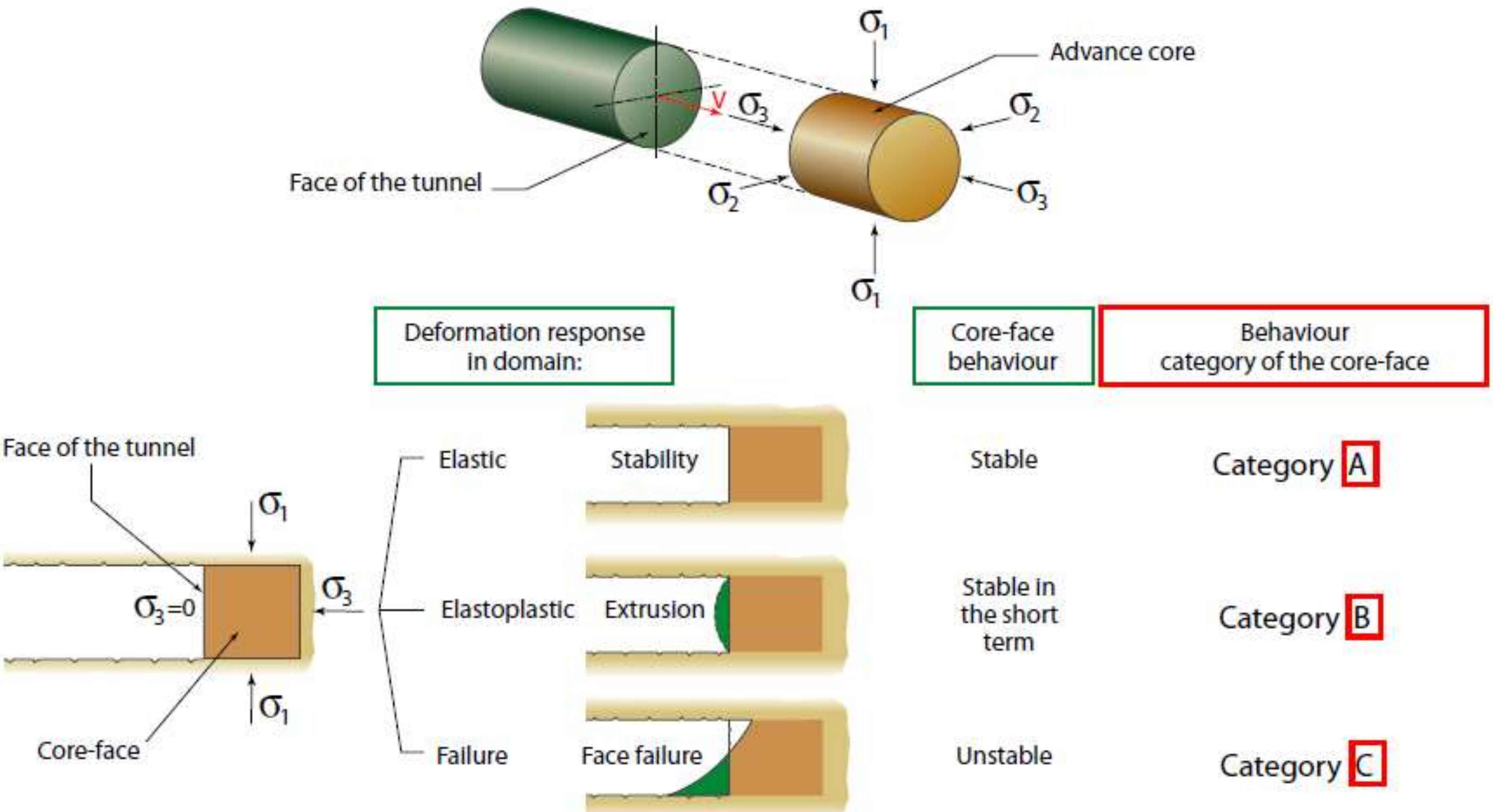
ANALYSIS of the Deformation Response according to ADECO-RS

SUMMARY OF THE RESEARCH FINDINGS

ANALYSIS of core-face Deformation Response according to ADECO-RS

According to the different possible stress-strain states, the behavior of the ground upstream of the excavation face, becoming zero the principal minor stress σ_3 as a consequence of the face advancement, can be indicatively classified in three different situations: stable core-face (elastic domain), core-face stable in the short term (elastoplastic domain), unstable core-face (failure domain), to which, in terms of simplification, can be respectively associated three fundamental behaviour categories: A, B and C.



ANALYSIS of core-face Deformation Response according to ADECO-RS

Example of

stable core-face

in elastic domain

(Category A)

ANALYSIS of core-face Deformation Response according to ADECO-RS

Example of stable core-face in the short term in elasto-plastic domain

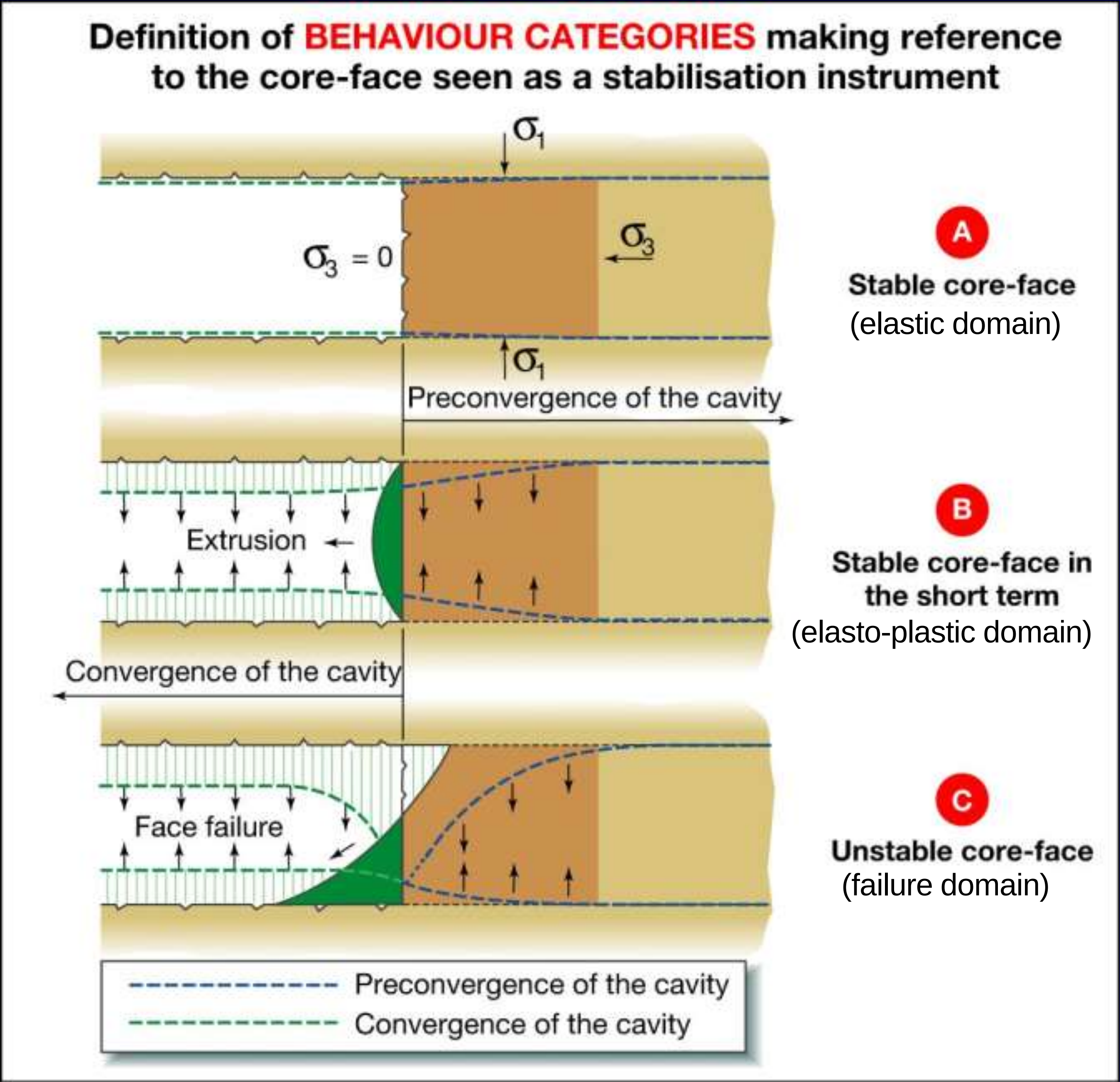
(Category B)

ANALYSIS of core-face Deformation Response according to ADECO-RS

Example of unstable core-face in failure domain

(Category C)

Analysis of the Deformation Response according to ADECO-RS



The stability of the core-face is analyzed by experimental and mathematical models up to identify the stress-strain behavior (categories A, B, C)

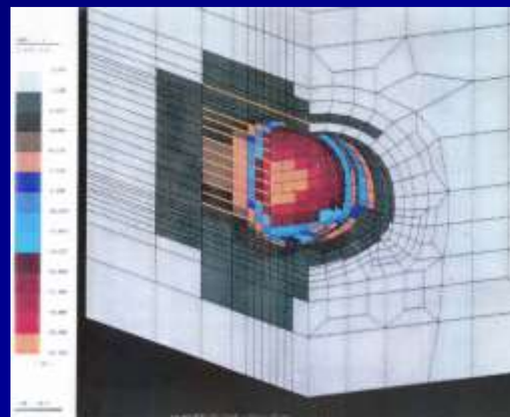
It has been shown that the type B and C behaviours can be reported under Category A by acting on the core-face rigidity

This is the main task of the tunnel designer

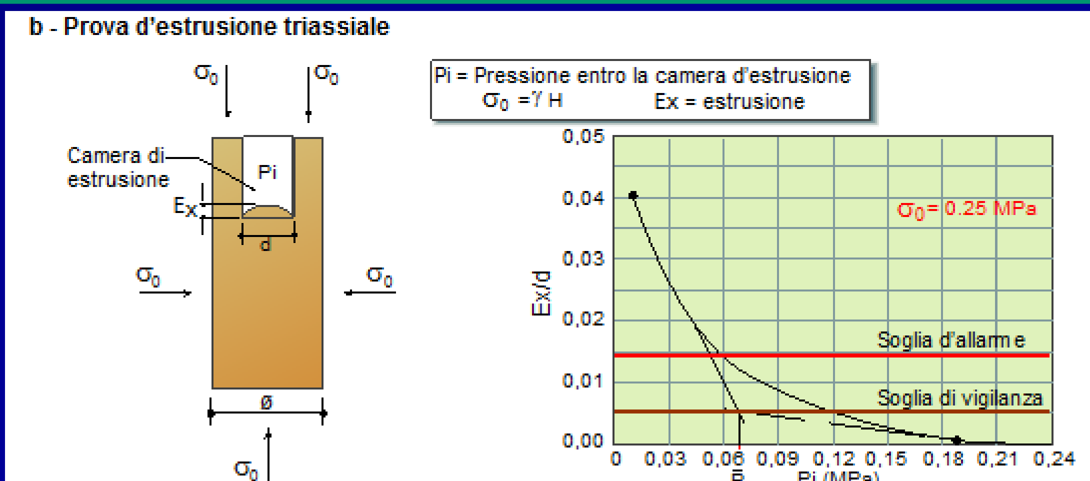
ANALYSIS of core-face Deformation Response according to ADECO-RS

During the design the theoretical prediction of the behavior categories A, B and C is done

3D Finite Elements



Numerical calculation



Experimentation on a reduced scale in the laboratory

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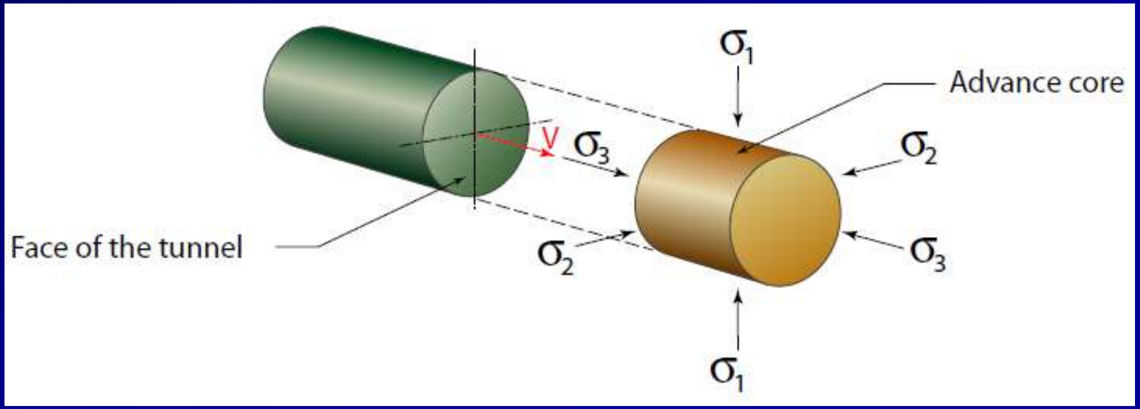
CONTROL of core-face Deformation Response according to ADECO-RS

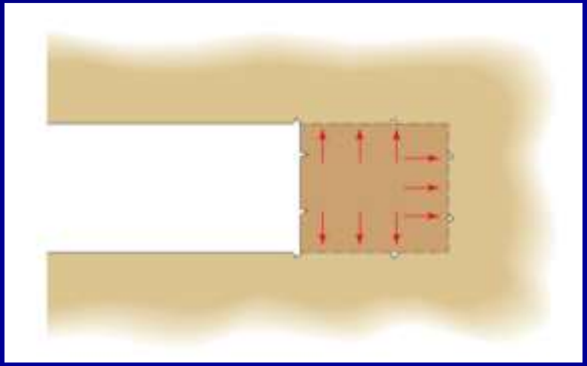


The ADECO-RS, as a result of the research results, recognizes the <u>centrality of the core-face as stabilization instrument for the cavity</u>; hence the imperative need <u>to always advance full face</u>, especially in the most difficult conditions, having shown that the instability of the cavity comes from the instability of the core-face.

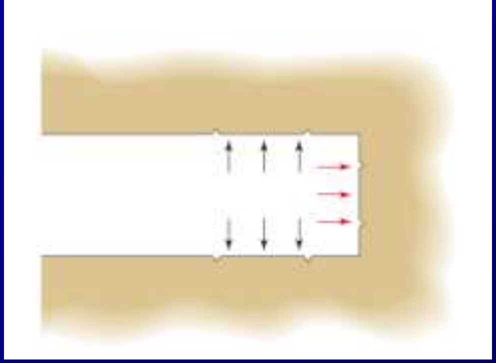
CONTROL of the Deformation Response according to ADECO-RS

CONTROL OF THE CORE-FACE DURING

DESIGN

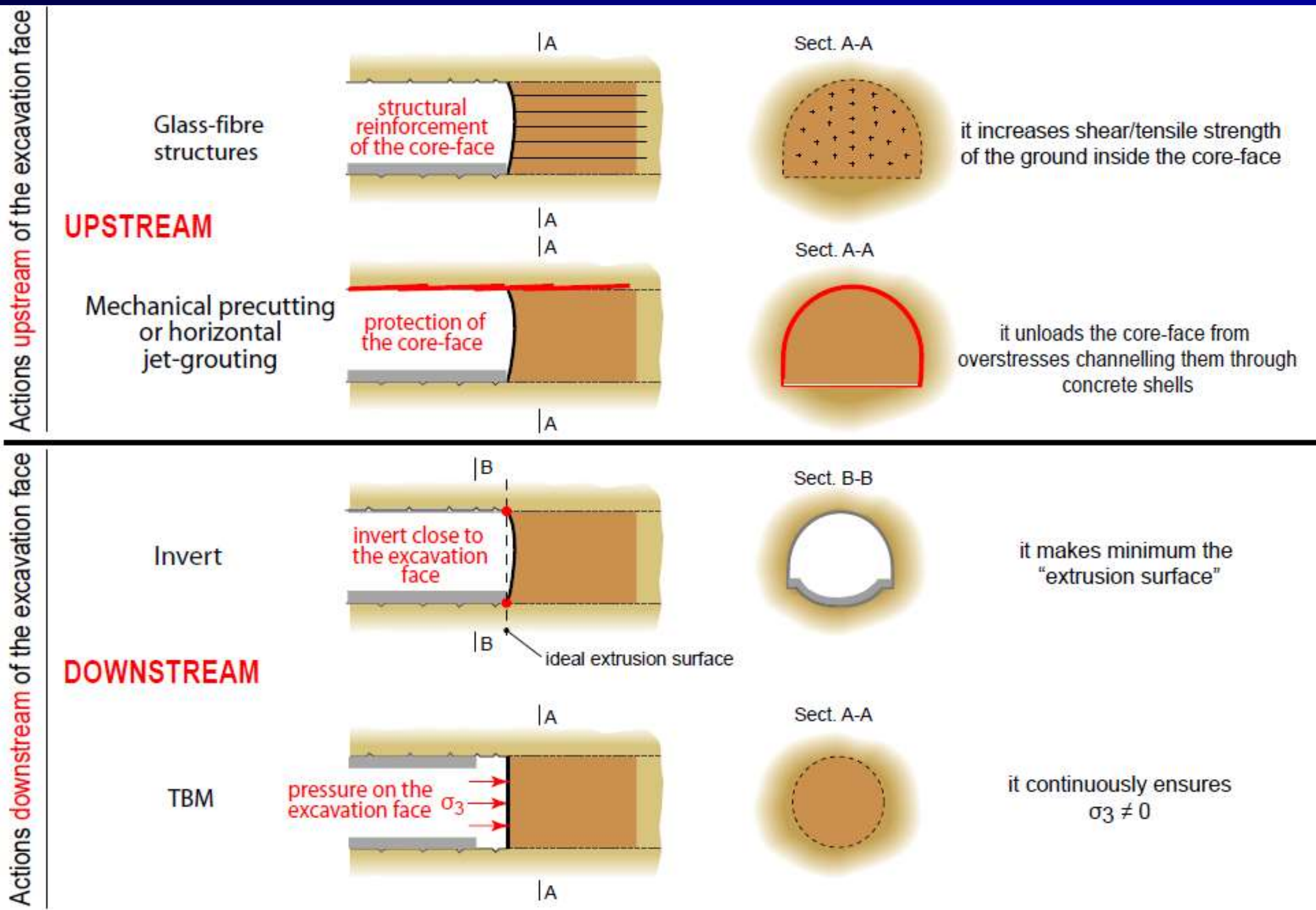


Preconfinement action



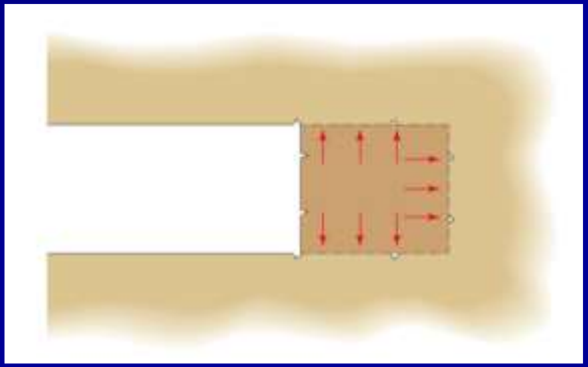
Confinement action

CONTROL of core-face Deformation Response according to ADECO-RS

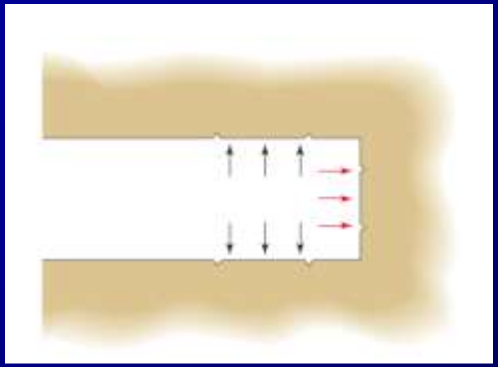


CONTROL of the Deformation Response according to ADECO-RS

CONTROL OF THE CORE-FACE DURING CONSTRUCTION



Preconfinement action

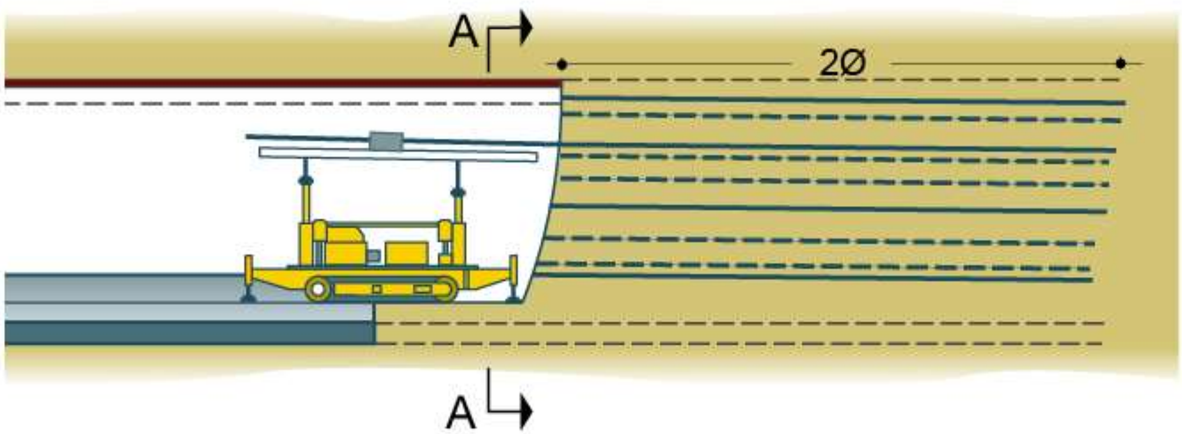


Confinement action

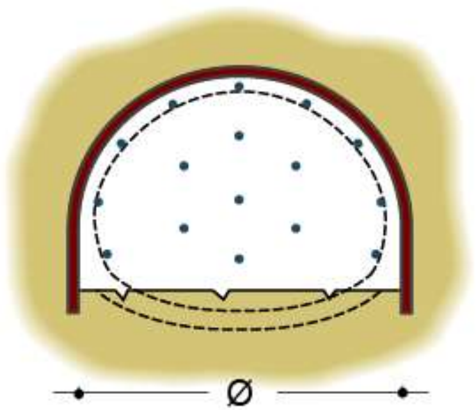
CONTROL of the Deformation Response upstream of the excavation face

Reinforcement of the core-face by means of glass-fibre structural elements

(conservation technique of reinforcement of the core-face)



Longitudinal section



Section A-A

CONTROL of the Deformation Response upstream of the excavation face

Reinforcement of the core-face with glass-fibre structural elements

CONTROL of the Deformation Response upstream of the excavation face

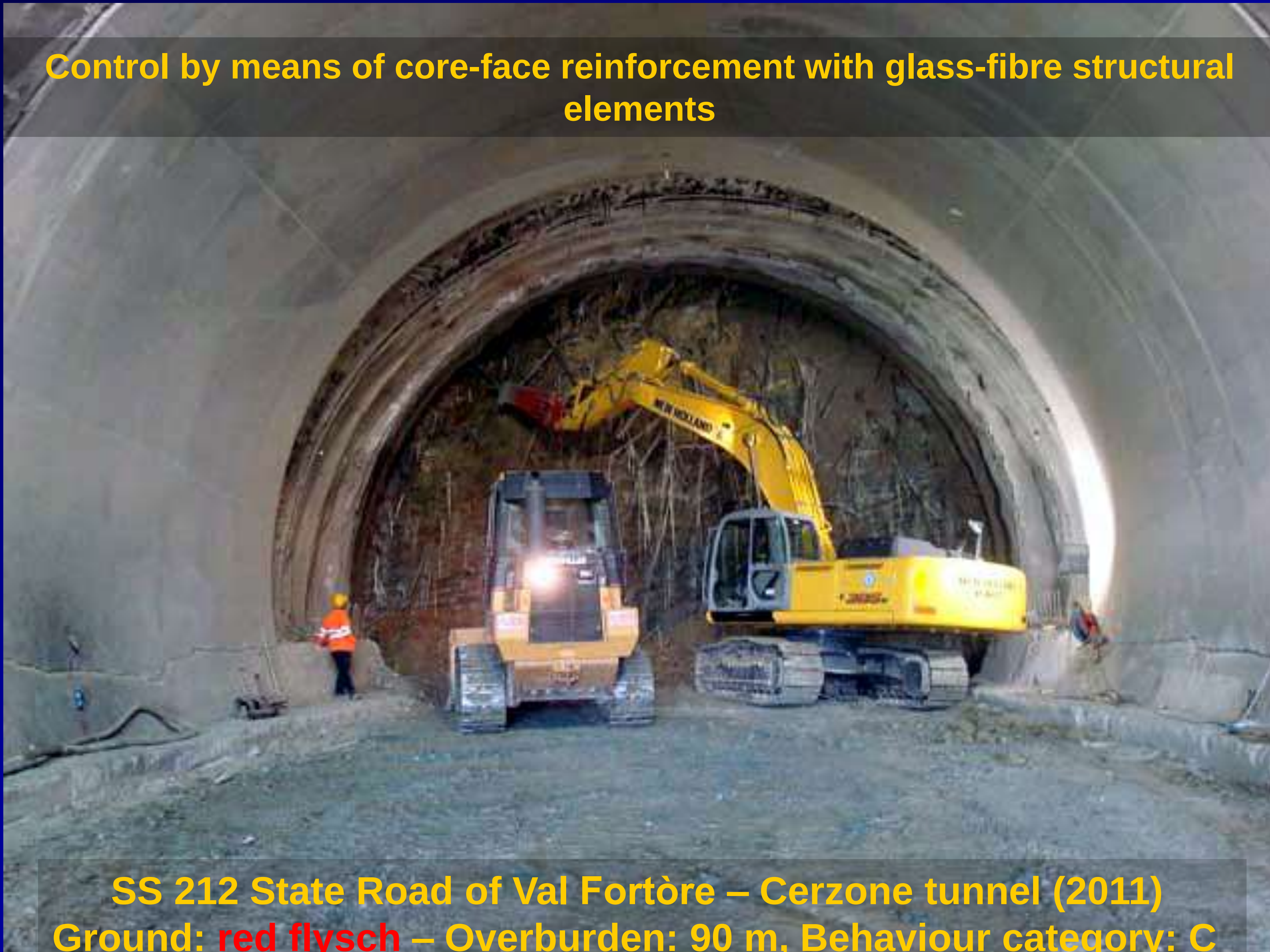
CONTROL of the Deformation Response upstream of the excavation face

Control by means of core-face reinforcement with glass-fibre structural elements

SS 212 State Road of Val Fortòre – Cerzone tunnel (2011)
Ground: red flysch – Overburden: 90 m, Behaviour category: C

CONTROL of the Deformation Response upstream of the excavation face

Control by means of core-face reinforcement with glass-fibre structural elements



SS 212 State Road of Val Fortòre – Cerzone tunnel (2011)
Ground: red flysch – Overburden: 90 m, Behaviour category: C

CONTROL of the Deformation Response upstream of the excavation face

Control by means of core-face reinforcement with glass-fibre structural elements

Keeping the exposed surface of the excavation face constantly concave-shaped

TGV Mediterranèe

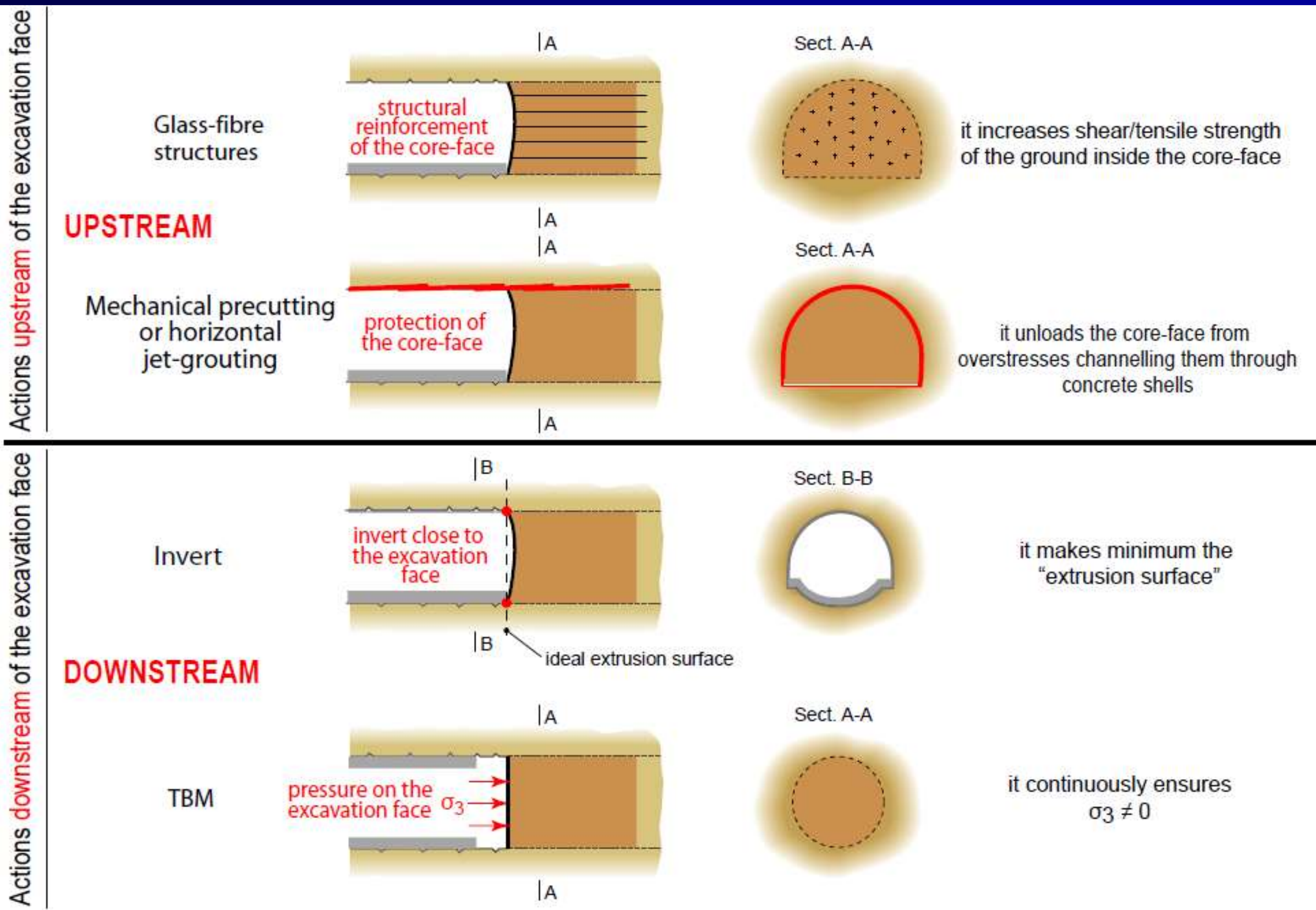
‘’Tartaiguille’’ tunnel (1997)

Ground: swelling clays

Span: 15 m,

Overburden: 150 m

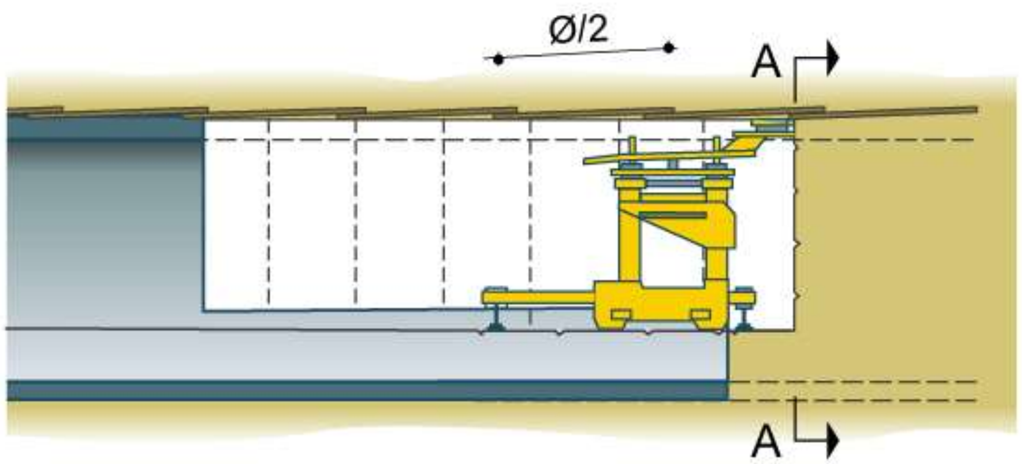
CONTROL of core-face Deformation Response according to ADECO-RS

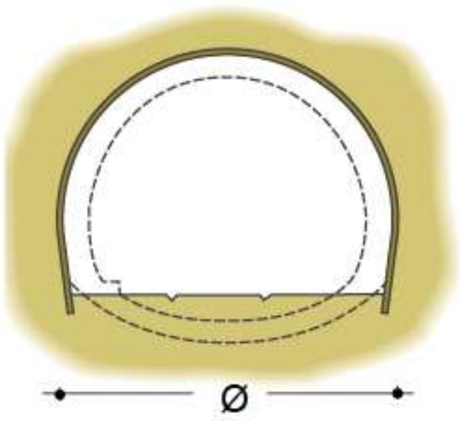


CONTROL of the Deformation Response upstream of the excavation face

Full face mechanical precutting

(conservation technique of protection of the core-face)





Longitudinal section

Section A-A

CONTROL of the Deformation Response upstream of the excavation face

Sibari-Cosenza railway line – Tunnel no. 2 (1985)

Ground: silty clays, Overburden: 90 m, Behaviour category: C

CONTROL of the Deformation Response upstream of the excavation face

Milan-Naples A1 motorway - "Nazzano" tunnel (2005)

Ground: silty sand, c' = 0,04 MPa, φ' = 24°, Overburden: 5÷40 m,

Behaviour category: C

CONTROL of the Deformation Response upstream of the excavation face

Full face mechanical precutting

Bologna-Taranto A14 motorway – “Montedomini” tunnel(2014)

Ground: clays, c’ = 0,3 MPa, φ’ = 22°, Overburden: 10÷40 m,

Behaviour category: C

CONTROL of the Deformation Response upstream of the excavation face

Full face mechanical precutting

CONTROL of the Deformation Response upstream of the excavation face

Full face mechanical precutting

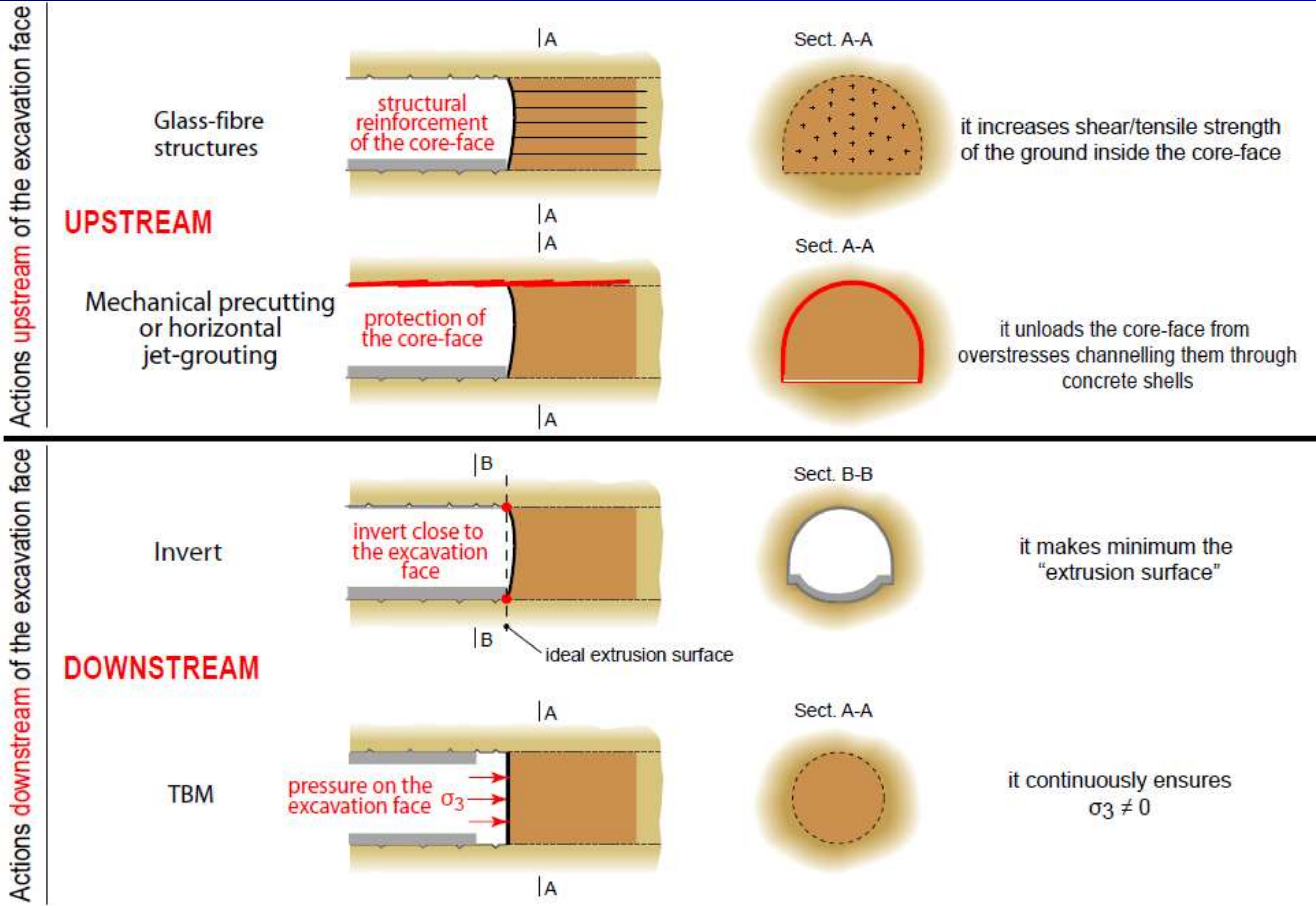
CONTROL of the Deformation Response upstream of the excavation face

Full face mechanical precutting

Sibari-Cosenza railway line – Tunnel no. 2 (1985)

Ground: silty clays, Overburden: 90 m, Behaviour category: C

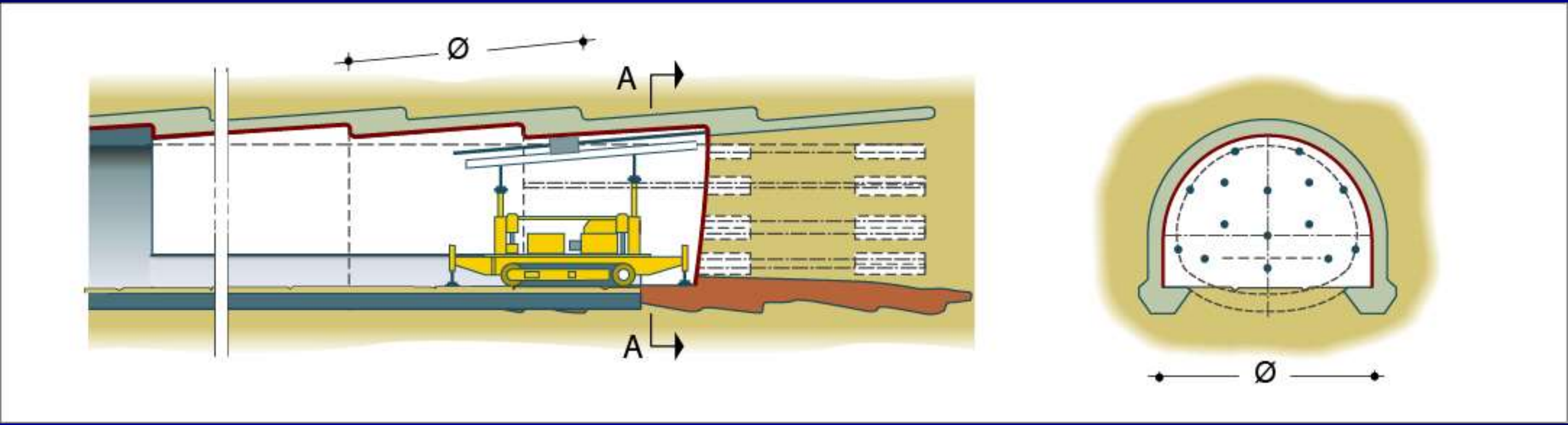
CONTROL of core-face Deformation Response according to ADECO-RS



CONTROL of the Deformation Response upstream of the excavation face

Full face sub-horizontal jet-grouting

(conservation technique of protection/reinforcement of the core-face)



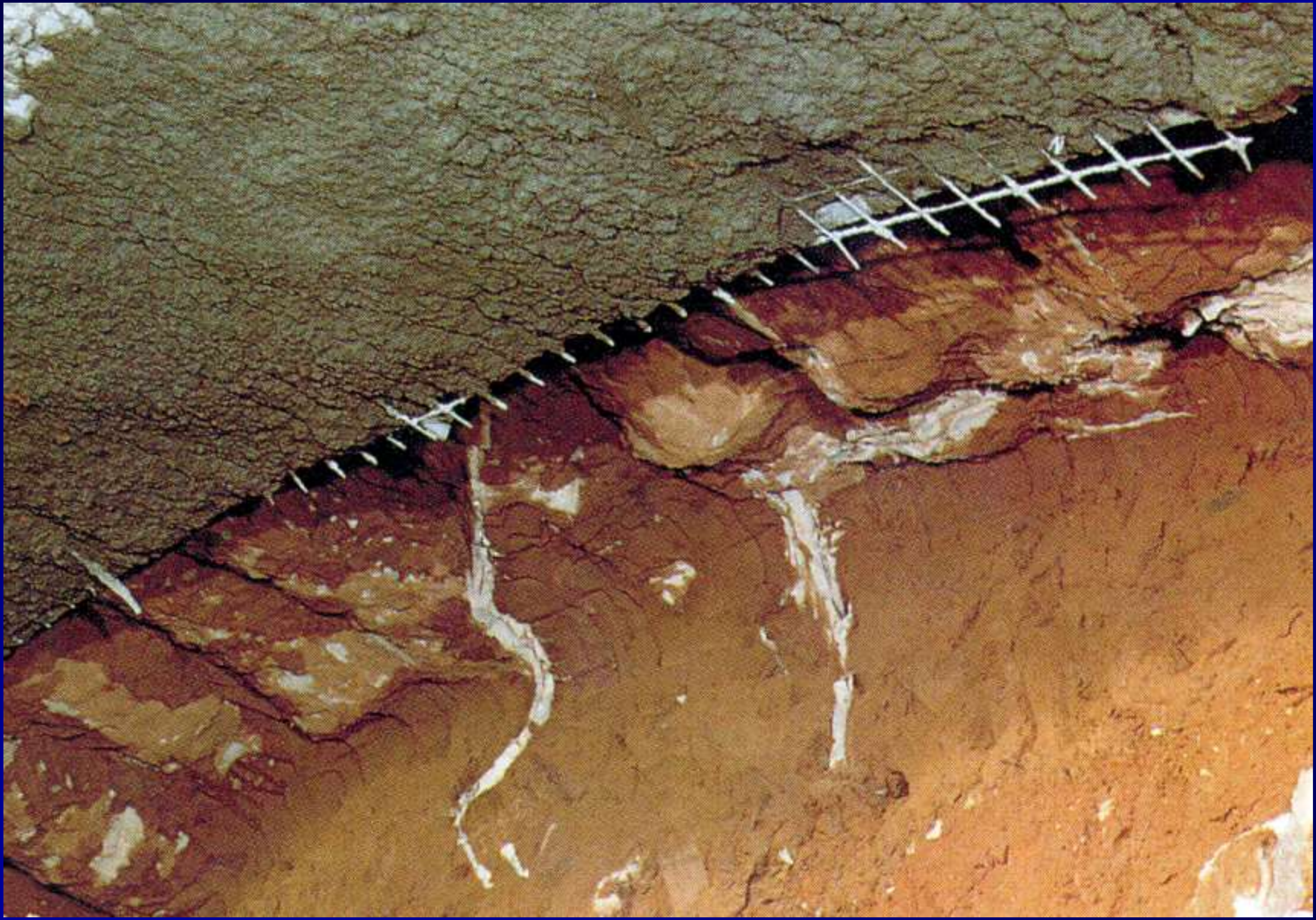
Longitudinal section

Section A-A

CONTROL of the Deformation Response upstream of the excavation face

Full face sub-horizontal jet-grouting

Ancona-Bari railway line – “Vasto” tunnel (1991)
Ground: silty clays, Overburden: 100 m, Behaviour category: C



MOTORWAY UNDERPASS OF THE CAMPINAS RAILWAY YARD (BRASIL), Ø = 14,9 m

Ground: heterogeneous sands, - c = 0,02 MPa, $\varphi = 28^{\circ}$ - Overburden: 2 ÷ 4 m

MOTORWAY UNDERPASS OF THE CAMPINAS RAILWAY YARD (BRASIL), Ø = 14,9 m

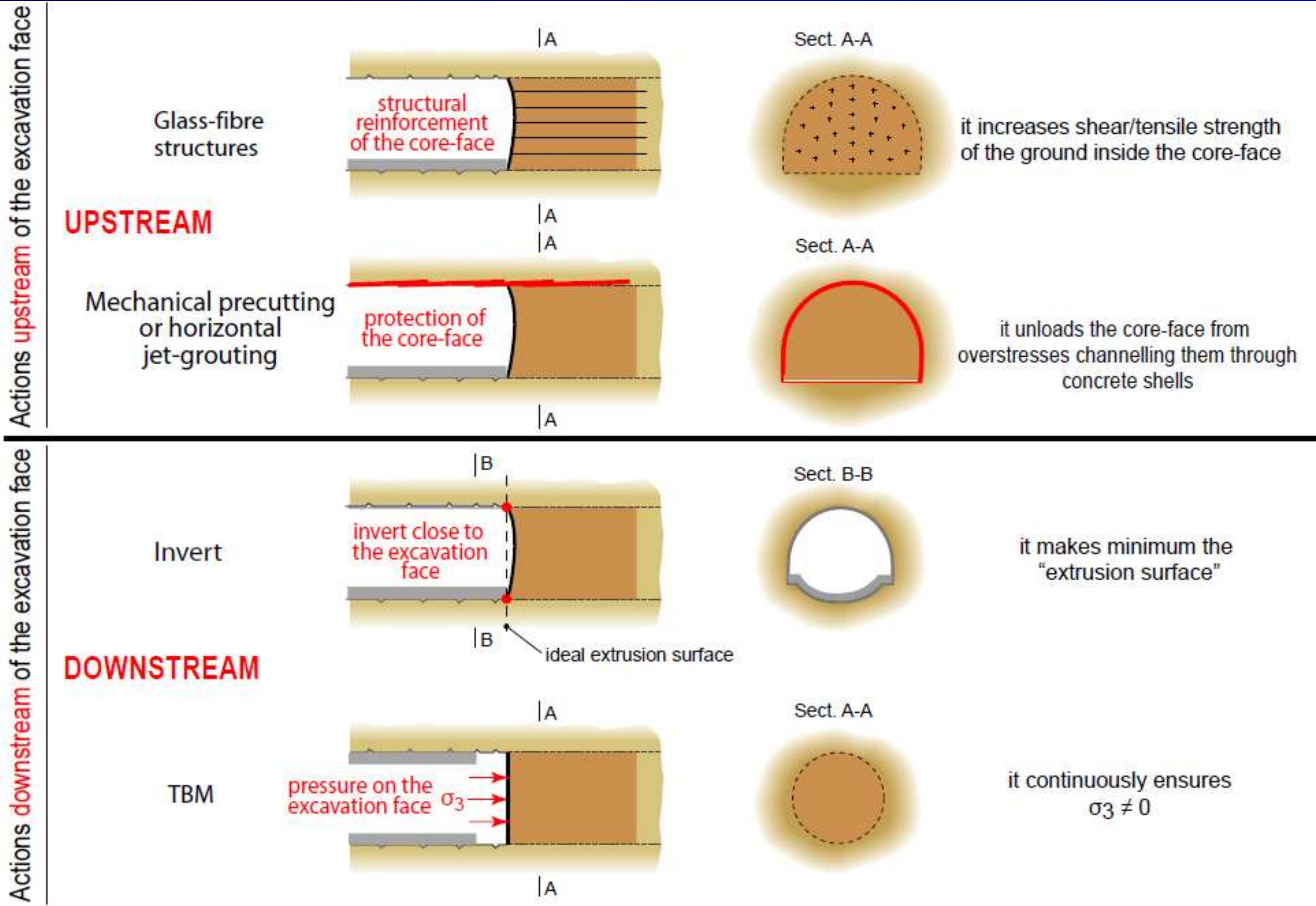
Ground: heterogeneous sands - c = 0,02 Mpa
φ = 28° - Overburden: 2 ÷ 6 m

CONTROL of the Deformation Response upstream of the excavation face

Bologna-Florence high speed railway line – Firenzuola tunnel

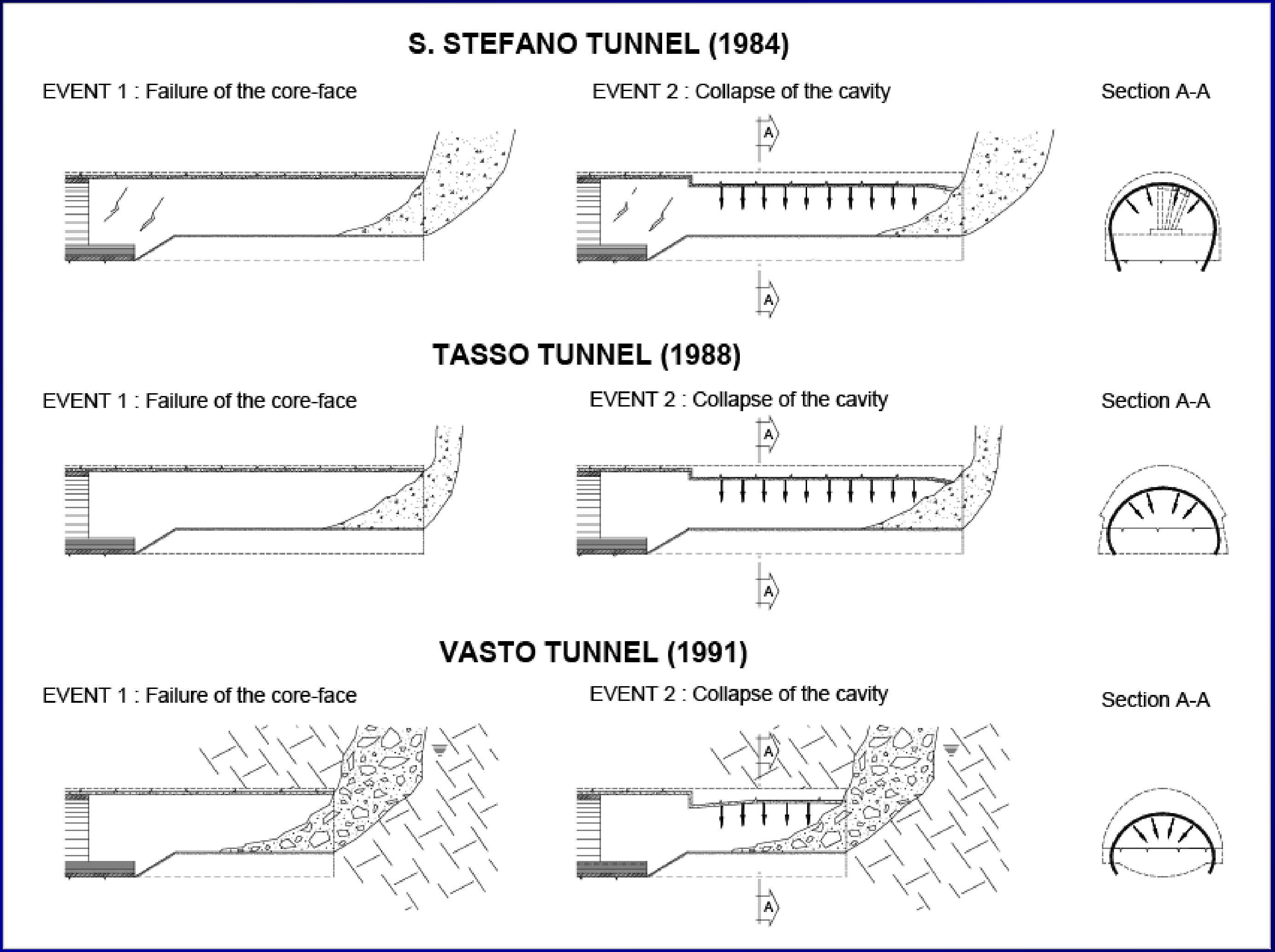
Ground: Silts and silty sands with interbedded gravel; Span: 13,90 m

CONTROL of core-face Deformation Response according to ADECO-RS



CONTROL of the Deformation Response downstream of the excavation face

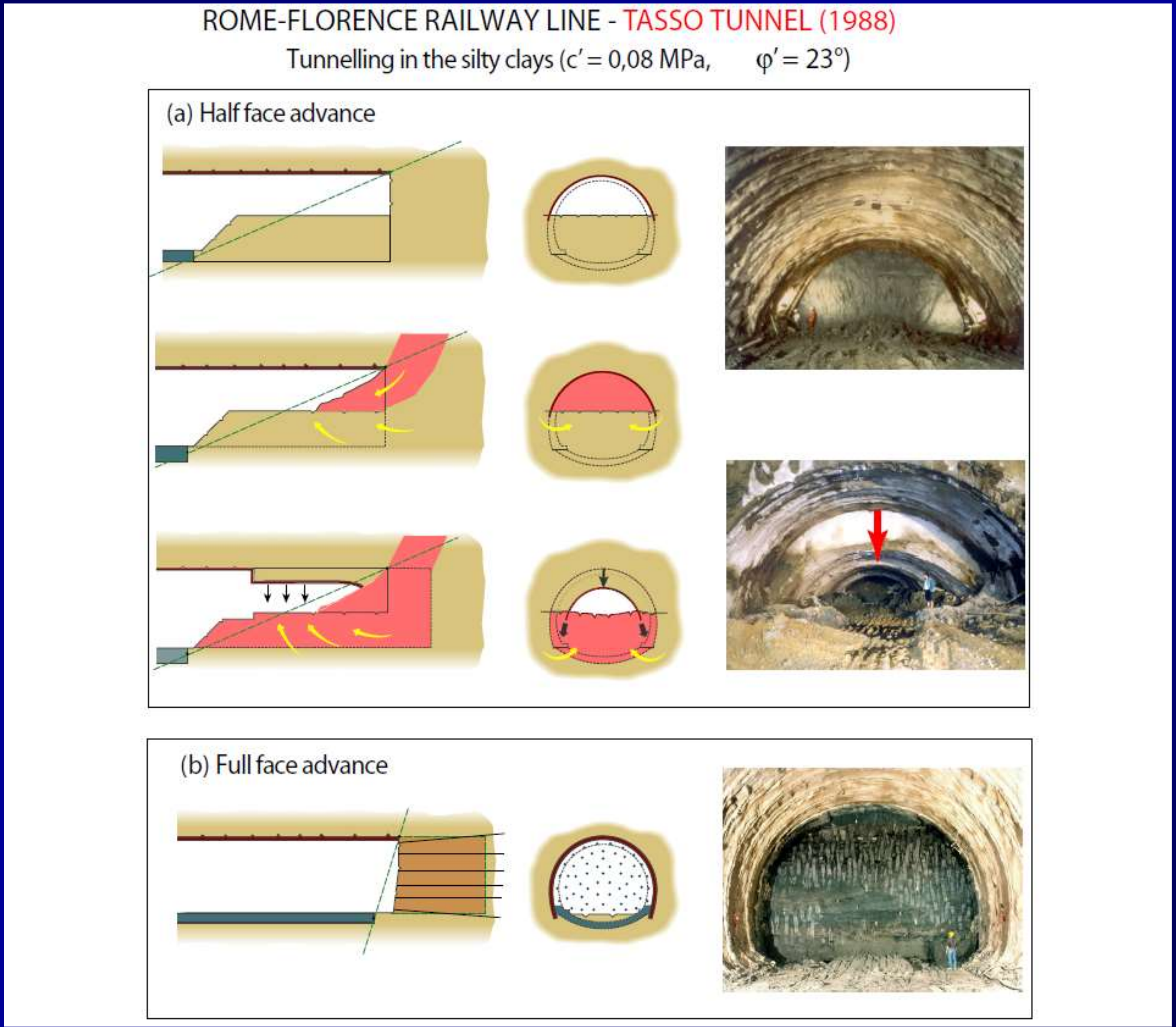
There is a close connection between the instability by extrusion of the core-face with the collapse of the cavity, although already stabilized



It was found that the failure of the core-face is systematically followed by the collapse of the cavity

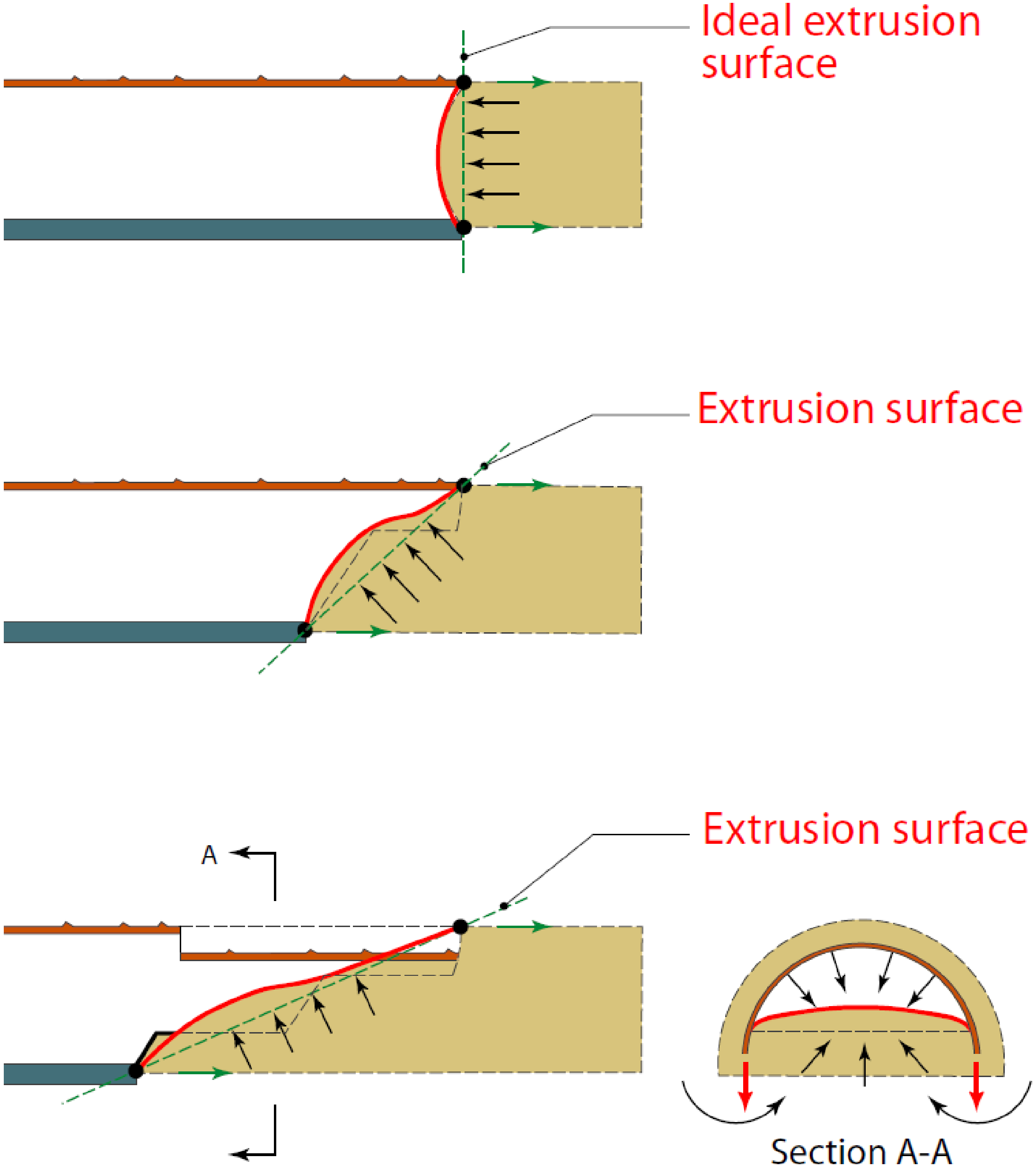
CONTROL of the Deformation Response downstream of the excavation face

The presence of the tunnel invert cast close to the excavation face becomes crucial if you want to prevent phenomena such as the following:



Control

Failure mechanism of the core-face in relation to the distance at which the invert is cast



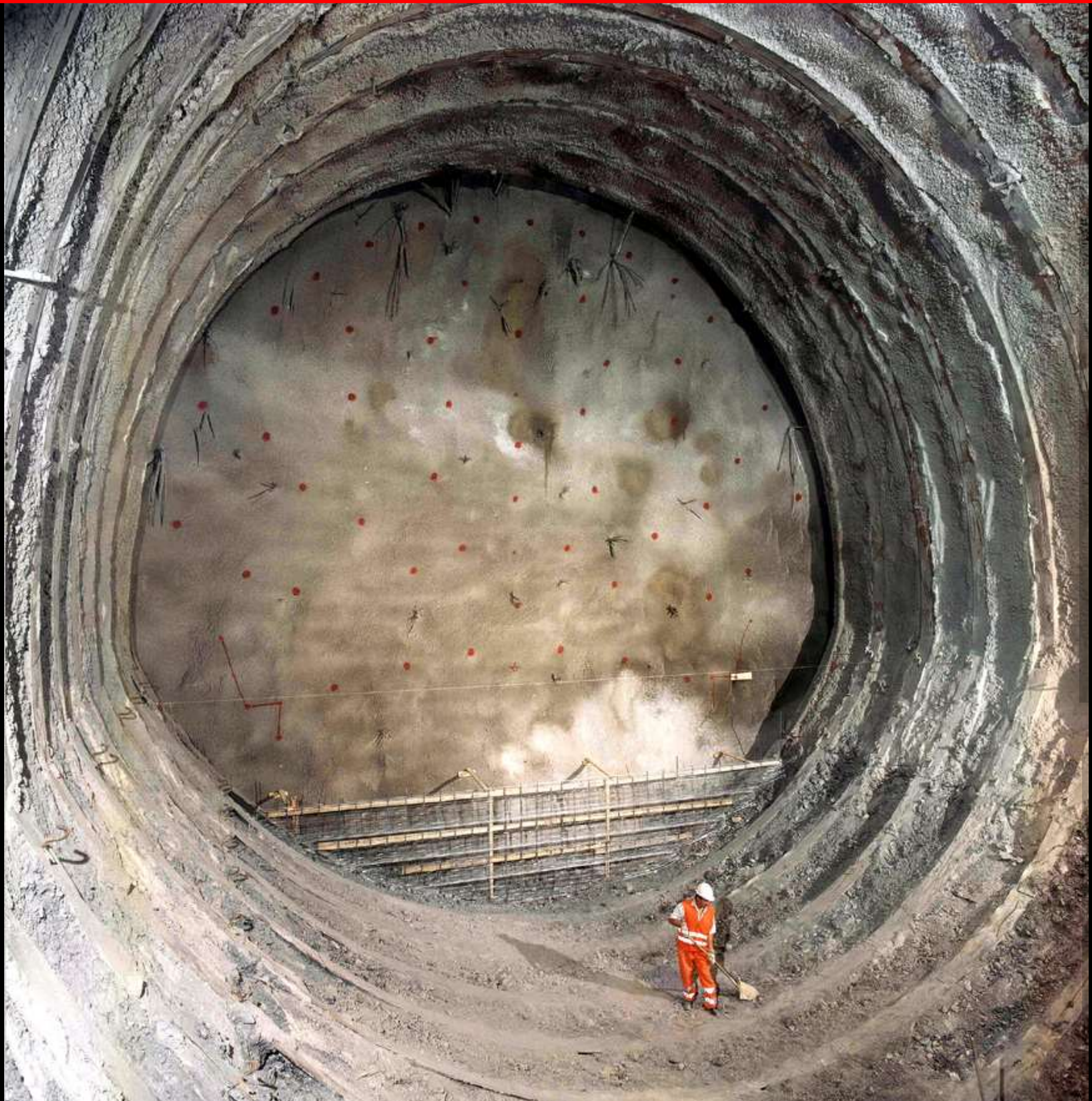
CONTROL of the Deformation Response downstream of the excavation face

We define the IDEAL EXTRUSION SURFACE

Hence the need

TO ALWAYS PROCEED BY USING THE FULL FACE EXCAVATION.

CONTROL of the Deformation Response downstream of the excavation face



Immediate control of the cavity by means of the invert cast close to the face

(conservation technique of confinement of the cavity back from the excavation face)

Bologna to Florence High Speed Railway line – Raticosa tunnel
Ground: scaly clays (Chaotic complex),
Behaviour category: C

CONTROL of the Deformation Response downstream of the excavation face

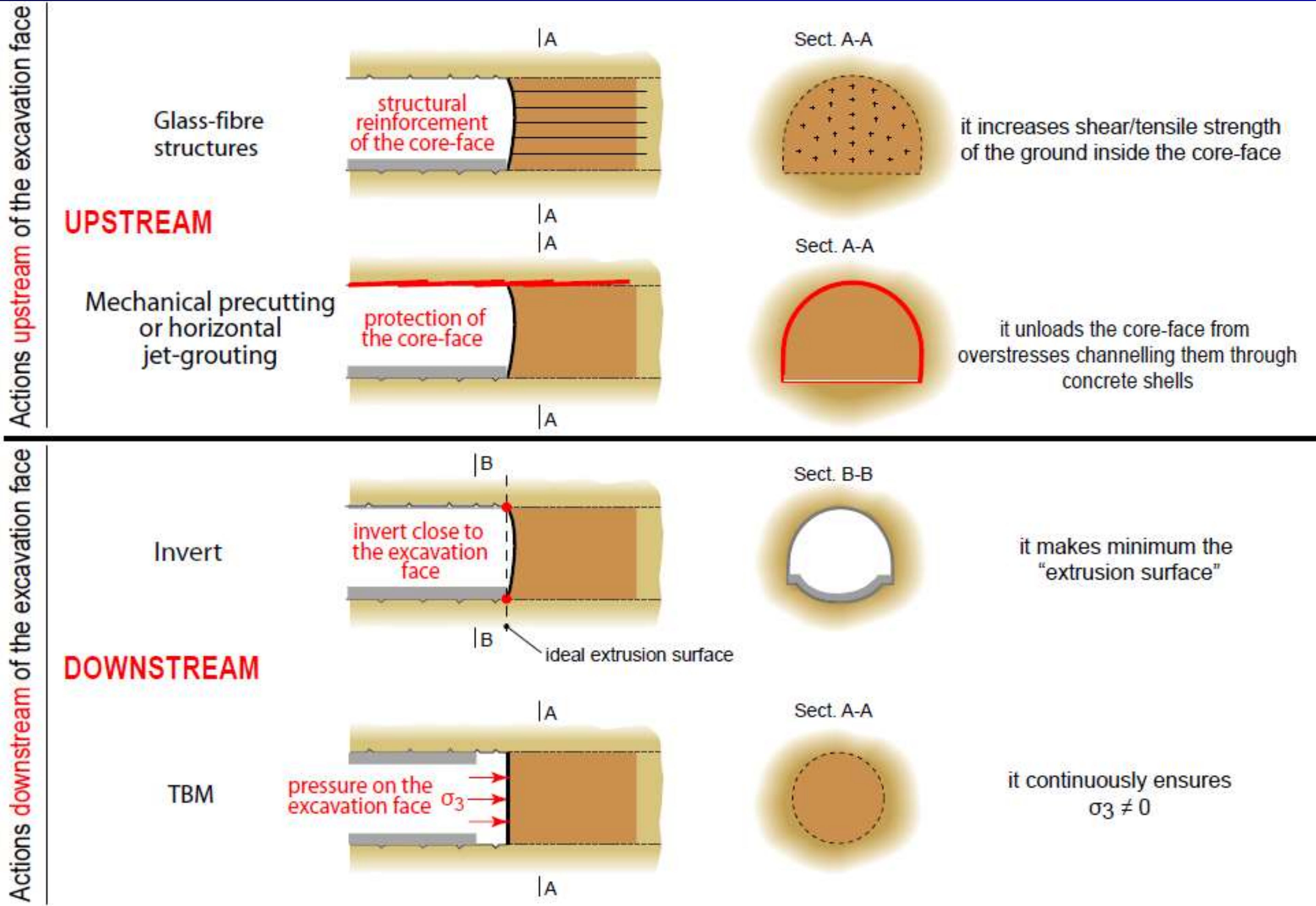
Control by means of the invert cast close to the face

(conservation technique of confinement of the cavity back from the excavation face)

TGV Mediterranèe – ‘’Tartaiguille’’ tunnel (1997)

Ground: swelling clays, Max overburden: 150 m, Behaviour category.: C

CONTROL of core-face Deformation Response according to ADECO-RS



CONTROL of core-face Deformation Response according to ADECO-RS

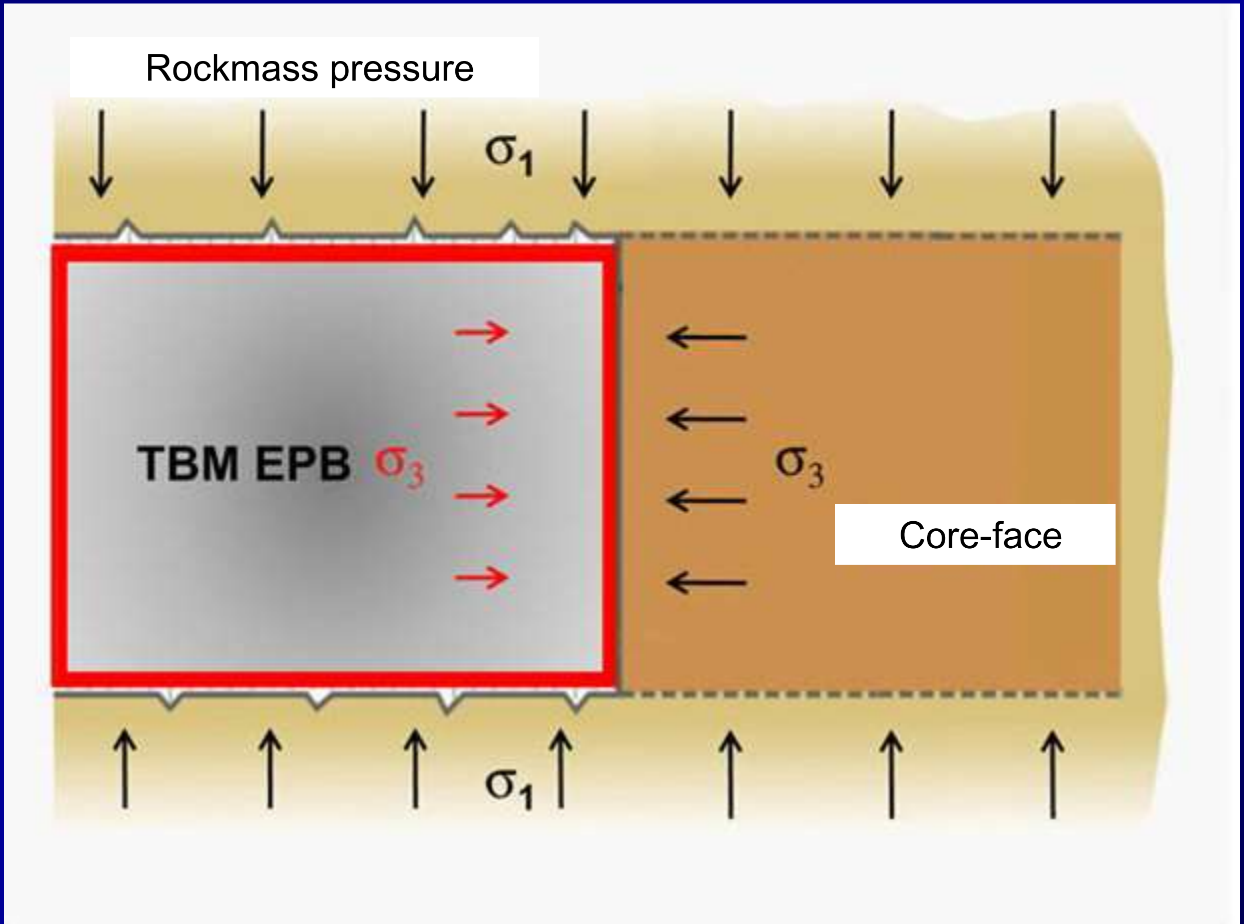
Speaking of TBMs, have we ever asked ourselves the secret to the increasing success of TBMs or mechanization of excavation for most types of grounds encountered when tunnelling? Well, the answer is clearly due to the confinement action (σ_3) which the machine constantly applies to the core-face during advancement. This action maintains the original tri-axial coaction in the ground mass within finite values, until the cavity can be confined during work by means of pre-lining or prefabricated segment lining.

P. Lunardi – Muir Wood Lecture 2015

CONTROL of the Deformation Response downstream of the excavation face

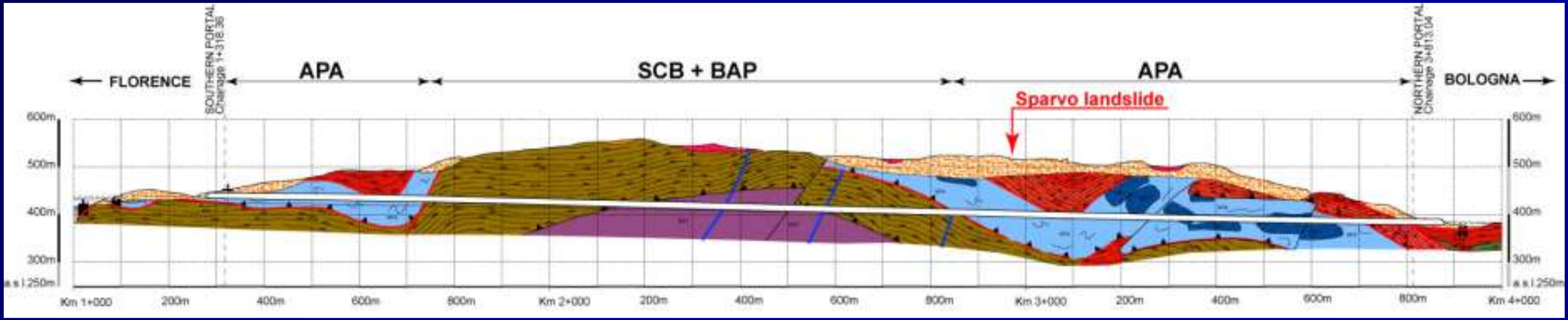
Confinement of the core-face by TBM

(conservation technique of confinement of the core-face)



(New Bologna-Florence motorway)

The "Sparvo" tunnel (2012-2015)



Geotechnical investigations on Palombini clays (APA)

- Unit weight: $\gamma = 21 \div 24$ kN/m^3
- Granulometric analysis: Clayey-sandy silt with gravel
- Mineralogic analysis: Presence of smectite in significant percentage
- Permeability (Lugeon): $10^{-7} \div 10^{-9}$ m/s

$c_{peak} = 5 + 1.95\ z$ [kPa]
$c_{residual} = 1.5\ z$ [kPa]

$\varphi_{peak} = 15 + 0.07\ z$ [°]
$\varphi_{residual} = 10 + 0.05\ z$ [°]

$E_{peak} = 13 + 6$ [Mpa]
$E_{residual} = 4$ [Mpa]

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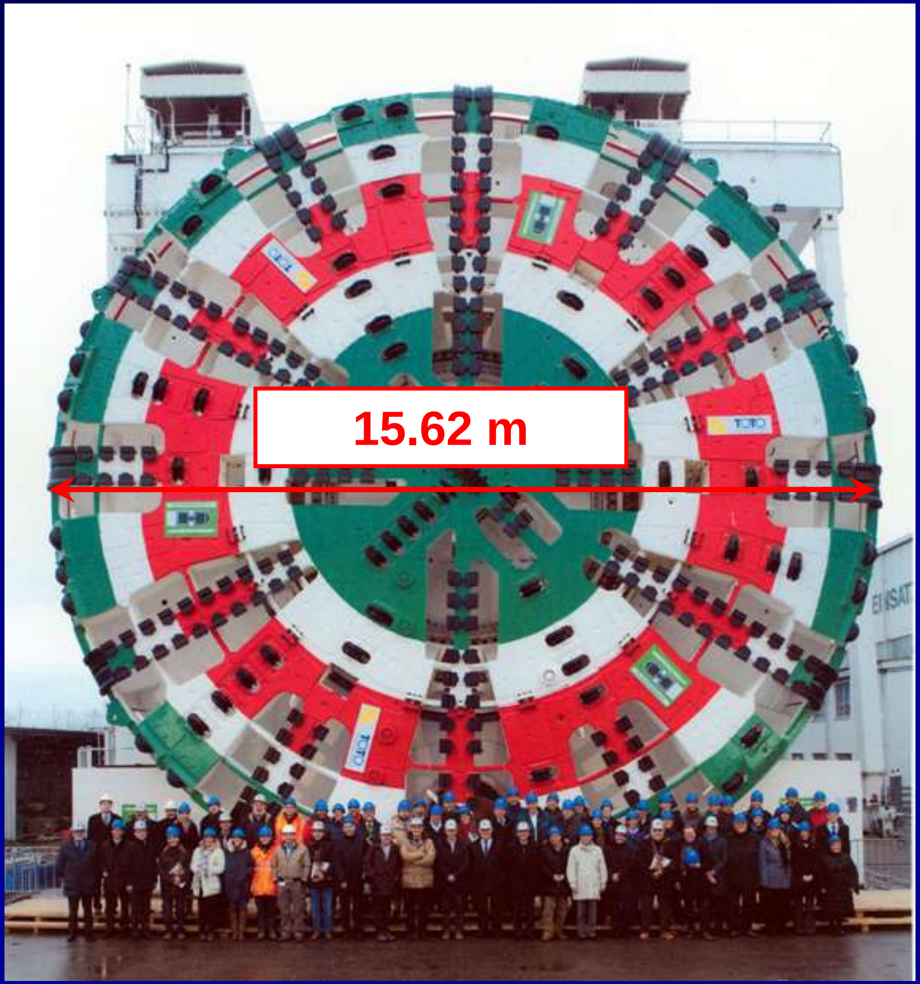
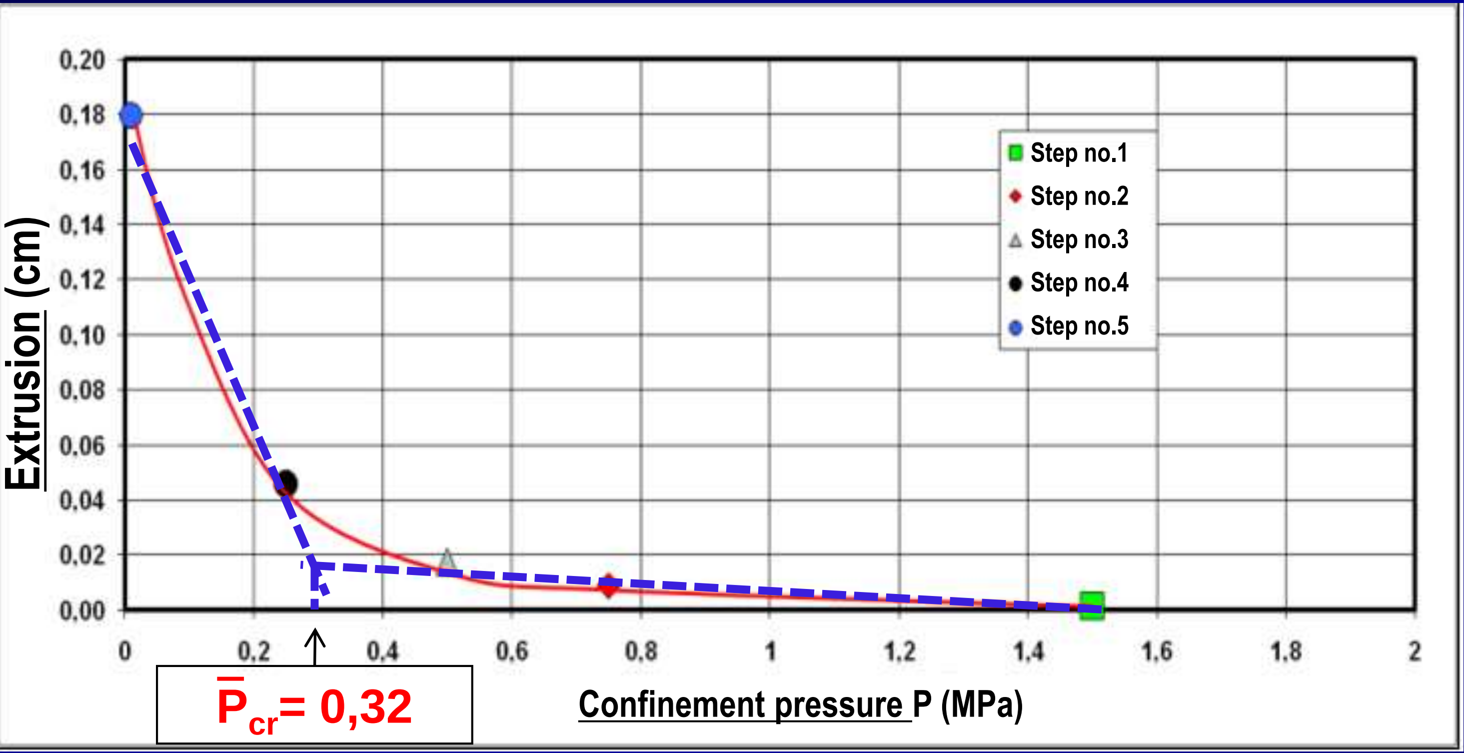
The TBM–EPB ''Martina'', the world's largest EPB TBM

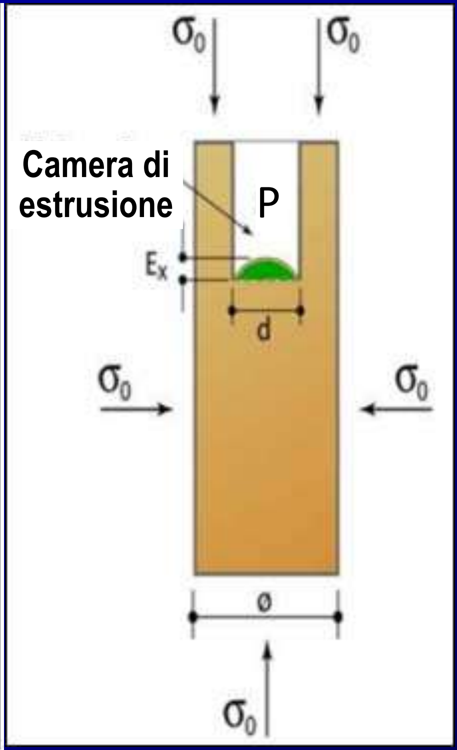


Technical caracteristics

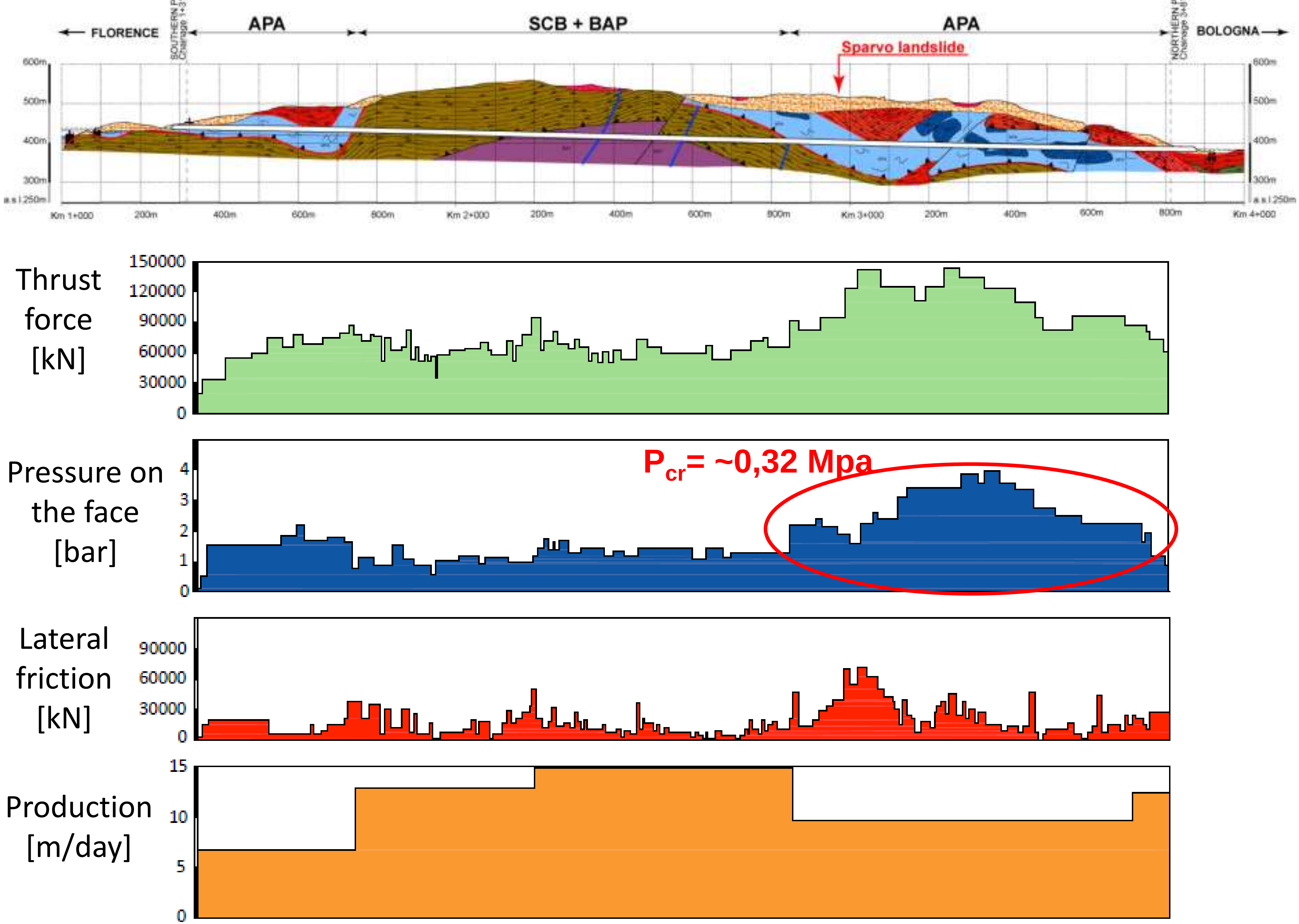
- Excavation diametre: 15.62 m
- Machine length: 110.00 m
- Shield length: 11.60 m
- Total weight: 5,000 t
- Installed power: 15,000 KW
- Average excavation speed: ~ 10 m/day
- Bearing diameter ~ 9 m
- Bearing weight ~ 200 t
- Excavation volume ~1,200,000 m^3

Extrusion of the core-face as a function of the confinement pressure P





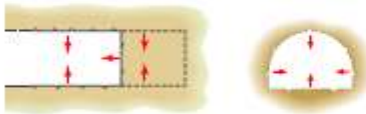
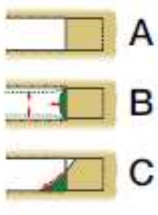
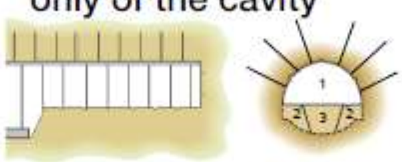
New Bologna-Florence motorway - ‘’Sparvo’’ tunnel (2012-2015)



New Bologna-Florence motorway – ‘’Sparvo’’ tunnel (2012-2015)
Ground: Palombini clays; Diametre: 15,62 m

New Bologna-Florence motorway – ''Sparvo'' tunnel (2012-2015)
Ground: Palombini clays; Diametre: 15,62 m

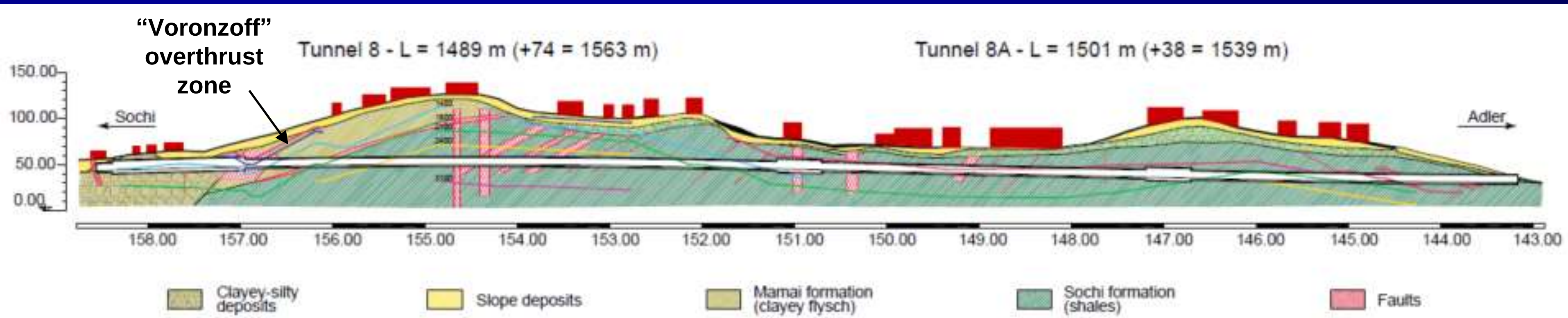
COMPARISON TABLE

DESIGN AND CONSTUCTION APPROACHES	NATM and derived methods	ADECO-RS
Model	2D 	3D 
Deformation Response components	convergence	extrusion, preconvergence, convergence
Analysis	geomechanical classifications	core-face stability – behaviour categories 
Control	only of the cavity  Partitioned face	of the core-face and the cavity  Full face

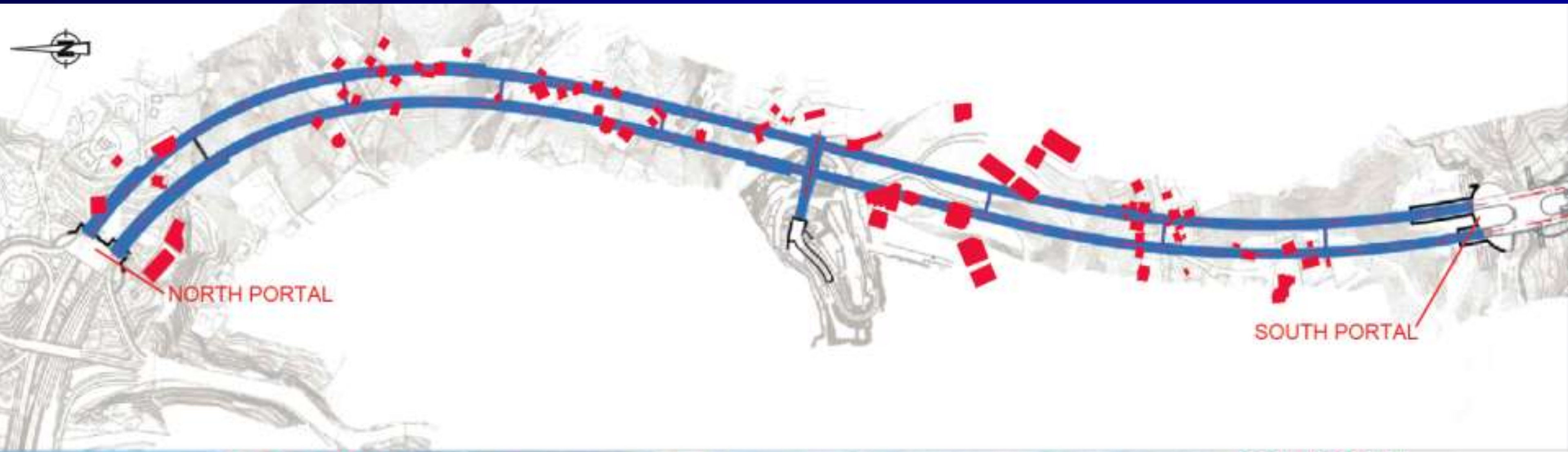
A great example of application of the ADECO-RS approach and industrialization of the excavations in difficult grounds:

the realization, in difficult stress-strain situations, of the T8 and T8A tunnels for the bypass highway of Sochi (Russia, 2013-2014), recently built for the Winter Olympic Games, respecting the construction times and costs predicted by the detailed design

BYPASS HIGHWAY OF SOCHI (RUSSIA, 2013-2014)

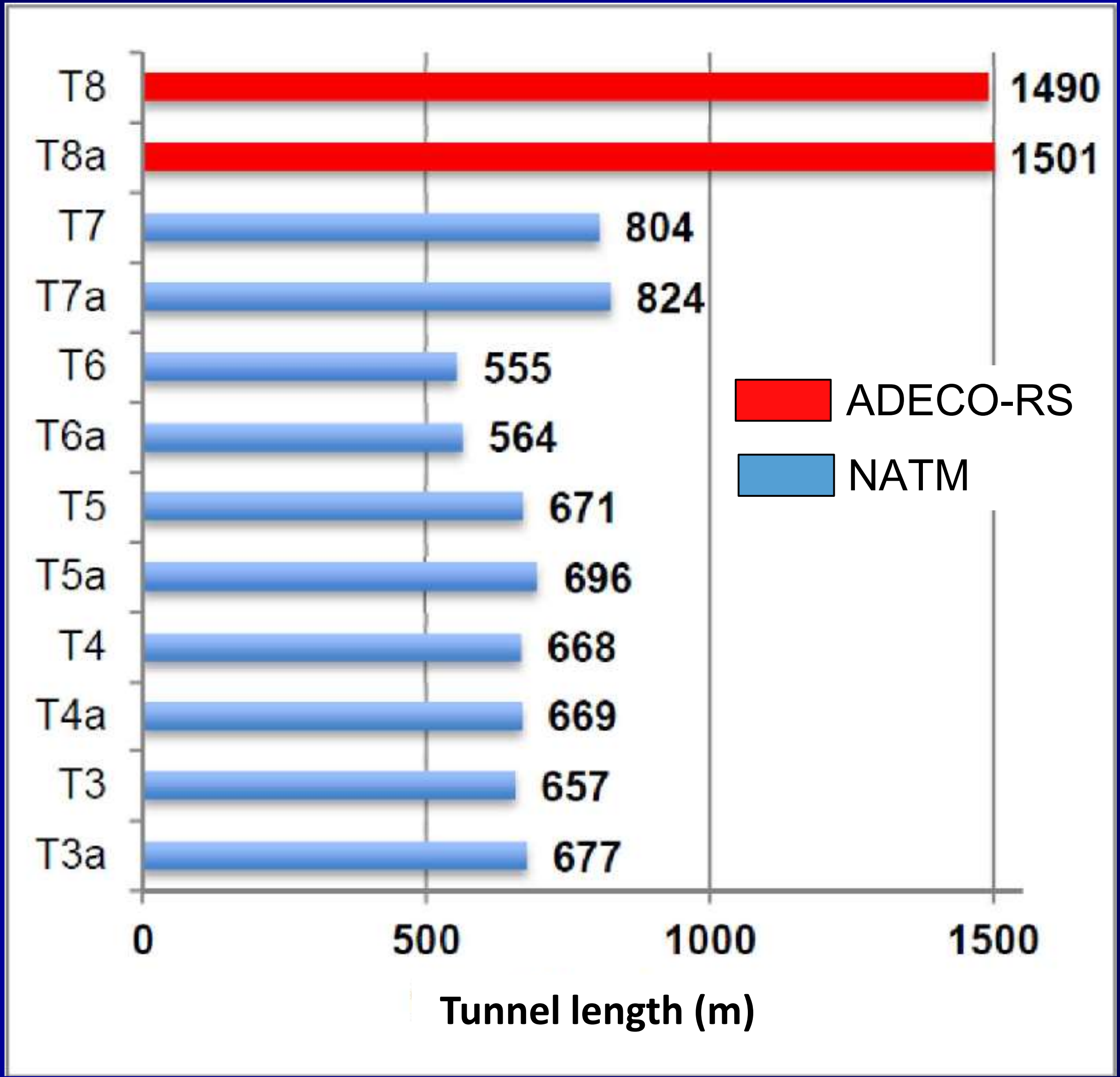


T8 and T8A tunnels (ADECO-RS)



BYPASS HIGHWAY OF SOCHI (RUSSIA, 2013-2014)

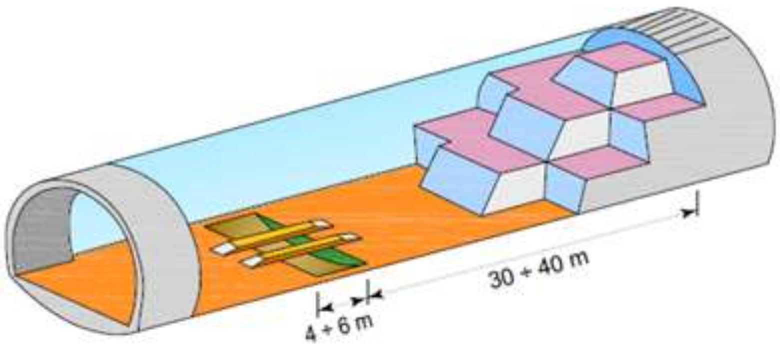
Tunnel length

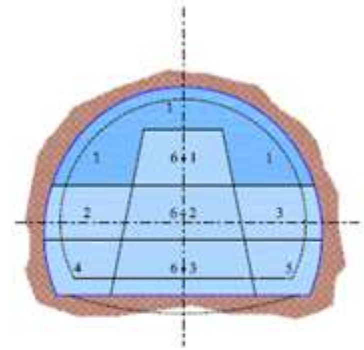


T8 and T8A tunnels (ADECO-RS)

Control of Deformation Response

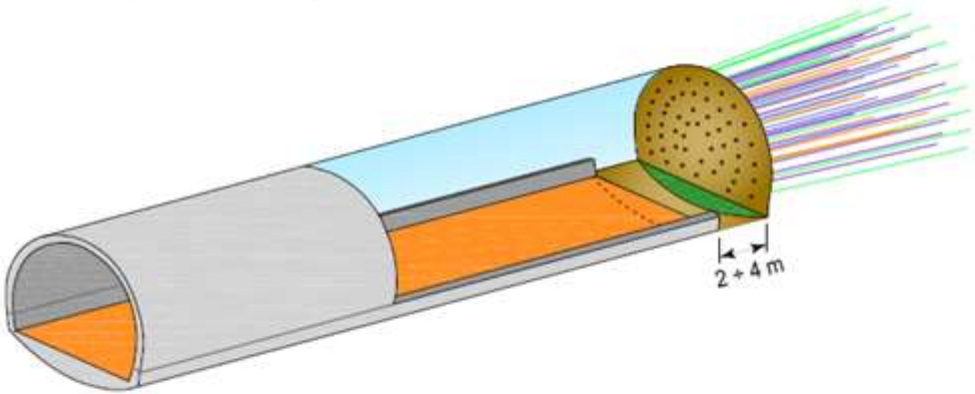
To stabilize the excavation face in difficult stress-strain conditions

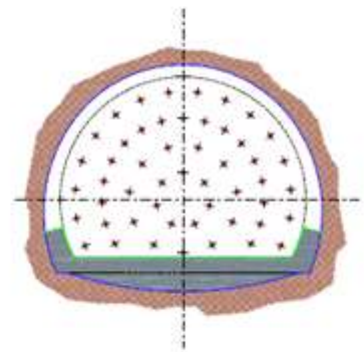




NATM

Partitioning of the excavation face

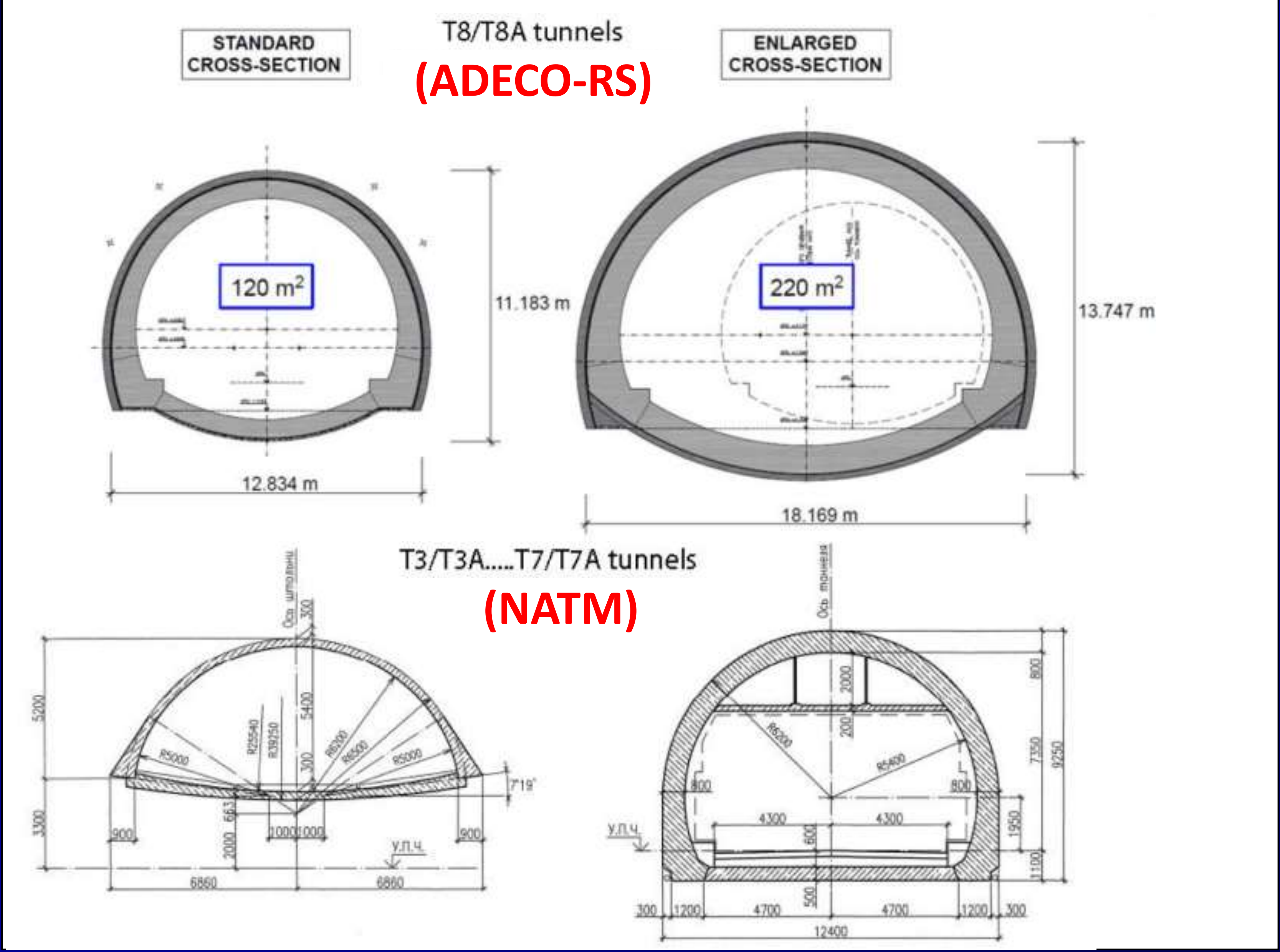




ADECO-RS

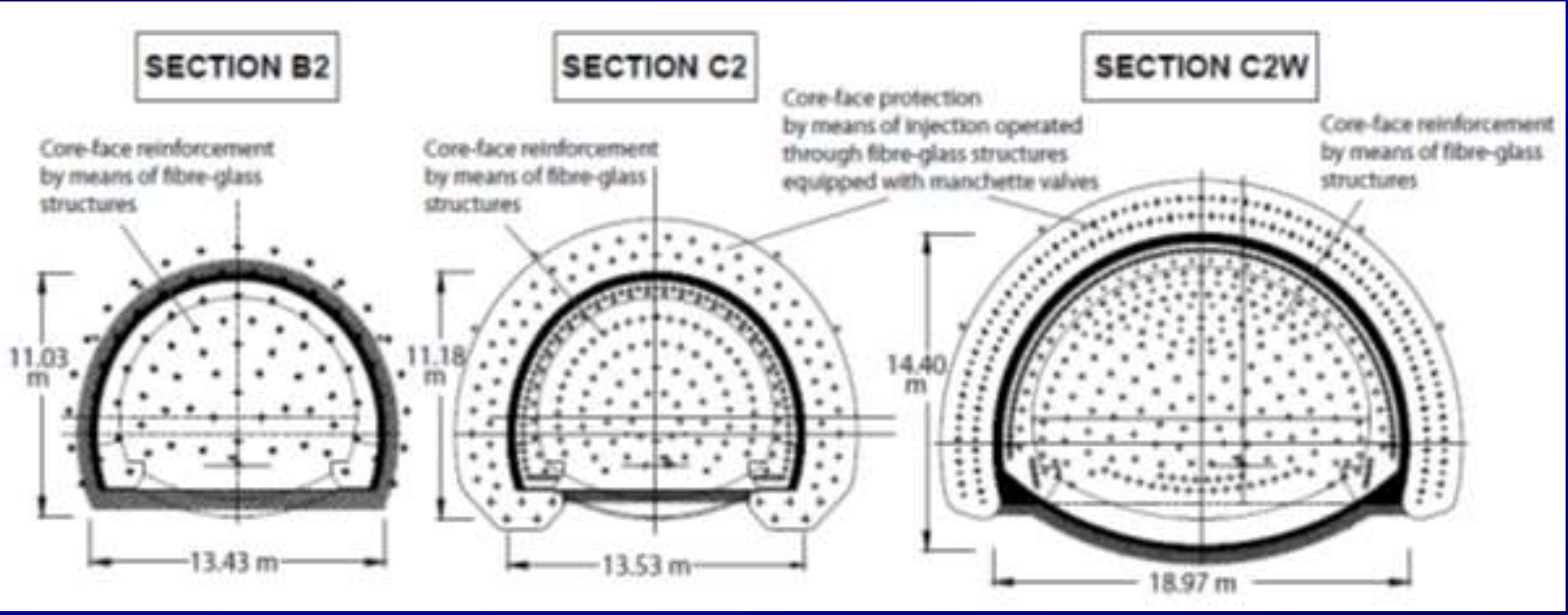
Always full face excavation with reinforced core-face

Geometrical characteristics of the tunnels in comparison



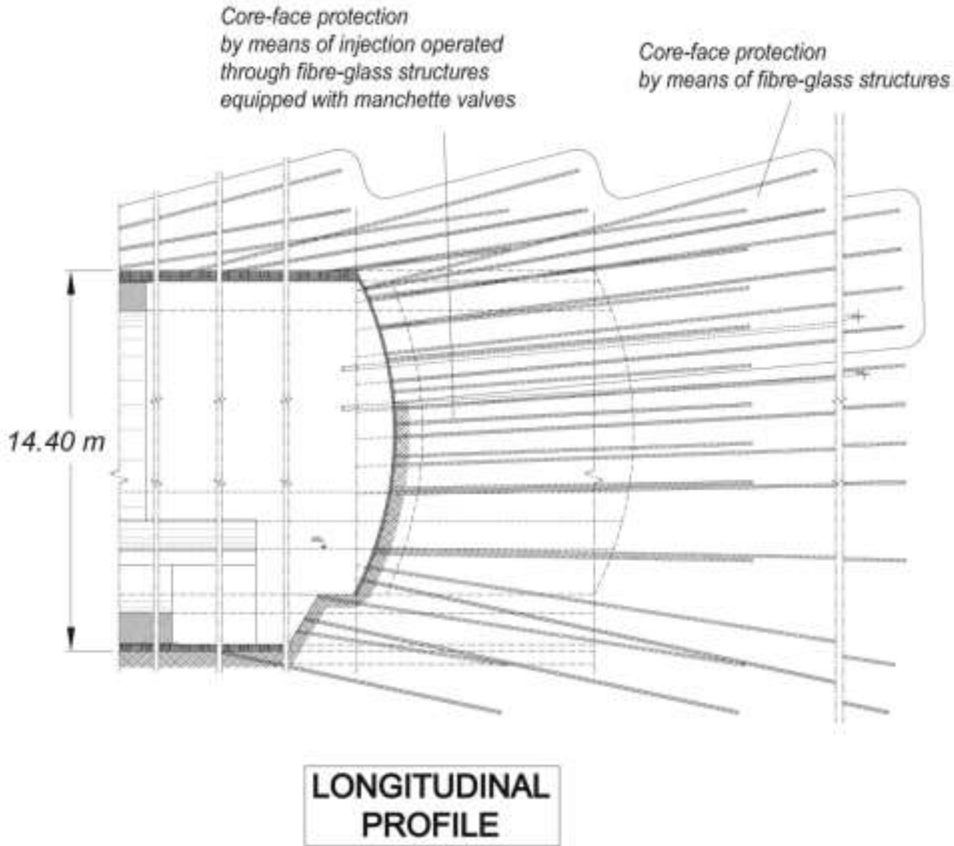
T8 and T8A tunnels

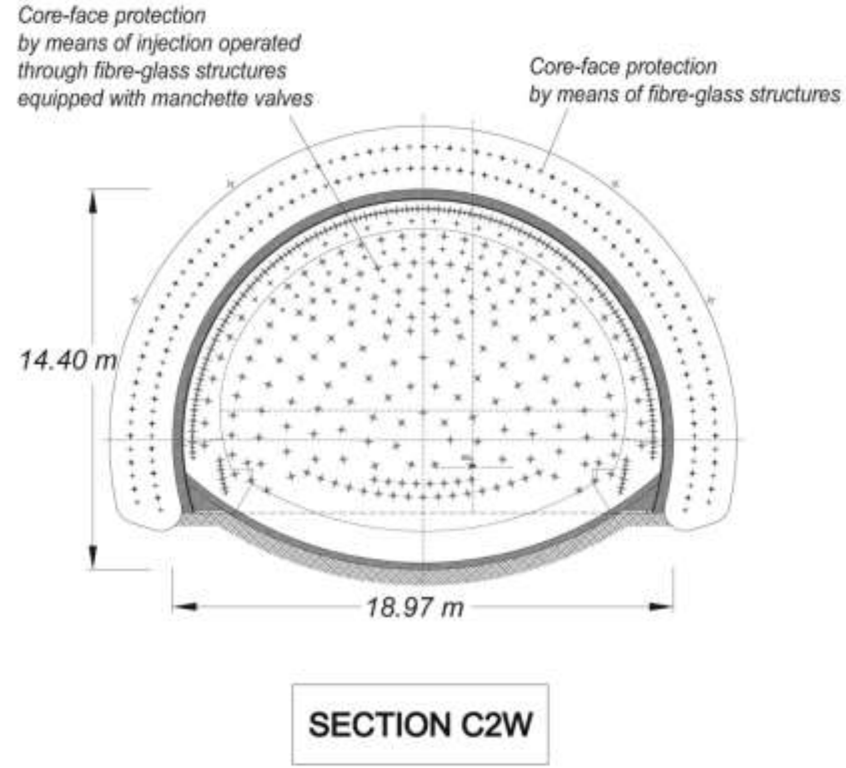
(ADECO-RS typical sections)



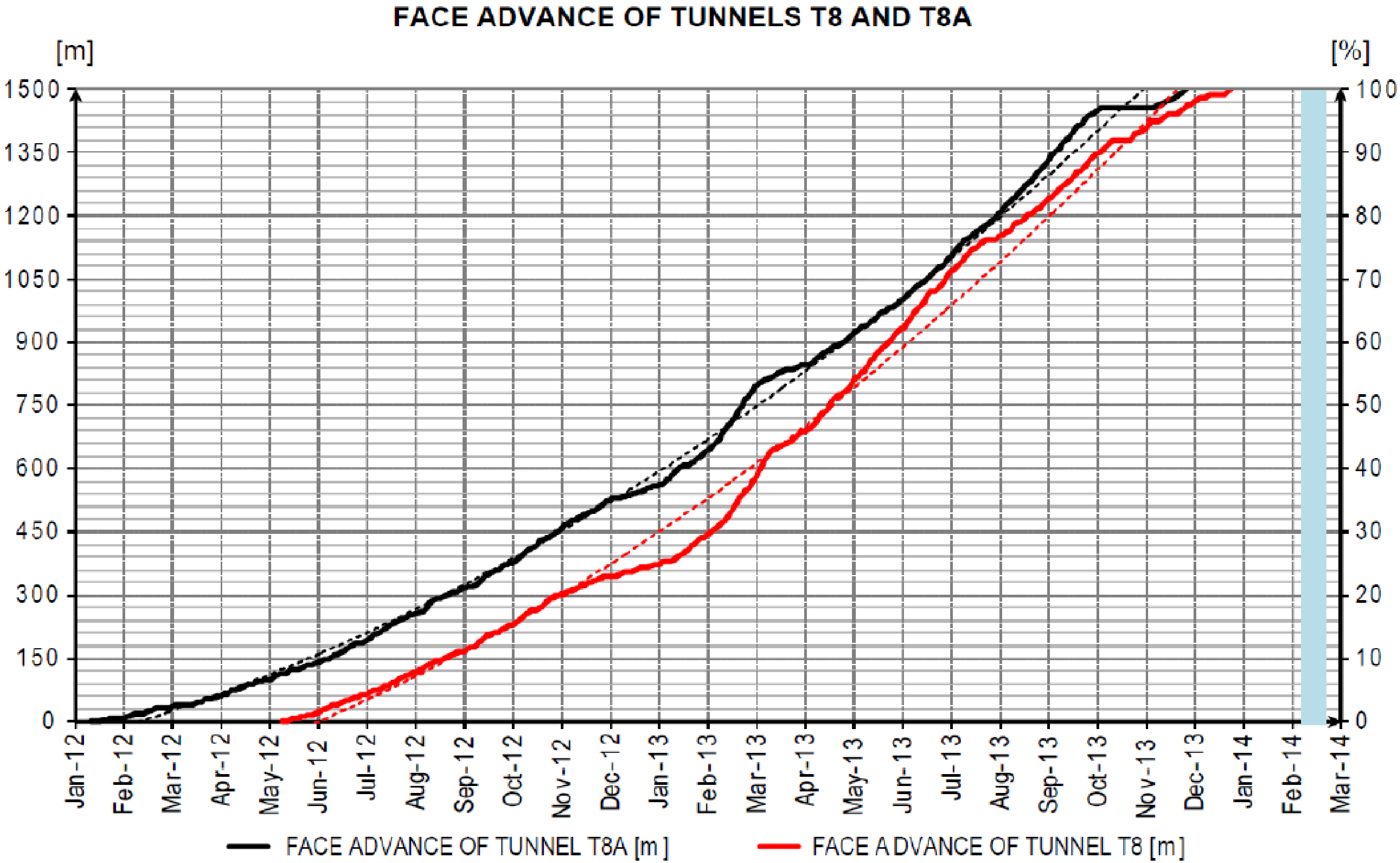
T8 and T8A tunnels

(ADECO-RS typical sections)



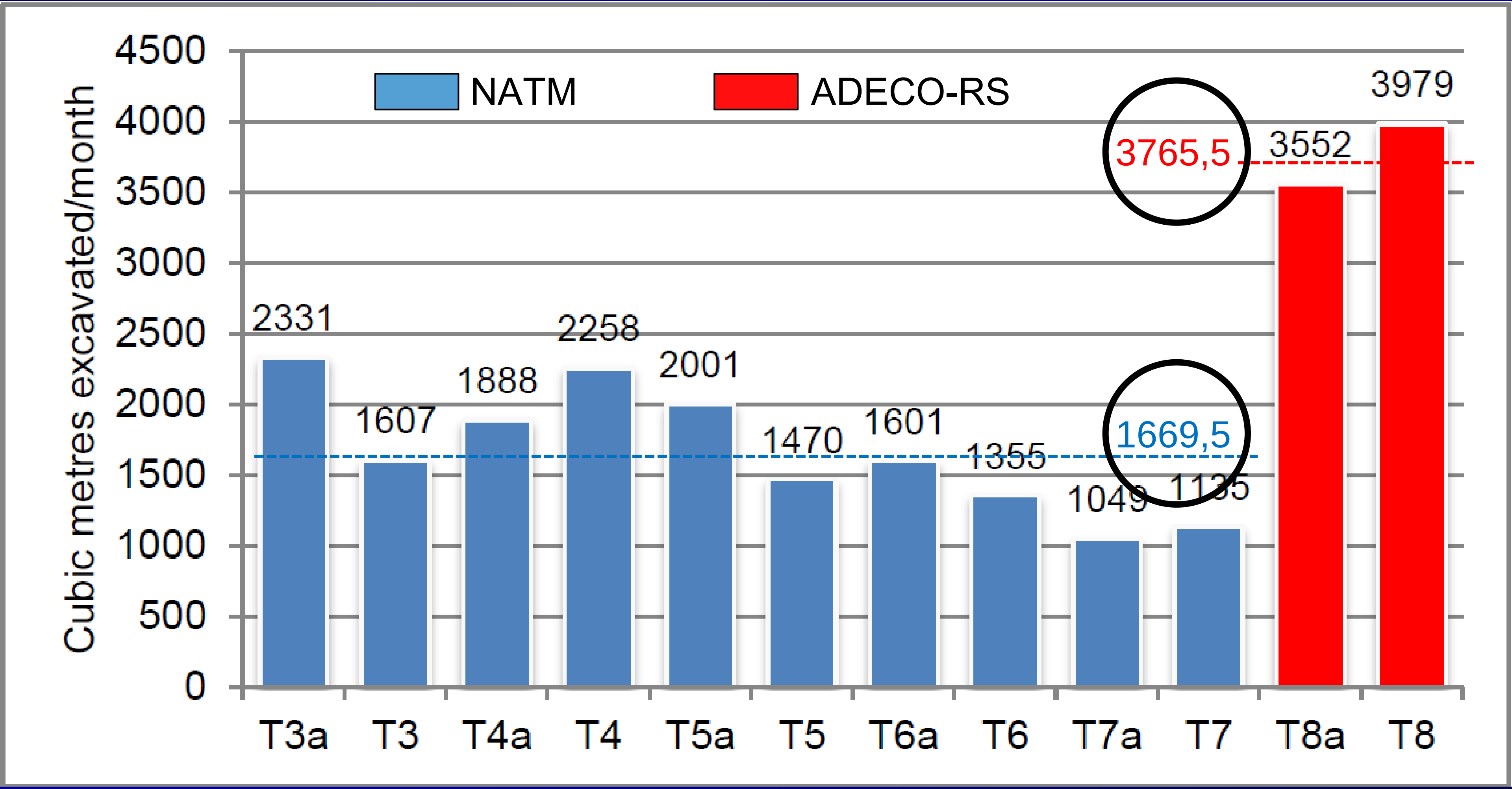


T8 and T8A tunnels (ADECO-RS)



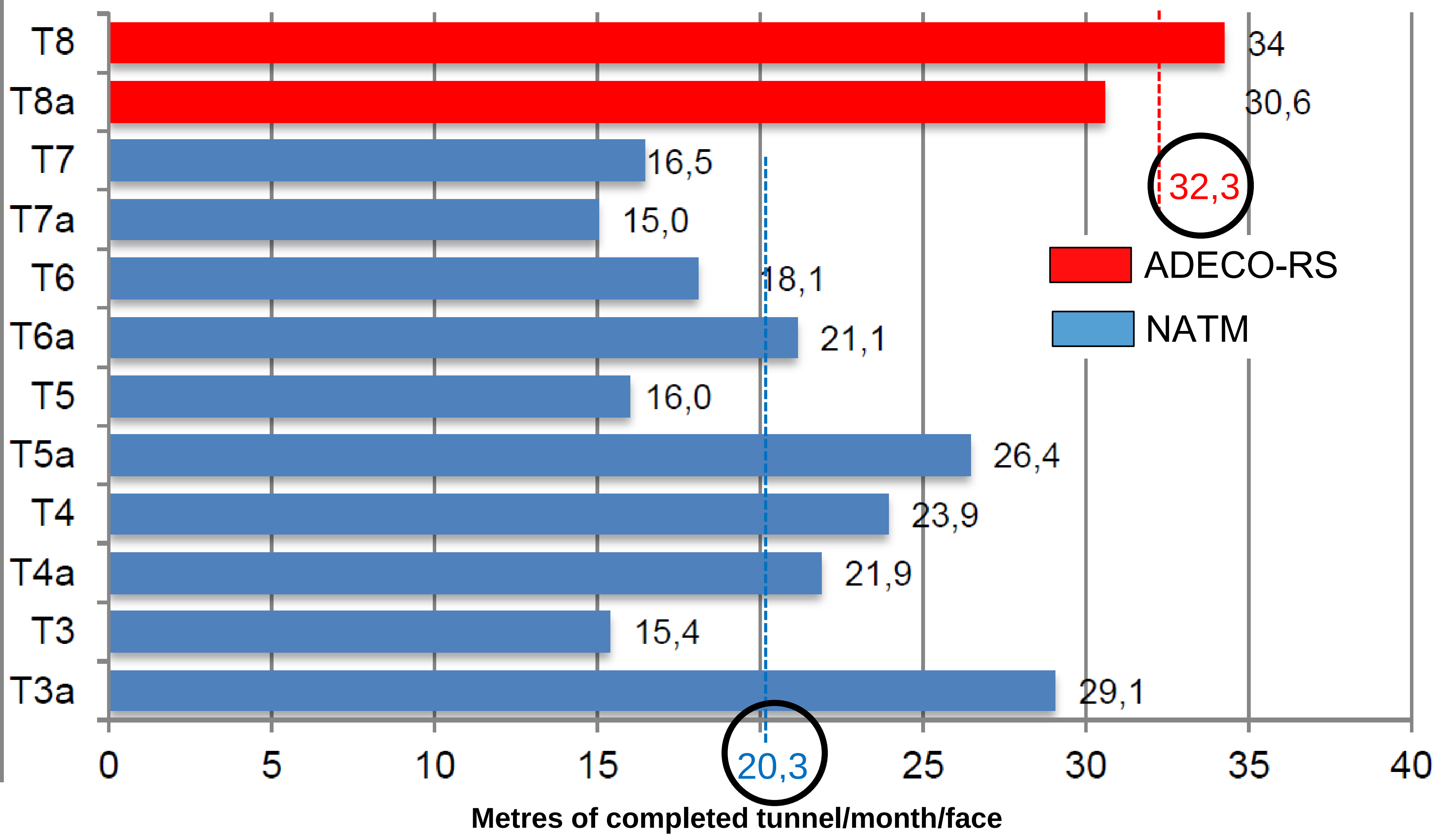
Cubic metres monthly excavated for each excavation face

NATM versus ADECO-RS



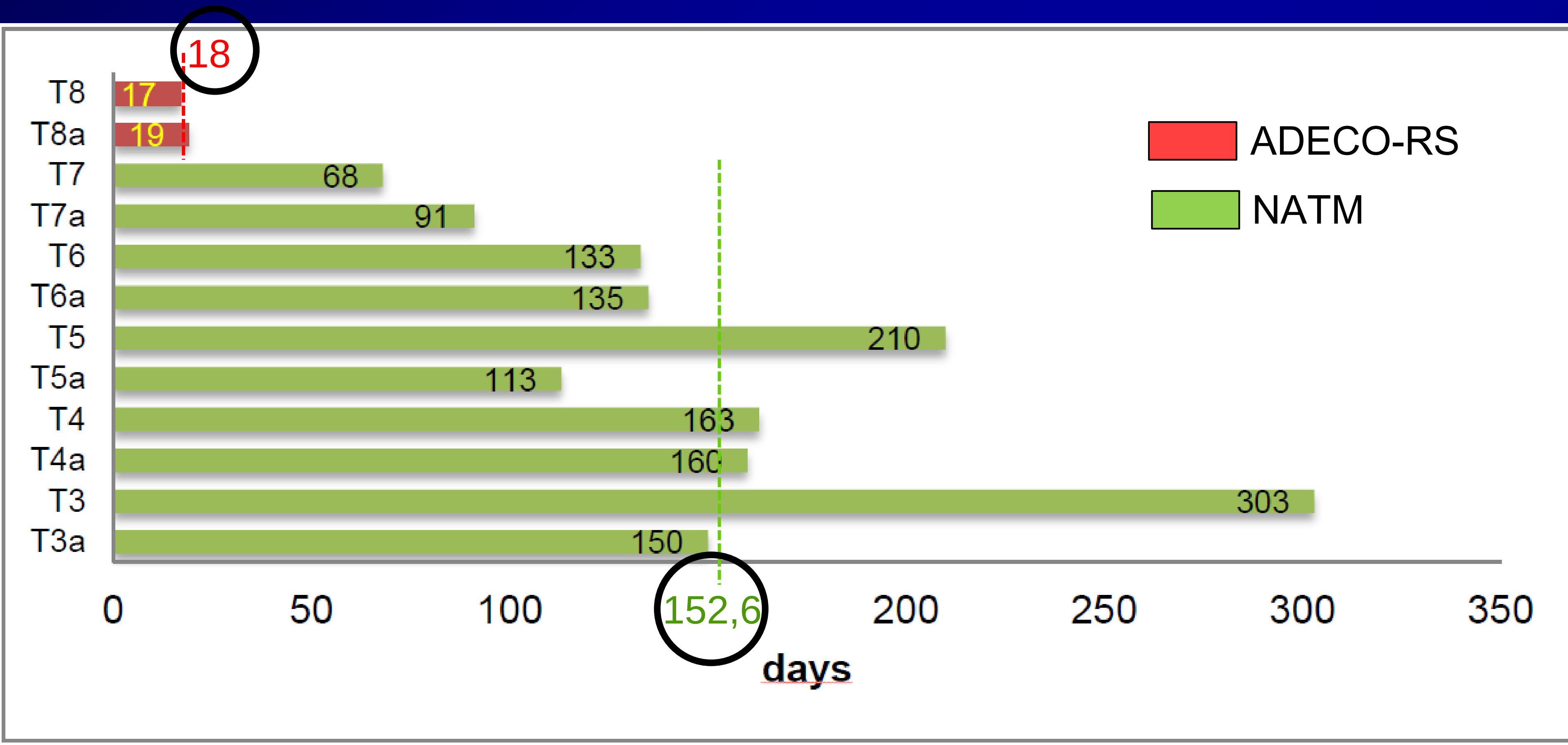
Average production of completed tunnel (Montly metres for each excavation face

NATM versus ADECO-RS



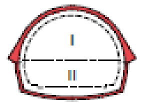
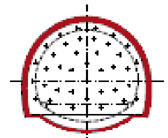
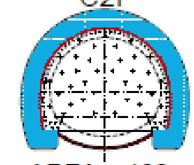
Time (days) between breakthrough and final lining installation

NATM versus ADECO-RS



COSTS

NATM versus ADECO-RS

	PARTITIONED FACE (Tunnels no. 3 and 3a)	FULL FACE (Tunnels no. 8 and 8a)	PARTITIONED FACE (Tunnels no. 3 and 3a)	FULL FACE (Tunnels no. 8 and 8a)
Section type	IV  AREA = 120 m^2	B2  AREA = 120 m^2	IIIб  AREA = 133 m^2	C2P  AREA = 136 m^2
Total cost per m* (rubles)	1,412,675.14	1,396,943.12	2,302,424.00	2,411,120.26

*Source: TRANSTROYTUNNELS, Moscow

The experience gained in Sochi shows that the NATM was generally more expensive than ADECO-RS because of the higher cost of workforce and machinery (NATM employs a number of workers on average 1.5 times higher than ADECO-RS and a large number of small machines against to a few, large and powerful machines used by ADECO-RS.

If you add to this the time saved for tunnel completion (30 to 40% shorter than NATM), and the high industrialization of the tunnel construction guaranteed, ADECO-RS appears without doubt more advantageous also with reference to the costs.

T8 and T8A tunnels

T8 and T8A tunnels

T8 and T8A tunnels

T8 and T8A tunnels

ADVANTAGES OF ADECO-RS APPROACH

-Tunnel is designed as a 3D problem

- Design stage and construction stage are clearly separated

- Few workers at the face

- Pleasant working environment at the face

- Safety during construction

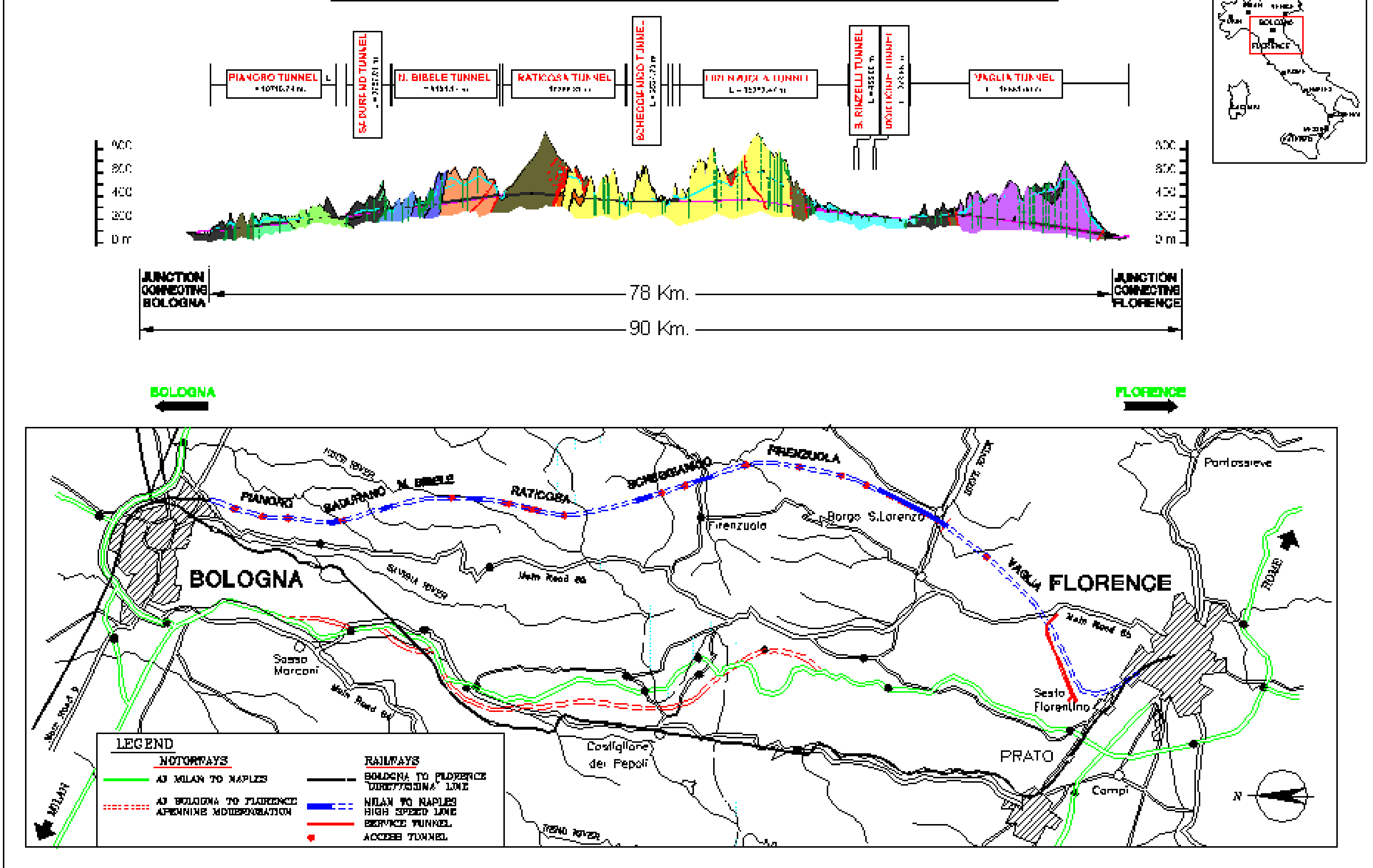
- Industrial production

- Respect of expected construction costs and times

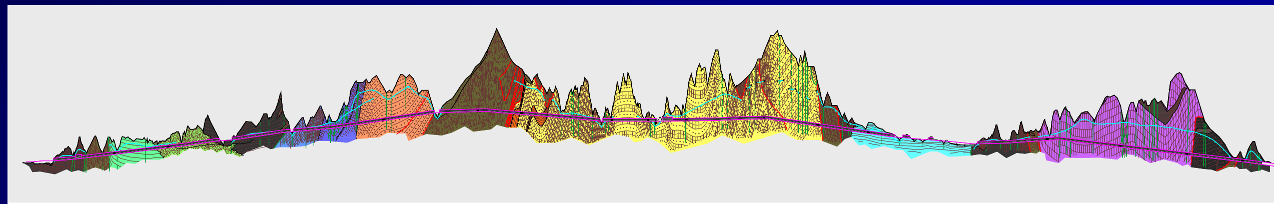
A great example of industrialization of the excavations in difficult grounds for nature and stress fields at stake, in one of the most important yards in the world, active from 1996 to 2005 on 104 km of tunnels for the new high speed railway line Milan-Rome-Naples:

HIGH SPEED RAILWAY SYSTEM

MILAN TO NAPLES RAILWAY LINE - BOLOGNA TO FLORENCE SECTION



HIG SPEED RAILWAY SYSTEM
MILAN TO NAPLES RAILWAY LINE * BOLOGNA TO FLORENCE SECTION



SOME CHARACTERISTIC DATA

Lengths

Length of the Apennines crossing (from Pianoro to Vaglia):	78 Km
Total length of the junctions at Bologna and Florence:	12 Km

Total route:	90 Km
Length of the route underground (from Pianoro to Vaglia):	73 Km
Length of the underground part of the junctions at Bologna and Florence	11,5 Km
Total length of access tunnels:	9,2 Km
Length of service tunnels:	10,6 Km

Total length to be tunnelled:	104,3 Km

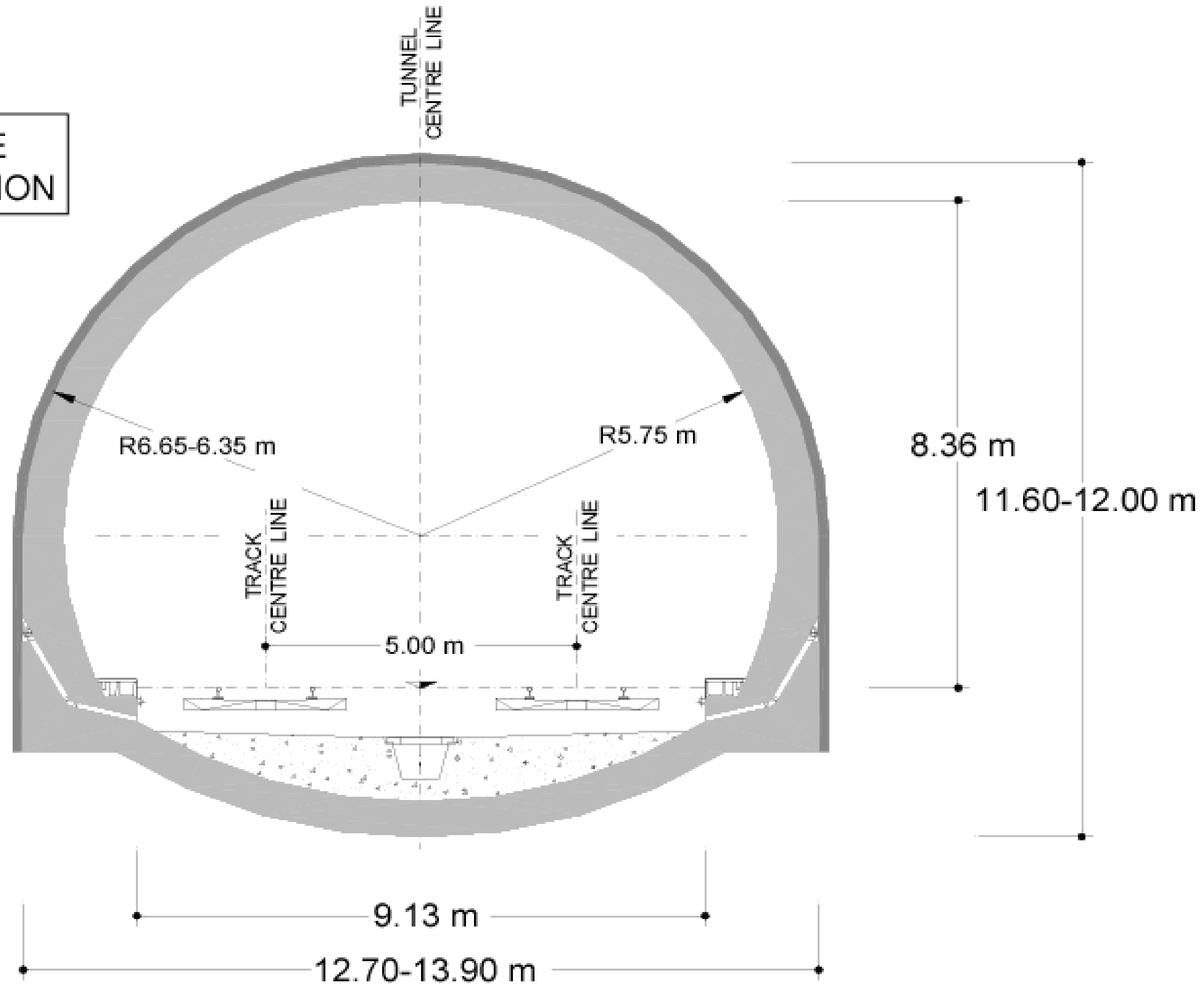
Tunnel cross-sections

Running tunnel average cross-section:	141 m^2
Access tunnel average cross-section:	60 m^2
“Ginori” service tunnel cross-section (to be bored using a shield):	31 m^2

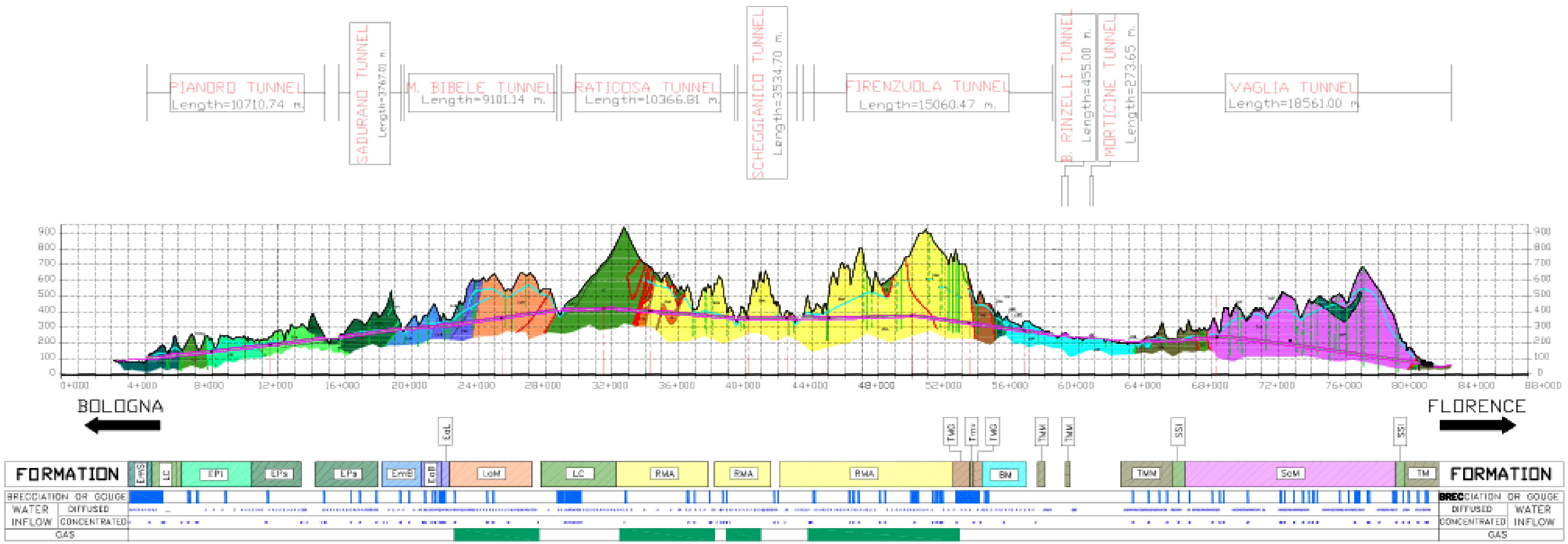
Total volume of excavation: 13.397.500 m^3

MINED TUNNEL SECTION TYPE

141 m² AVERAGE EXCAVATION SECTION

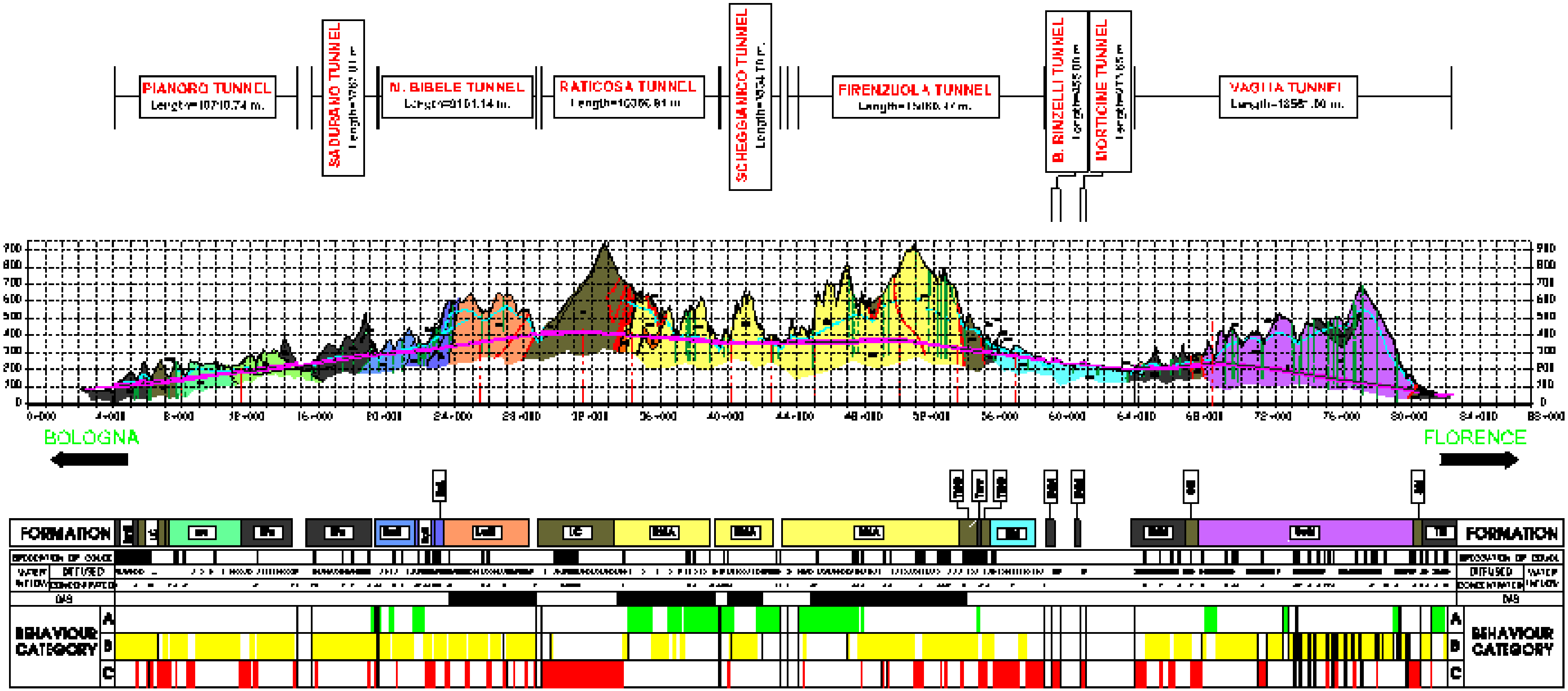


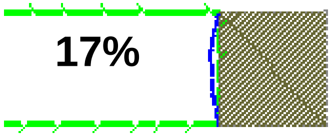
Survey phase



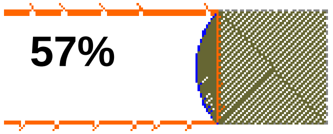
FORMATION		LENGTH [m]	OVERBURDEN [m]	Cohesion [Mpa] Angle of friction [°]	Modulus of elasticity [Gpa]
Schlier Marls (EmS)		2012	0 -120 (Pianoro Tunnel)	c = 0.25-0.3 φ = 28 - 30	E = 2.9 - 3.4
Pliocene Intrappenninico Superiore (EpS)		11445	0 - 245 (Sadurano Tunnel)	c = 0.5-0.7 φ = 28 - 30	E = 3.0 - 6.0
Bismantova Marls (EmB)		7055	0 -140 (Monte Bibele Tunnel)	c = 0.8-1.35 φ = 29 - 33	E = 4.0 - 6.0
Flysch di Monghidoro (LaM)		9115	0 - 290 (Monte Bibele Tunnel)	c = 0.12-0.5 φ = 23 - 35	E = 3.0 - 8.5
Chaotic Complex (LC)		11187	0 - 520 (Raticosa Tunnel)	c = 0.03-0.7 φ = 10 - 25	E = 0.1 - 1.8
Marly-Sandstone Formation (RMA)		39961	0 - 550 (Firenzuola Tunnel)	c = 2.0-2.2 φ = 24 - 38	E = 15 - 20
Clays of Mugello Basin (aBM)		7404	0 - 80 (Firenzuola Tunnel)	c'_p= 0.03 φ'_p = 26 - 28	E = 0.01 - 0.3
Monte Morello Formation (ScM)	limestones	13861	25 - 560 (Vaglia Tunnel)	c = 1.0-1.4 φ = 42 - 45	E = 7 - 15
	clays and marls			c = 0.18-0.24 φ = 28 - 33	E = 2 - 8

Diagnosis phase

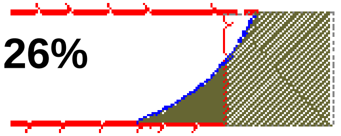




CATEGORY "A" BEHAVIOUR
STABLE CORE-FACE

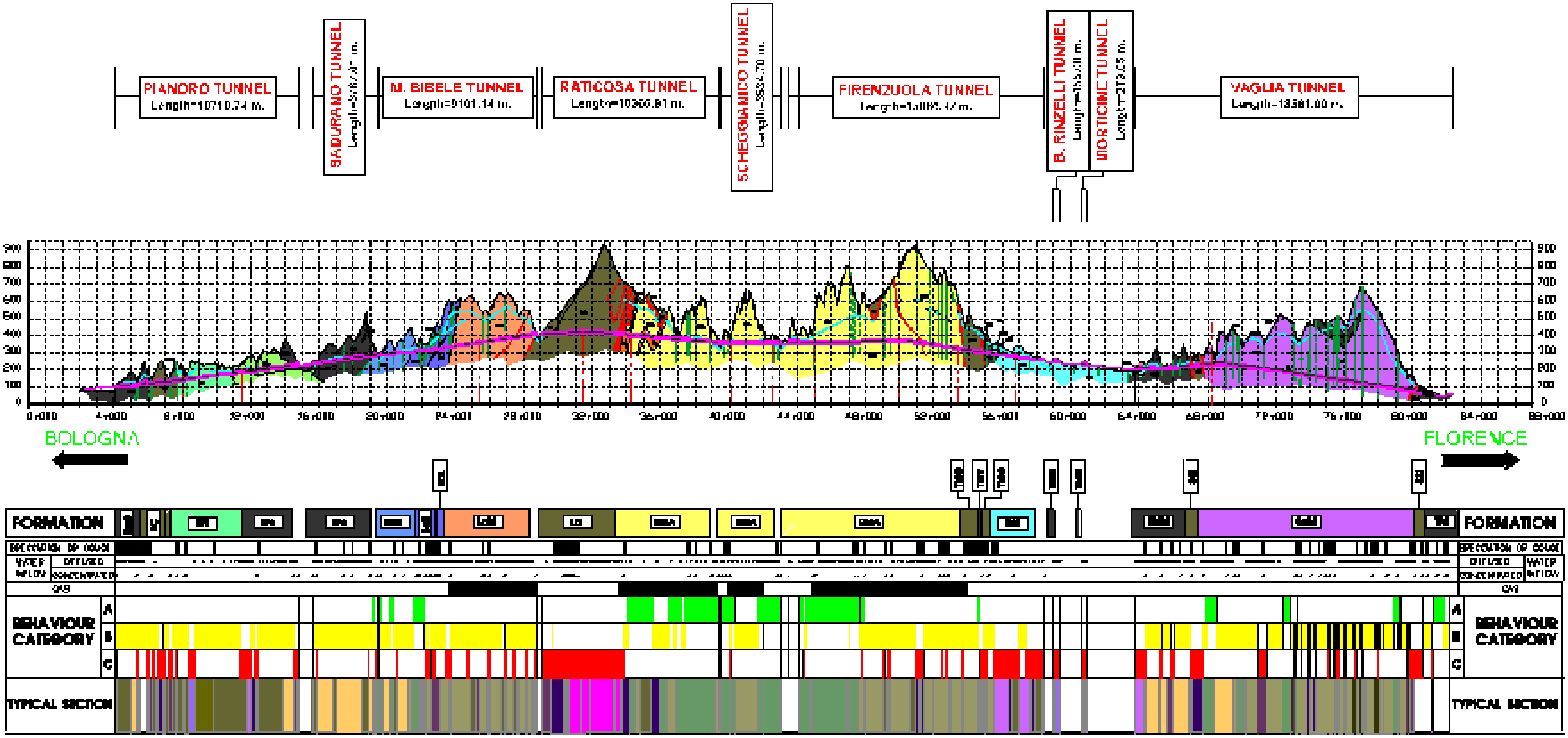


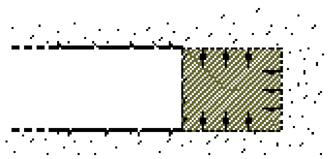
CATEGORY "B" BEHAVIOUR
CORE-FACE STABLE
IN THE SHORT TERM

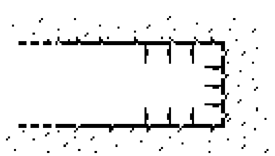


CATEGORY "C" BEHAVIOUR
UNSTABLE CORE-FACE

Therapy phase



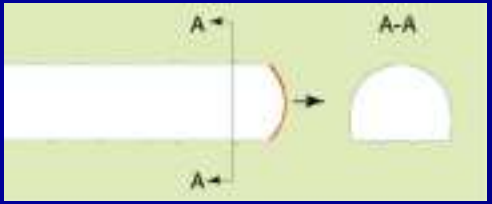




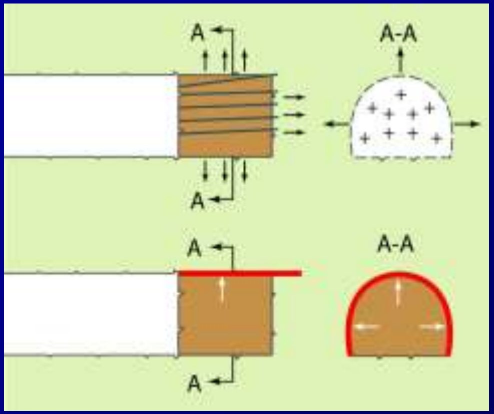
Therapy phase

The main principles on which the design of the tunnel section types was based were as follows:

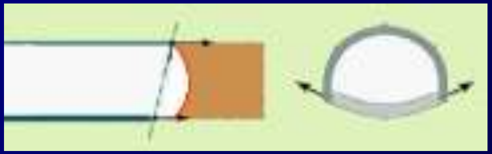
1. full face tunnel advance always, expecially under difficult stress-strain conditions, maintaining a strong concavity of the face;



2. application where necessary of pre-confinement and/or confinement measures able to anticipate and neutralise all movement of the ground at the outset or to absorb a significant proportion of the deformation without collapsing;

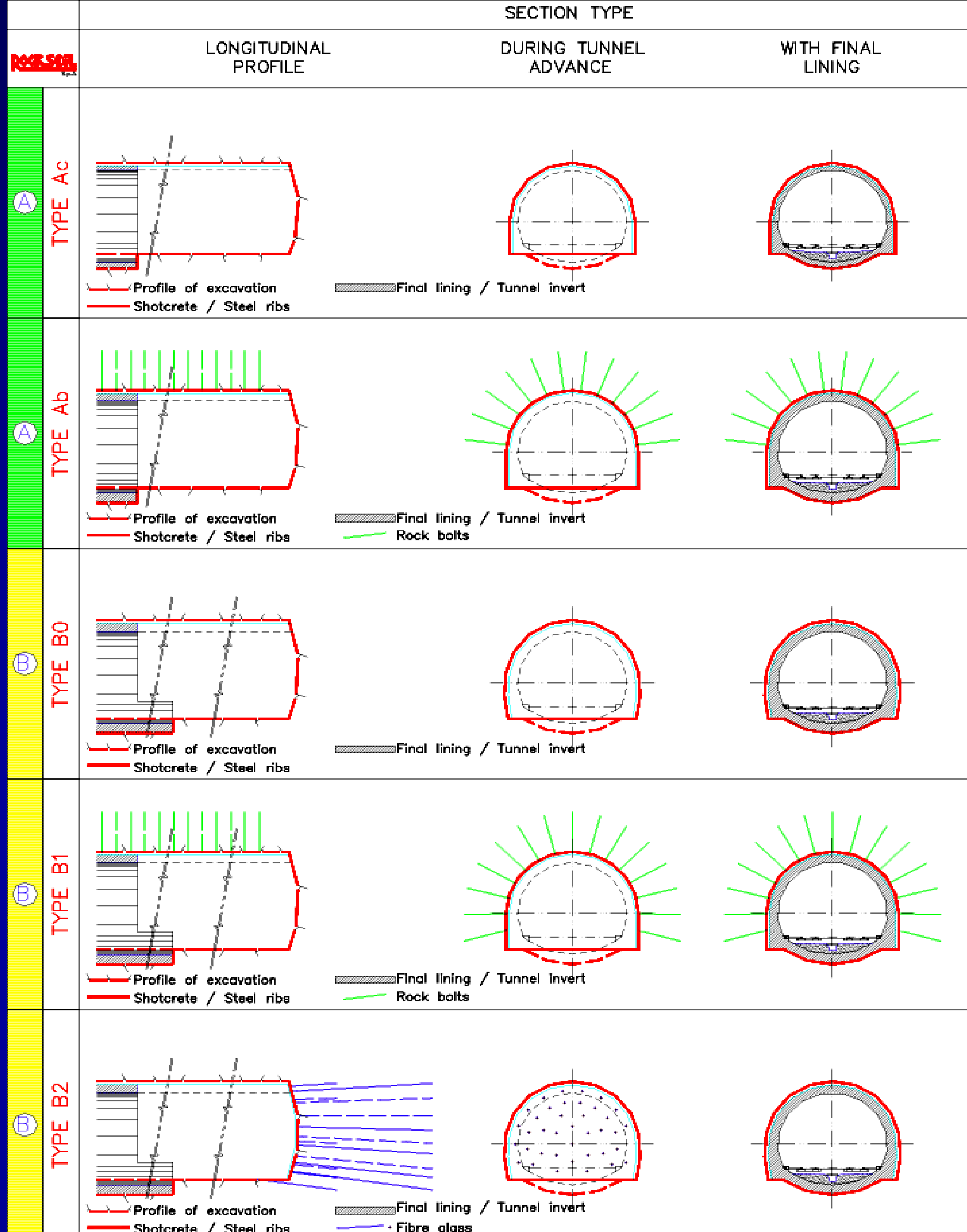


3. casting of the tunnel invert immediately behind the face, where necessary to halt deformation phenomena promptly

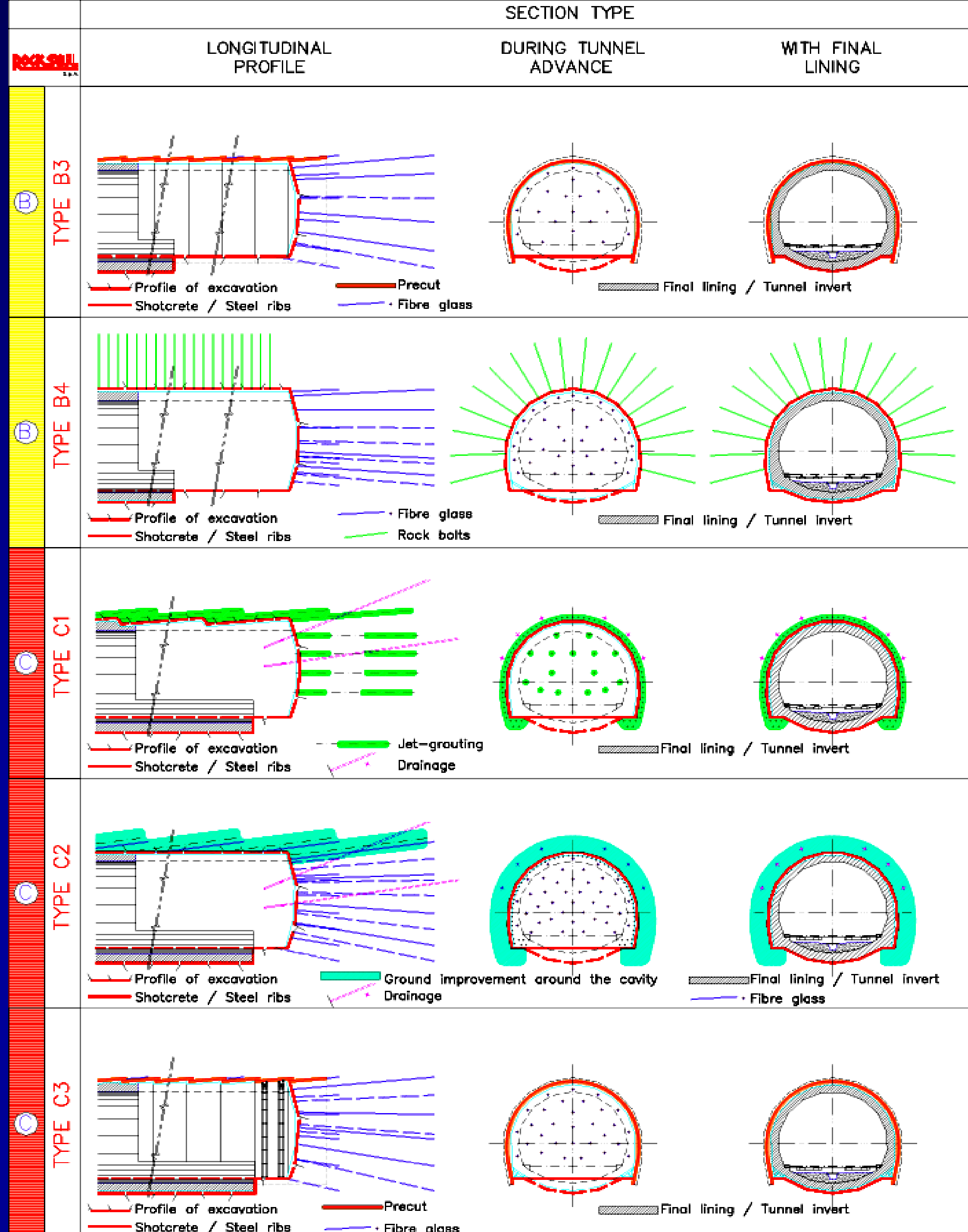


ROCKSOIL S.p.A.

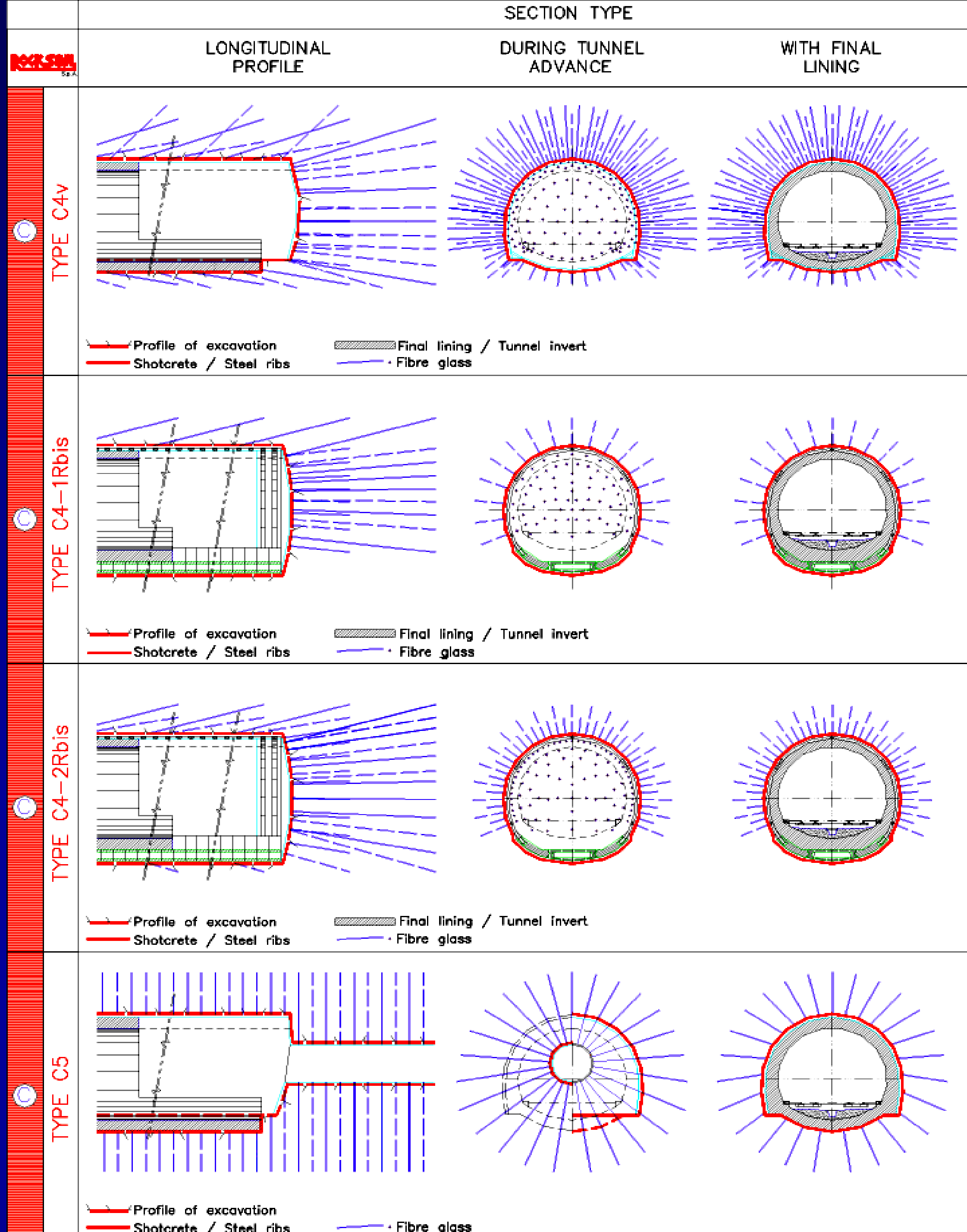
Therapy phase



Therapy phase



Therapy phase



DISTRIBUTION OF DIFFERENCES IN SECTION TYPES BETWEEN THE FINAL DESIGN SPECIFICATIONS AND THE TUNNEL AS BUILT

HIGH SPEED/CAPACITY TRAIN - Milan to Naples Line - SECTION TYPES DISTRIBUTION

FINAL DESIGN

TUNNEL	Length [m]	SECTION TYPES DISTRIBUTION [m] A	B0	B0V	B1	B2	B3	B4	C1	C2	C3	C4	C4V	C5
Pianoro	10293,4		951,8			3886,4	3036		62,0	948,8	1083	310		15,5
Sadurano	3778,0	64,0	2580,8			875,0			68,0	190,3				
M. Bibele	9118,5	978,2	1094,6		4529,1	1212,2			76,0	1112,8		115,6		
Raticosa	10381,0	3043,0			972,2	758,4			40,0	786,7		4465,1		315,67
Scheggianico	3530,6	2089,9			1404,7					36,0				
Firenzuola	14311,5	3528,7			5950,4	716	412,2		227,5	511,9	2226,8	738,1		
B. Rinzelli	455,0								160		295			
Morticine	273,7								80	193,7				
Vaglia	16757,0	2017,2	3104,3	1129,8	5629,0			1151,2	692	708,5			2325,2	
TOTAL LENGTH [m]	68898,6	11721,0	7731,5	1129,8	18485,2	7447,9	3448,2	1151,2	1405,4	4488,6	3604,8	5628,8	2325,2	331,2
SECTION TYPES DISTRIBUTION [%]		17,0	11,2	1,6	26,8	10,8	5,0	1,7	2,0	6,5	5,2	8,2	3,4	0,5

AS BUILT

TUNNEL	Length [m]	Tunnelled length [%]	Tunnelled length [m]	SECTION TYPES DISTRIBUTION [m] A	B0	B0V	B2	B2pr	B2V	C1	C2	C4	C4V	C6
Pianoro	10710	100,0	10710,0		8167,0		682,5		63,0	3,5			1794,3	
Sadurano	3767,0	100,0	3767,0	2213,1	1408,0		85	53			8			
M. Bibele	9101,0	100,0	9101,1	2935,5	2015,7		3965,8		97,9	41	45			
Raticosa	10367,0	100,0	10367,2	3680,0	786,0		857		25	85		1468	673,4	2792,6
Scheggianico	3535,0	100,0	3535,0	3517,0	18,0									
Firenzuola	15211,0	100,0	15211,0	6833,1	3556,3		3081,8		263,5	577,1	9		125,83	43,46
B. Rinzelli	528,5	100,0	528,5					303,5			225,1			
Morticine	565,5	100,0	565,5					537,0			28,5			
Vaglia	16757,0	100,0	16757,7	5287,60	9299,50	96,60	1547,0		296,70	128,25	101,4			
TOTAL LENGTH [m]	70542,3	100,0	70542,4	24466,2	25250,5	96,6	10219,1	893,5	746,1	834,8	417,0	1468,0	2593,5	2836,1
SECTION TYPES DISTRIBUTION [%]				34,7	35,7	0,1	14,5	1,3	1,1	1,2	0,6	2,1	3,7	4,0

Final design specifications:

Section types: $\begin{cases} A = 17\ \% \\ B = 57\ \% \\ C = 26\ \% \end{cases}$

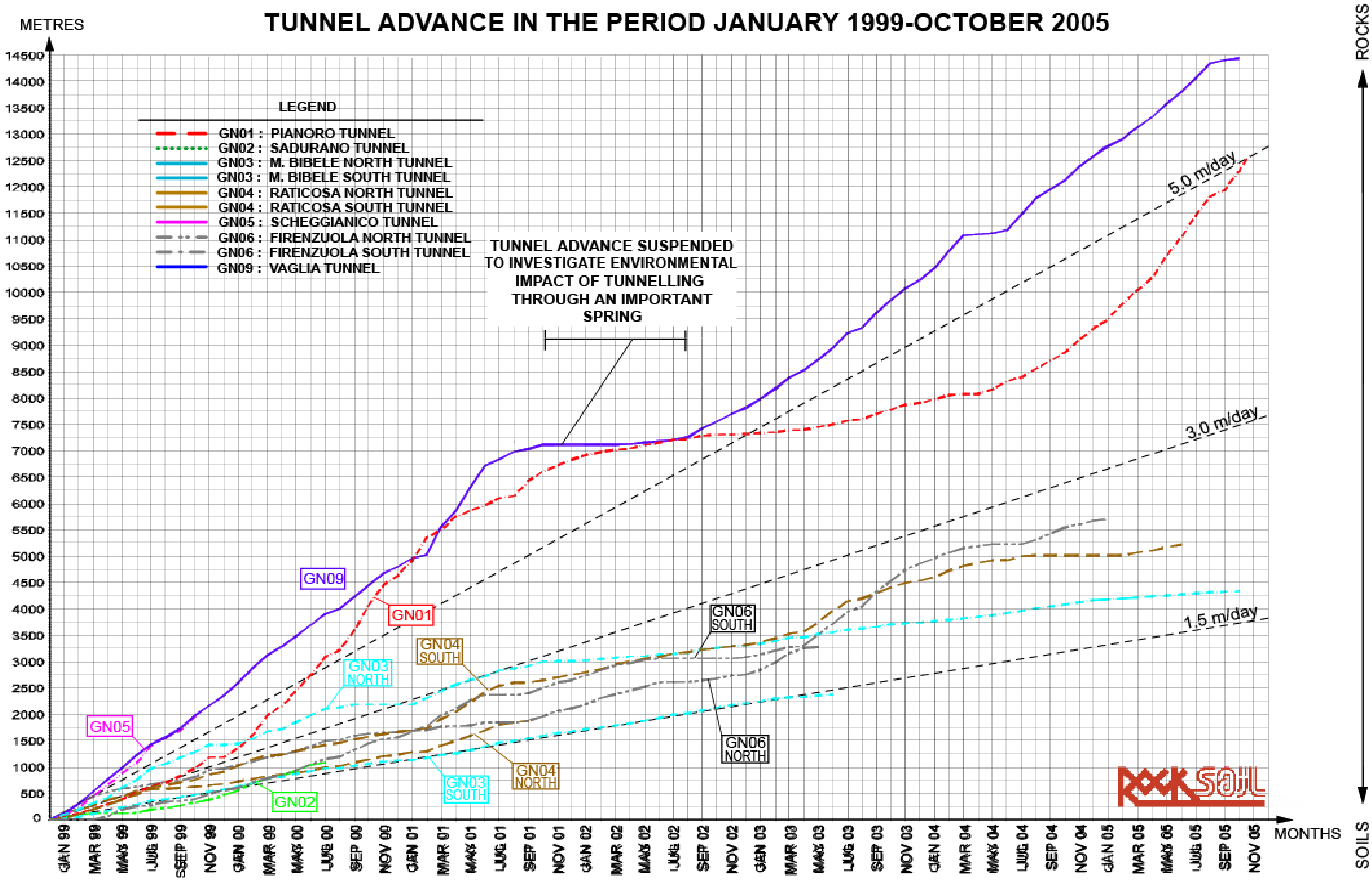
Tunnels as built:

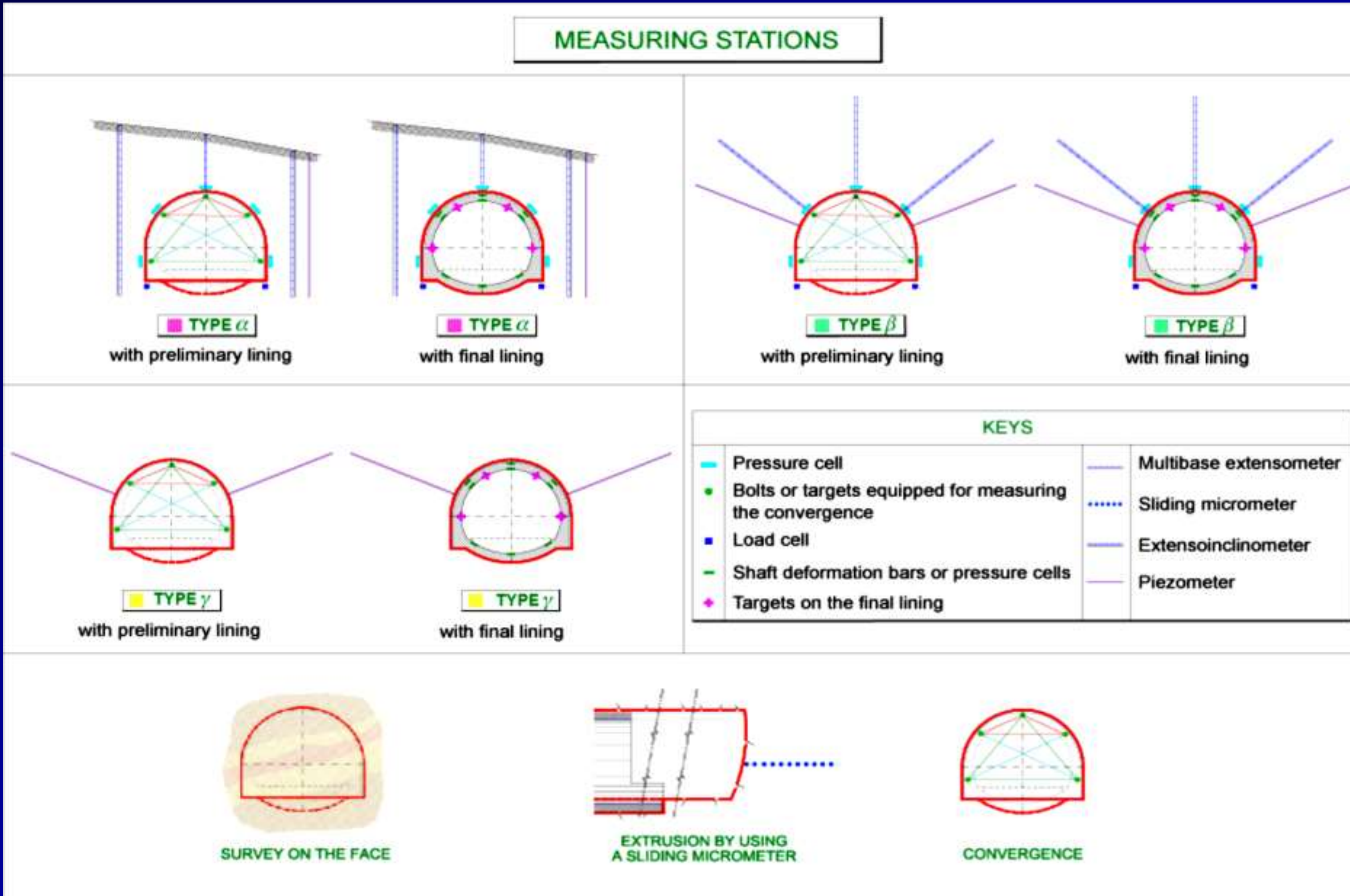
Section types: $\begin{cases} A = 34.7\ \% \\ B = 53.7\ \% \\ C = 11.6\ \% \end{cases}$

Please note that only one survey per kilometre was available

S.p.A.

INDUSTRIAL-LIKE PRODUCTIONS





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Vaglia tunnel

Ground: limestones, marls and sandstones (Monte Morello Format.); Overburden: 600 m, Behaviour cathegory: A-B)

Pianoro tunnel

Ground: silty marls (Marne di Schlier Formation); Overburden: 80 m, Behaviour cathegory: A)

Monte Bibele tunnel

Ground: marls (Bismantova Formation); Overburden: 40 m, Behaviour cathegory: A-B

Firenzuola tunnel

Ground: marls and sandstones (Marnoso-Arenacea Formation); Overburden: 500 m, Behaviour category: A-B

Pianoro tunnel

Ground: slightly cemented sandstones arenarie (Pliocene Intrappenninico Superiore); Overburden: 150 m, Behaviour category: B-C

Monte Bibele tunnel

Ground: flysch (Monghidoro Flysch); Overburden: 200 m, Behaviuor category: B-C

Raticosa tunnel

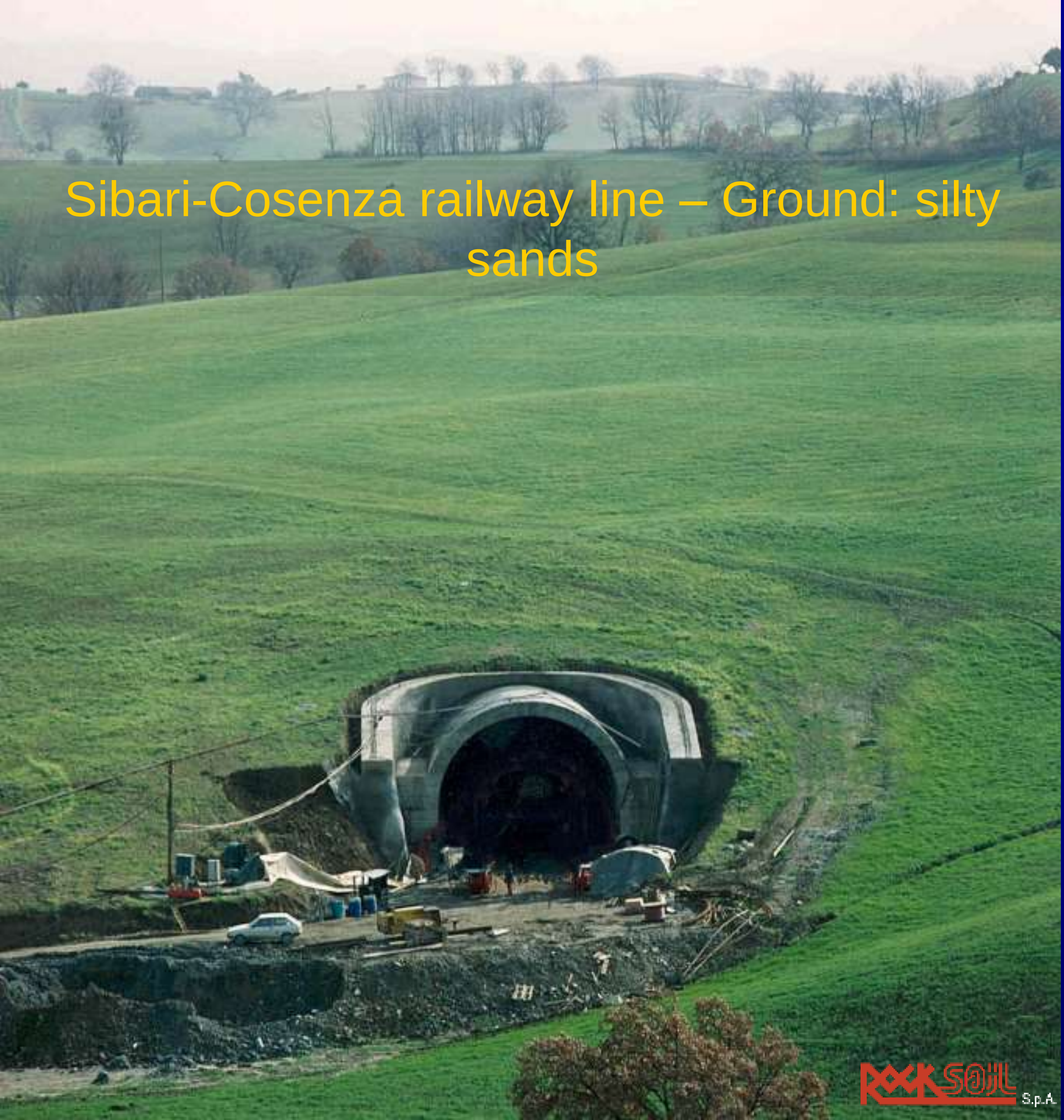
Ground: scaly clays (Complesso Caotico), Overburden: 550 m, Behaviour cathegory: C

Firenzuola tunnel

Ground: silts and silty sands with intercalated pebbly (Bacino del Mugello Formation); Overburden: 40 m, Behaviour category: C

Vaglia tunnel

Ground: Bacino del Mugello clays; Overburden: 15 m, Behaviour category: C



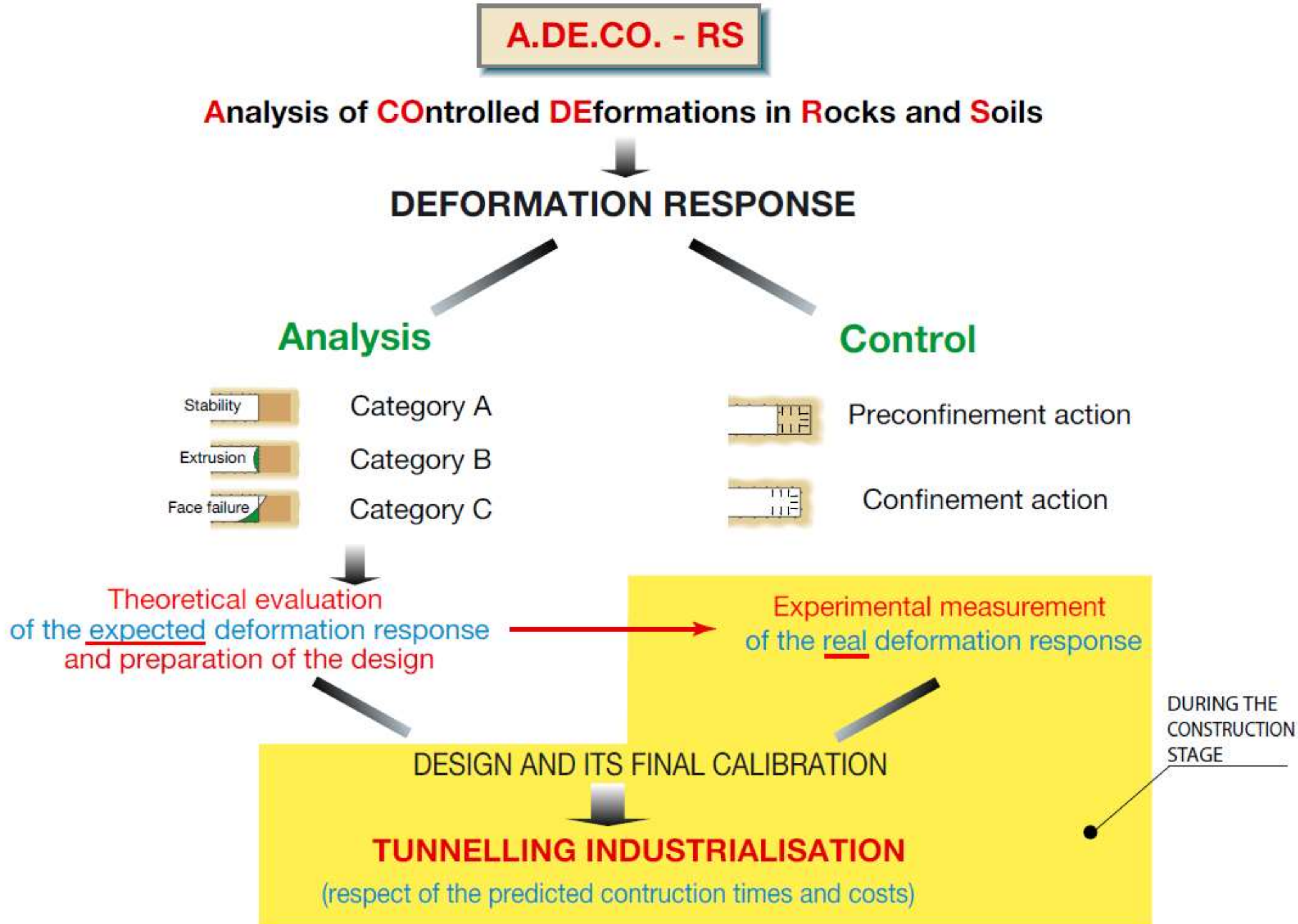
Sibari-Cosenza railway line – Ground: silty sands

In tunnel construction entrances often presents situations that are very delicate. Even in this case the preconfinement of the core-face allows to begin the tunnel safely and without defacing the slope with disproportionate incisions

CONCLUSIONS

NATM and derived methods

ADECO-RS



Today, the industrialization of the excavations both by mechanized and conventional systems is a reality and underground works are finally real engineering works due to the respect of times and costs

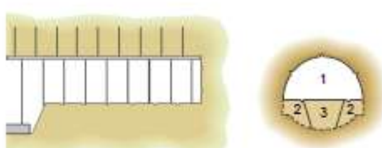
(“*Tunnels should be driven full face whenever possible, although* (today) *this cannot always be done....*”) (Rabcewicz, 1964)

“*The strategy for a project needs therefore to be fashioned in considerable detail before major resources are committed*”) (Muir Wood, 2002),

ANALYSIS AND CONTROL OF THE DEFORMATION RESPONSE

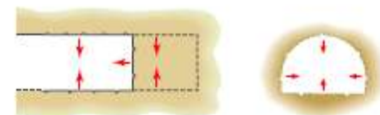
NATM and derived methods

They act late in the cavity accepting the convergences

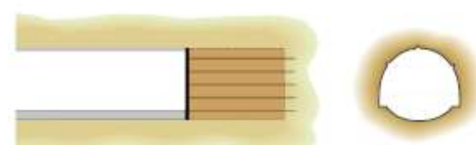


Precarious stability

ADECO-RS



It acts preventively on the core-face anticipating extrusion phenomena and then the convergences



Secure stability

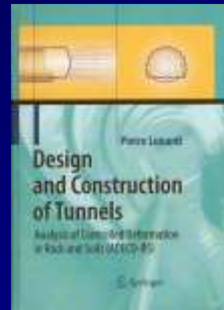
ADECO-RS

The Italian Approach to Tunnelling

Analysis of Controlled DEformations

in Rocks and Soils

Italian



English

Chinese

Korean

Volume one

Volume two

Persian

A brochure on *"Design & constructing tunnels – ADECO-RS approach"* can be downloaded from the www.rocksoil.com web site.