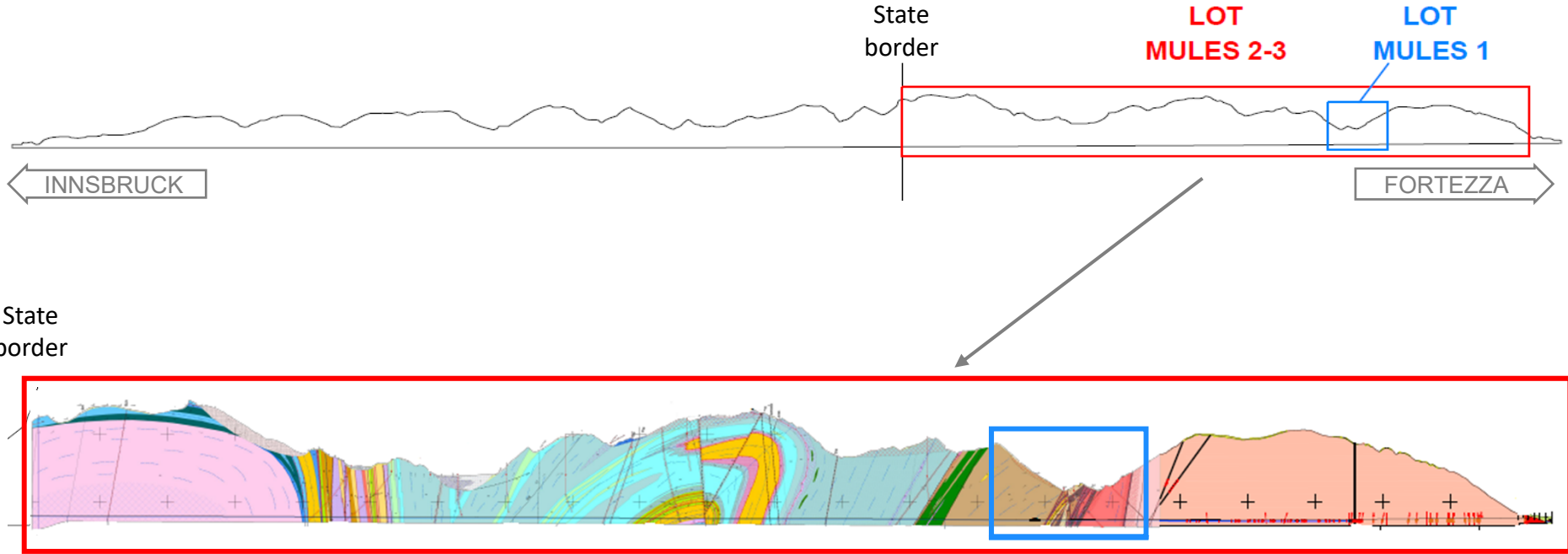
Introduction – The system



Main system components:

- 2 **Railway Tunnels**, generally single track, 8.8 m wide (internal), running 40-70 m apart from one another.
- 1 **Exploratory Tunnel** between the two main tunnels and about 12 m below them, 5.0 m wide, aiming to provide information on the rock mass, to drain rock mass water and working as service tunnel during BBT operation .
- **Cross-tunnels** every 333 m, used in emergencies as escape routes and accommodating plants facilities.
- 3 **Emergency Stops (ES)** for train halt in case of unforeseen events.
- 4 **Access Tunnels (AT)** to connect the system with the outside.

Introduction – Geology



Introduction – Construction lots on Italian side

Preparatory Lot (2008 – 2011) First phase of logistic works for following lots

- Exploratory Tunnel from Unterplattner construction site to Mules underground logistic hub (10.5 km)
- Unterplattner Tunnel from Unterplattner construction site to Hinterrigger main repository (0.4 km)
- Mules access Tunnel from Mules construction site to Mules underground logistic hub (1.7 km)

Mules 1 Lot (2011 – 2015) Second phase of logistic works for following lots

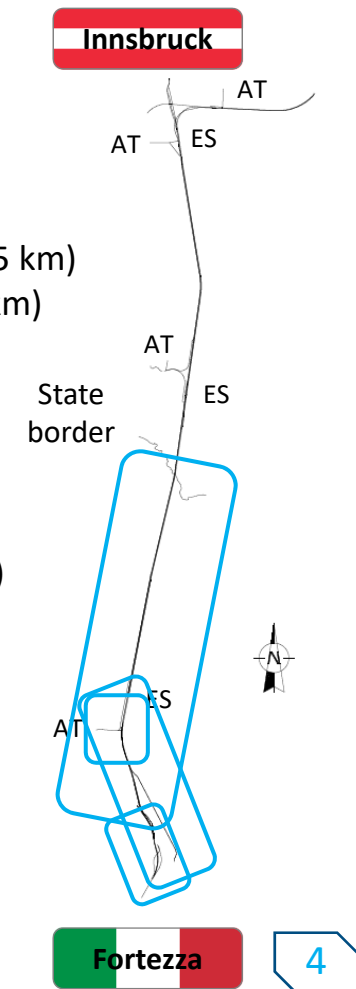
- Mules underground logistic hub completion.
- Ventilation chamber and shaft for logistics during construction and for final phase ventilation
- Crossing of Mules Fault Line with Exploratory Tunnel (19. km) and Railway Tunnels (1.8 + 1.8 km)

Isarco river underpass (2014 – ongoing) Connection with Fortezza station







- Underpass of Isarco River and other facilities (A22 Highway, SS12 Motorway, existing railway line) both via cut and cover and mining methods

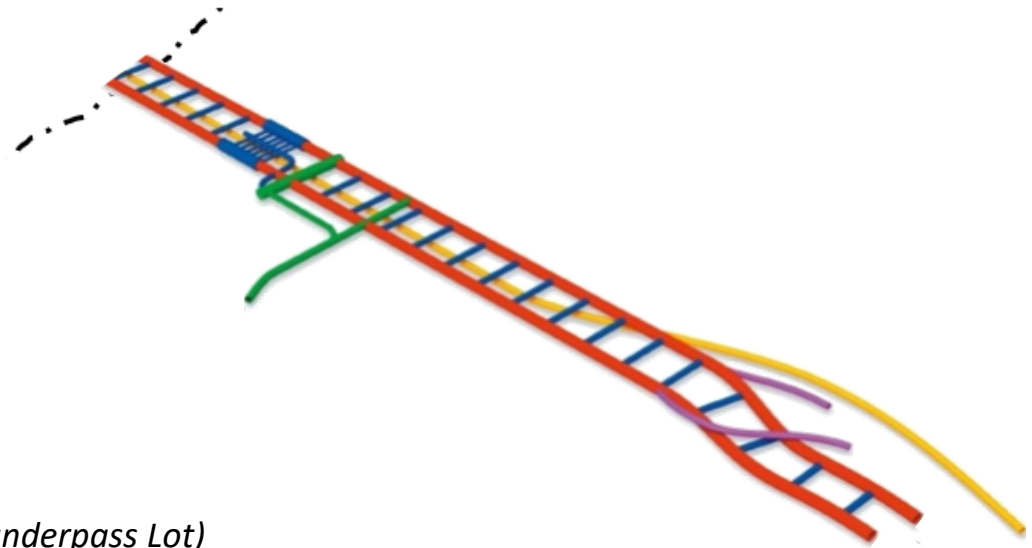
Mules 2-3 Lot (2016 – ongoing) Connection with Austrian side

- Main construction lot on Italian side (completion of Exploratory Tunnel and of Railway Tunnels, construction of 1 Emergency Stop, final lining of all works)



Lot Mules 2-3 – Civil works

-  22.0 km of twin Railway Tunnels
-  17.0 km of new Emergency Tunnel
-  3.8 km of new Access Tunnel
-  69 Cross Tunnels
0.7 km of Ventilation Tunnel
-  0.5 km of Emergency Stop
-  connection tunnels (*in Isarco river underpass Lot*)



Lot Mules 2-3 – Logistics

Northern limit of Mules 2-3 Lot: Pfon-Brenner Lot on Austrian side (in construction)

Southern limit of Mules 2-3 Lot: Isarco river underpass Lot (in construction)



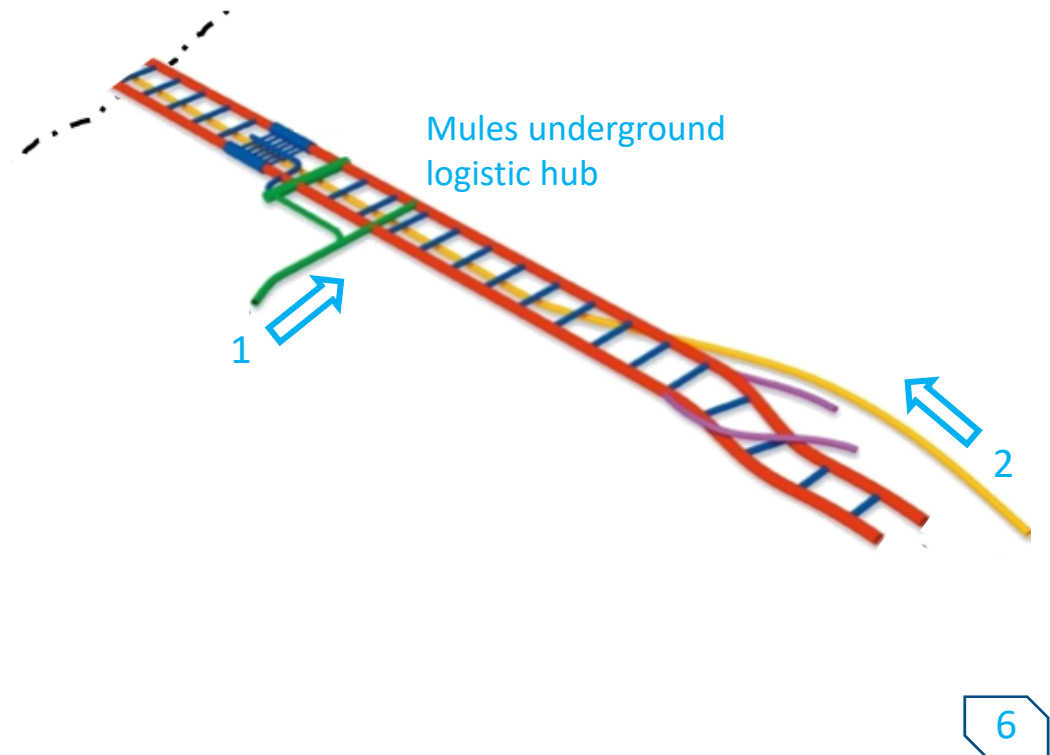
Only two accesses for the construction:

1. Mules Access Tunnel

Not barycentric to the lot (17 km toward North, 5 km toward South) and with 9 % longitudinal slope

2. Exploratory Tunnel

10 km from Mules underground logistic hub to its southern adit in Aica (far from railway tunnels southern adit)



Lot Mules 2-3 – Design phase: construction methods

Northern stretch of Exploratory Tunnel and Railway Tunnels

- End of Mules Fault Line still uncertain
- Emergency stop bigger than current railway tunnels, with many openings for cross and ventilation tunnels
- Possible geomechanical problems both in Emergency Stop area and in northern part of the lot



Mining methods in a first, shorter stretch

- Exploratory tunnel: up to the end of Mules Fault Line
- Railway tunnels: up to the end of Emergency stop

Single shield TBM in the following, longer stretches (both Exploratory and Railway Tunnels)

Excavation method	Work	Stretch
Single shield TBM	Exploratory tunnel	From the end of the Mules Fault Line to state border (13.9 km)
2 Single shield TBMs	Railway tunnels (North)	From 150 m North of the Emergency Stop to state border (12.0 + 12.0 km)
Open TBM	Railway tunnels (South)	From Mules underground logistics hub to the southern limit of the lot (3.5 + 3.5 km)
Mining methods	Exploratory tunnel	First part 0.8 km)
Mining methods	Railway tunnels (North)	First part (3.0 + 3.0 km)
Mining methods	Access Tunnel to Emerg. Stop	All (4.5 km)

Lot Mules 2-3 – Design phase: construction methods

Southern stretch of Railway Tunnels

- Good geomechanical conditions
- Not on the critical path, but need to anticipate the setting up (arriving from the South)
- A maximum of five simultaneously active advancements fronts (ventilation limits)



Open TBM (to be used for both tunnels)

Excavation method	Work	Stretch
Single shield TBM	Exploratory tunnel	From the end of the Mules Fault Line to state border (13.9 km)
2 Single shield TBMs	Railway tunnels (North)	From 150 m North of the Emergency Stop to state border (12.0 + 12.0 km)
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Lot Mules 2-3 – Design phase: construction methods

Access Tunnel to the Emergency Stop

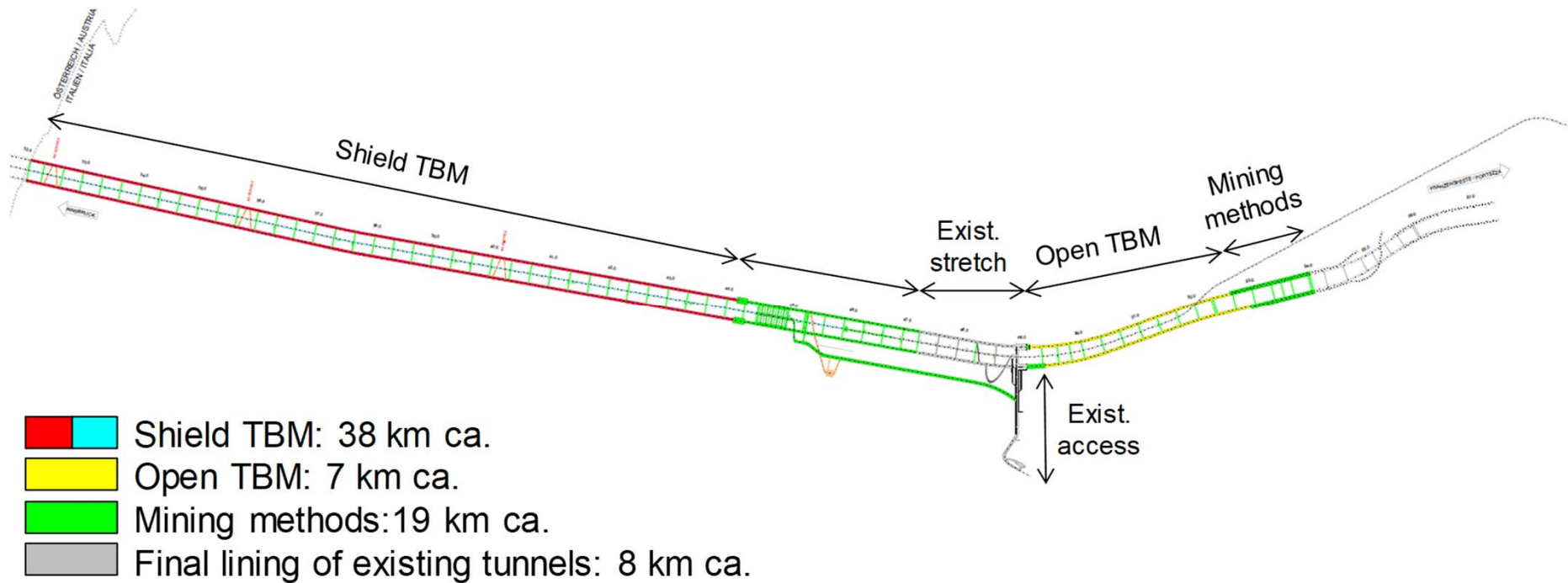
- Relatively short track
- High slope stretch at the crossing point of the Western Railway Tunnel
- Variability of the sections along the works



Mining methods

Excavation method	Work	Stretch
Single shield TBM	Exploratory tunnel	From the end of the Mules Fault Line to state border (13.9 km)
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Lot Mules 2-3 – Design phase: construction methods



Lot Mules 2-3 – Design phase: logistics

Goals of design logistics study

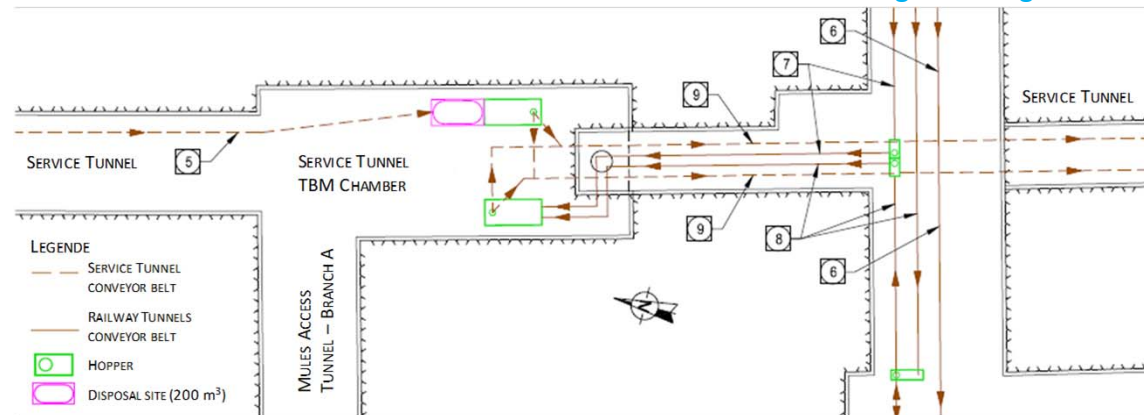
- Organize building sites in the most possible rational and operative way
- Reduce the impact on the territory and environment



Features of design logistics study:

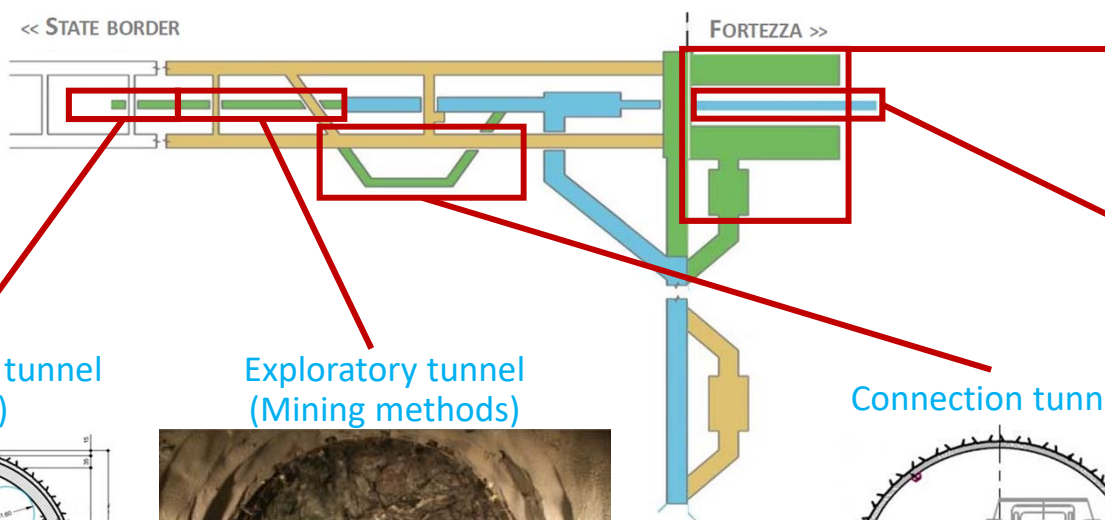
- Re-use good quality excavated rock mass as much as possible (concrete aggregate, fillings)
- Distributing poor quality excavated rock mass on the shortest route
- Mechanize as much as possible the transport of spoils and supply materials, thus reducing the road transport
 - Spoil management with conveyor belts from the excavation fronts to Mules underground logistics hub, to convey the spoils in two directions: materials for concrete production to Mules construction site; materials not suitable for concrete to Hinterrigger final repository
 - Railway system with shuttle trains to supply the fronts with construction materials (e.g. precast segments, concrete both sprayed and cast).

Detail of Mules underground logistic hub



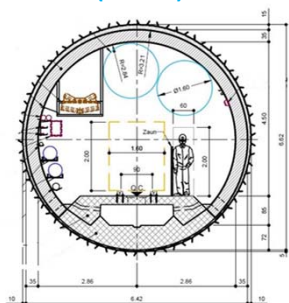
Lot Mules 2-3 – Design phase: logistics

Mules underground logistic hub



Logistic chambers

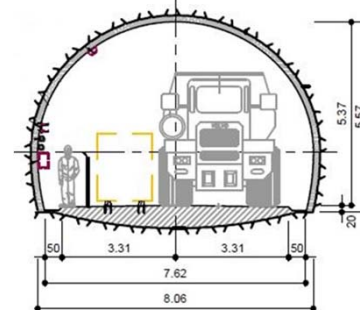
Exploratory tunnel (TBM)



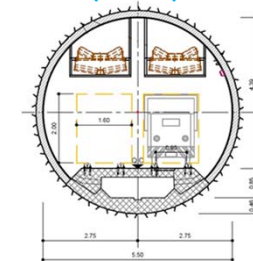
Exploratory tunnel (Mining methods)



Connection tunnel



Exploratory tunnel (TBM)



Brenner Base Tunnel, Italian side: construction methods for a railway 22 km long tunnel

Lot Mules 2-3 – Design phase: logistics

Mules area:

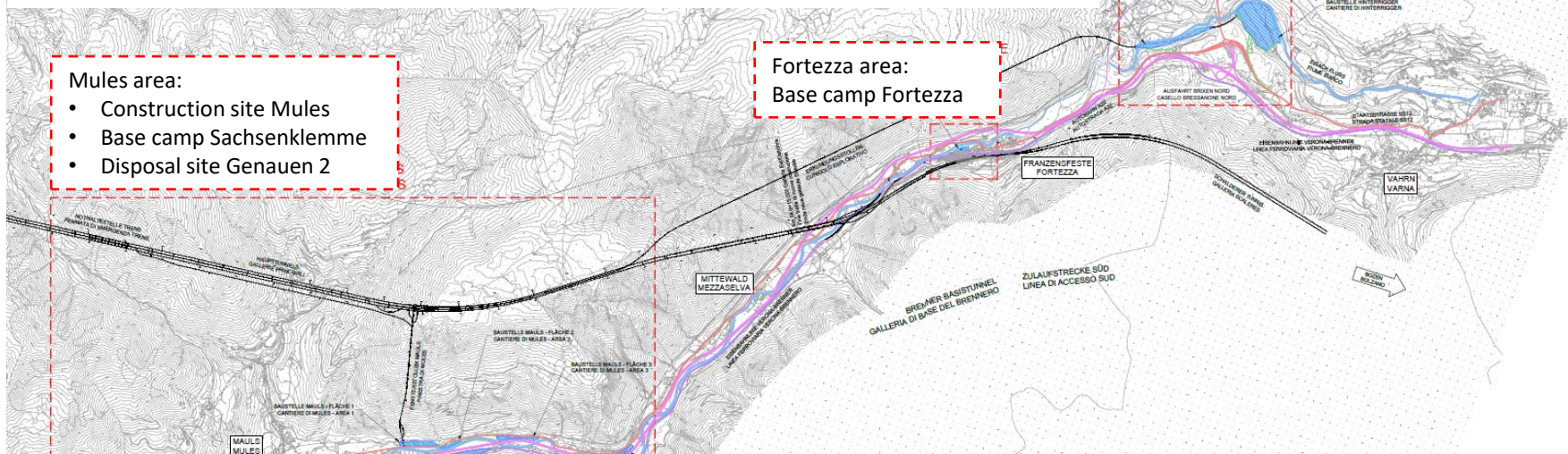
- Construction site Mules
- Base camp Sachsenklemme
- Disposal site Genauen 2

Fortezza area:

Base camp Fortezza

Aica area:

- Construction site Unterplattner
- Disposal and construction site Hinterrigger



Mules construction site



Unterplattner construction site



Hinterrigger repository / construction site



Lot Mules 2-3 – Construction phase: construction methods

Northern stretches of Exploratory Tunnel and Railway Tunnels

In Tender phase, in-depth evaluation of the Contractor together with TBM producers



Double shield TBM

With some features allowing to really **guarantee the performances of a single shield TBM**, when forced to operate in single shield mode:

- **Thrust system** with capacity equivalent to a single shield TBM
- **Reduction of shield length**
- **Increasing the conical shape** of the shields
- **Increasing the number of positions** for ground improvements and investigation



Exploratory Tunnel (Ø6.8 m)



Railway Tunnels (Ø10.7 m)

Lot Mules 2-3 – Construction phase: construction methods

Northern stretches of Exploratory Tunnel and Railway Tunnels

- Mules Fault Line ends further South than expected
- No major geomechanical problems in Emergency Stop area (after Exploratory Tunnel excavation via TBM)
- Contractor in-depth analysis on the Emergency Stop to verify its possible execution with TBM (slight planoaltrimetric misalignment between railway and excavation axis; connection between final lining and precast segments).



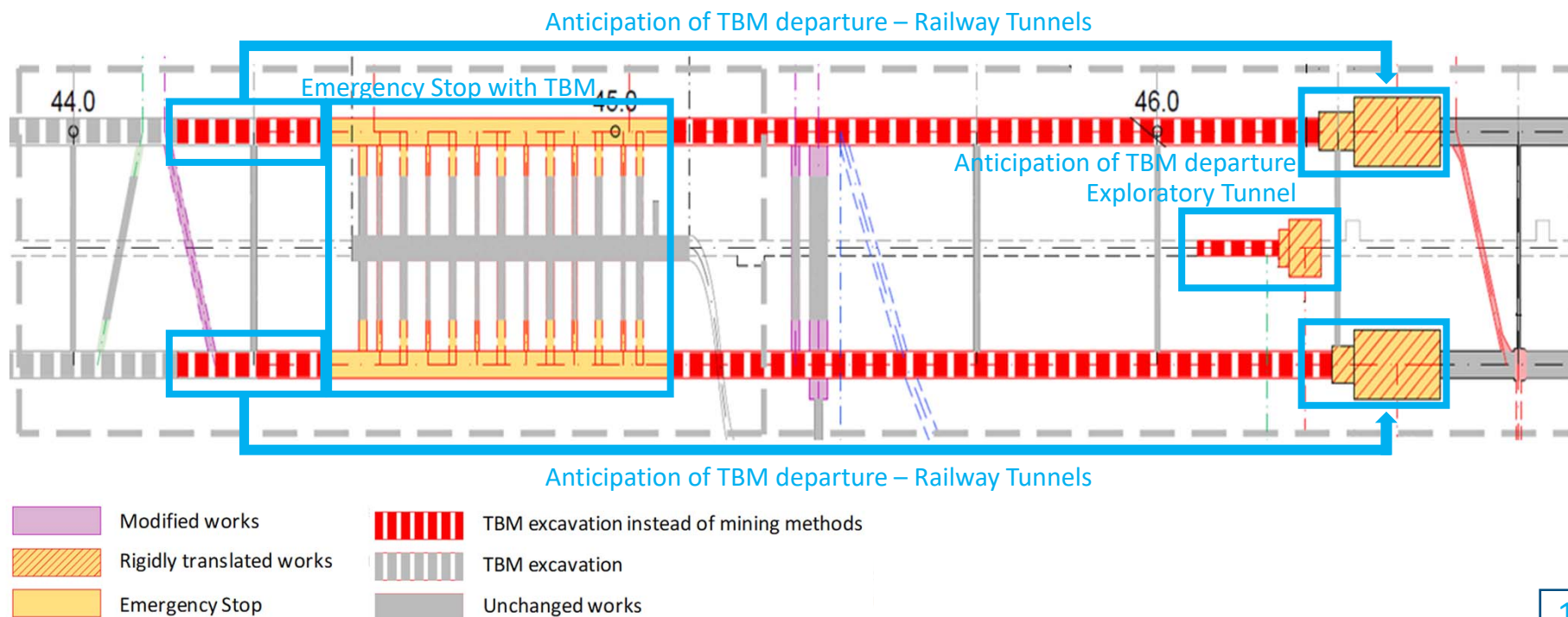
Anticipation of TBM departure

- Exploratory Tunnel: 200 m further South
- Railway Tunnels: 2.2 km further South



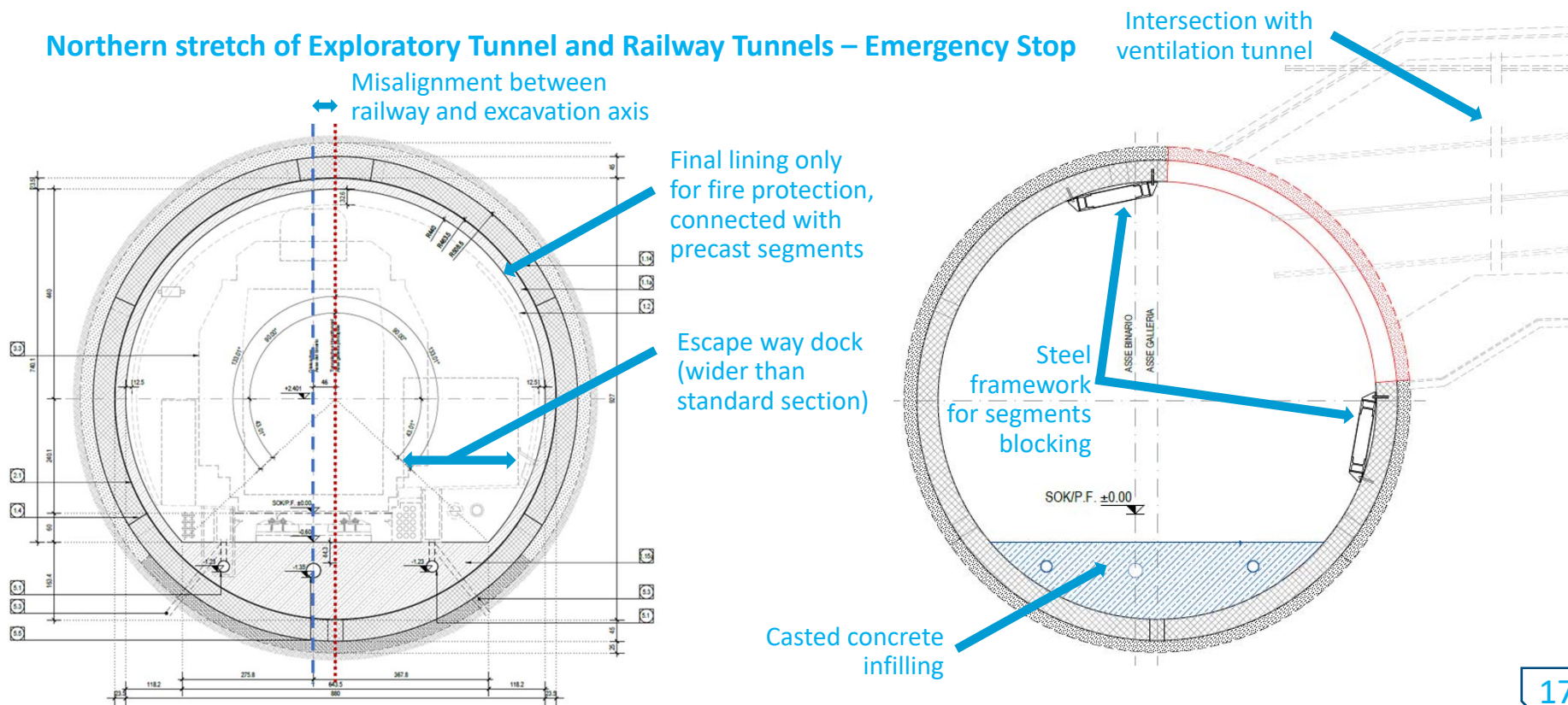
Lot Mules 2-3 – Construction phase: construction methods

Northern stretch of Exploratory Tunnel and Railway Tunnels



Lot Mules 2-3 – Construction phase: construction methods

Northern stretch of Exploratory Tunnel and Railway Tunnels – Emergency Stop



Lot Mules 2-3 – Construction phase: construction methods

Southern stretch of Railway Tunnels

- Guaranteeing the efficiency of the ventilation system, allowing six simultaneous advancements fronts



Mining methods

- Simultaneous excavation of both southern railway tunnels
- Compliance with the planned construction time ensured by casting of the final lining along with the excavation



Lot Mules 2-3 – Construction phase: logistics

The Contractor is allowed to set up its own logistics, according to its own equipment, experience and organization, respecting three constraints:

- Areas for construction sites and repository
- Compliance with the requirements (especially the environmental ones) imposed by authorities
- Amendments cannot entail aggravations for the Client in terms of construction times and / or costs



Main change proposed: **installation of a prefabrication plant for TBM segments in Hinterrigger**

- **Saving in time and costs for the Client** (eliminates transfer of aggregates to external plants)
- **Reduction of impact on the territory** (handling of aggregates and segments takes entirely place within the construction site)



Lot Mules 2-3 – Conclusions

BBT Railway system

- Considerable length
- Geological-geomechanical complexity
- Logistical complexity (just one point of attack + 1 logistic access)



Definition of the construction methods based on many factors, such as the advancement safety and the respect of times and costs of construction



Only the synergy between Client, Designer and Contractor can guarantee the optimal achievement both in construction and in operation



Brenner Base Tunnel, Italian side: construction methods for a railway 22 km long tunnel

THANKS FOR YOUR ATTENTION!