



SAFETY AND INNOVATION: SMART SOLUTIONS FOR UNDERGROUND CONSTRUCTIONS

February 27, 2024

MACCAFERRI



- 5' *Introduction*
- 5' *Our portfolio to face the challenges of underground constructions*
- 10' *Safety that drives innovation: Automated Tunnel Ribs*
- 10' *Operational and engineered safety: the PER Ground System*

Q&A Session

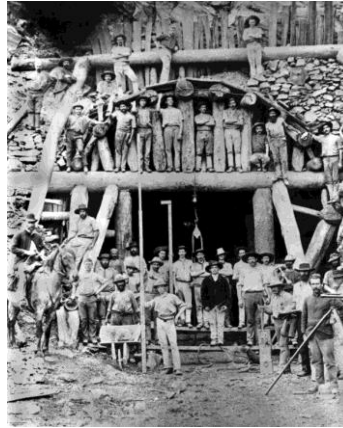
Speakers

Caterina Zanca – Environmental Engineer

Alberto Turra – Tunnelling Technical Specialist

The technical choices made during the construction of underground works have a significant impact on the safety, quality, timeline, and overall project costs





The methods and excavation techniques for tunnel construction have changed significantly over the years.

Technological evolution has introduced a drastic reduction in manual labor but greater complexity in operations.



Investing in the research
of innovative solutions
enables effective
handling of potential
challenges that may
arise during project
execution





One of the primary objectives driving innovation and research within the underground construction sector is the enhancement of safety levels through technological evolution

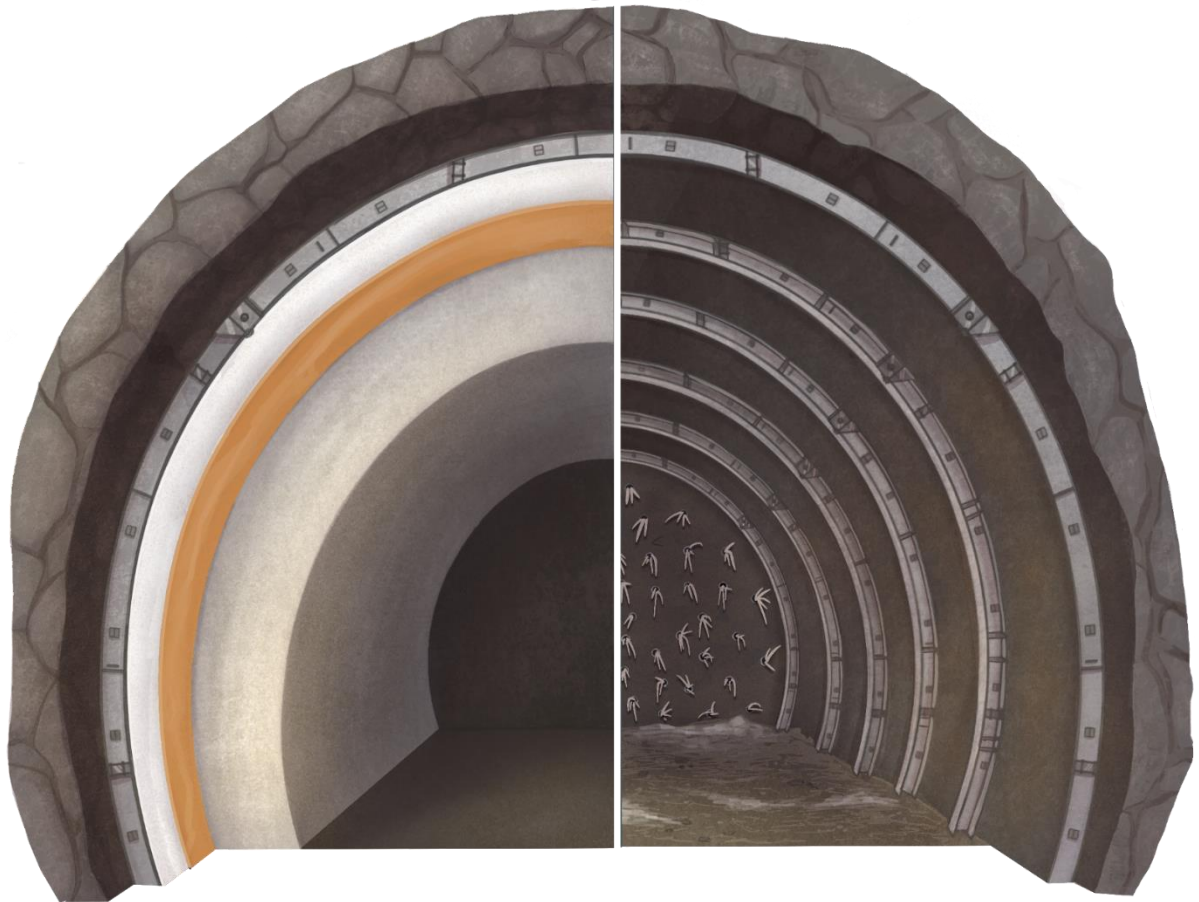
Maccaferri is consistently committed to advancing technological development that meets the needs of underground excavation.

This dedication has given rise to a comprehensive and innovative portfolio.



OUR SOLUTIONS

The Maccaferri portfolio



OUR SOLUTIONS

MACCAFERRI

The Maccaferri portfolio

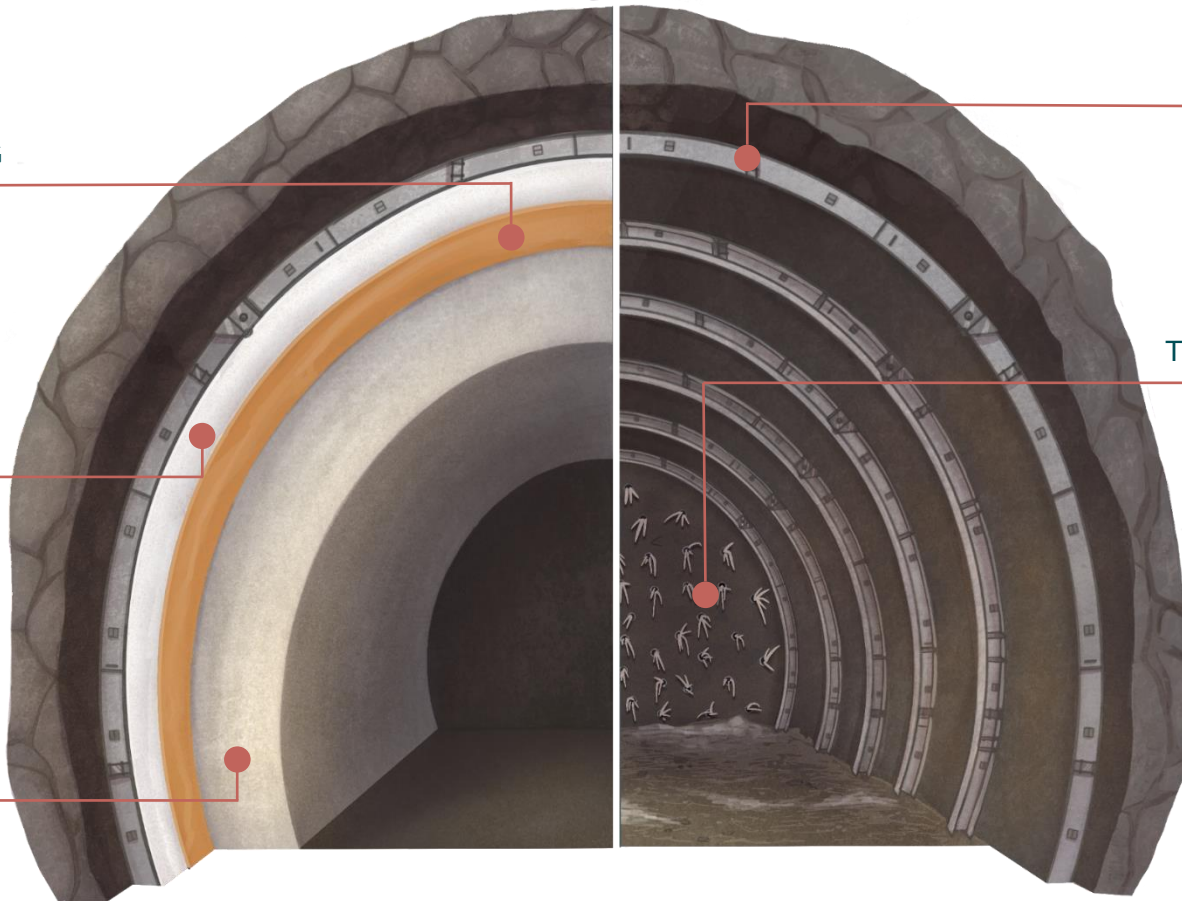
WATERPROOFING

DRAINAGE AND
PROTECTION

FINAL LINING

PRIMARY LINING

CONSOLIDATION AND
REINFORCEMENT OF
THE EXCAVATION FACE

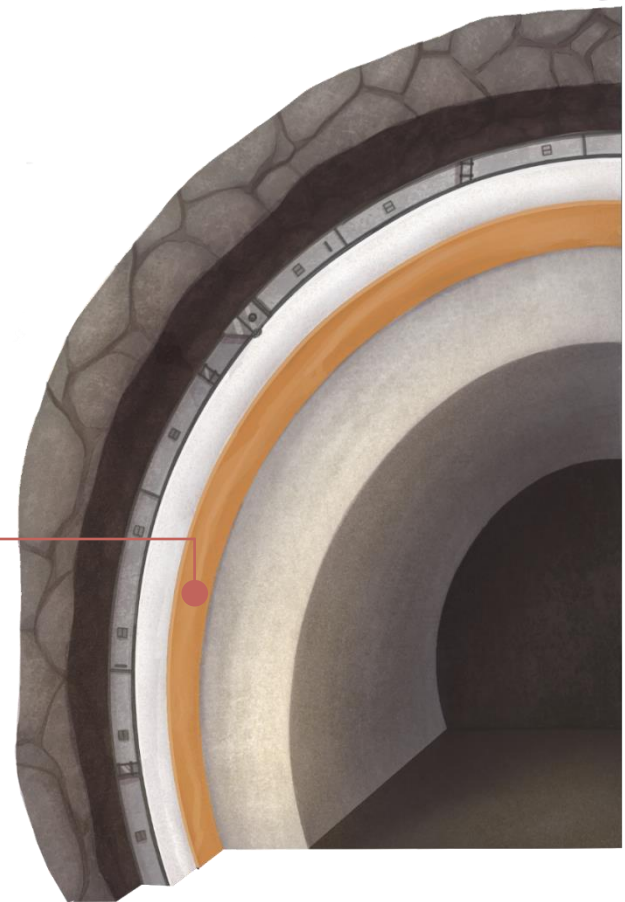


WATERPROOFING



MACLINE™

A polymeric geomembrane that guarantees an extremely low permeability, preventing any water ingress and infiltration.

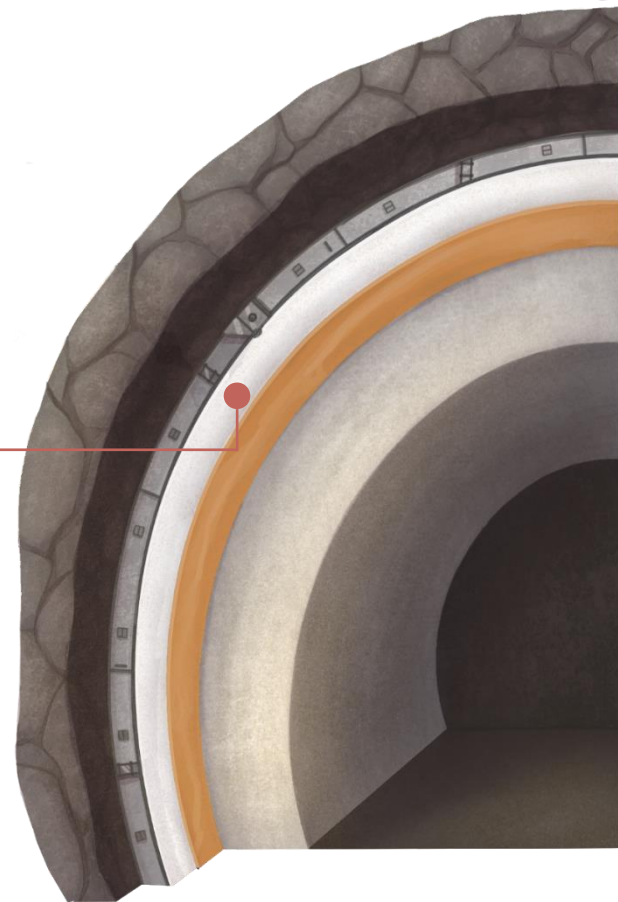


DRAINAGE AND PROTECTION



MACDRAIN™

A geocomposite consisting of a drainage core between two layers of geotextile. Its dual function of drainage and protection allows for a single installation and process optimization.



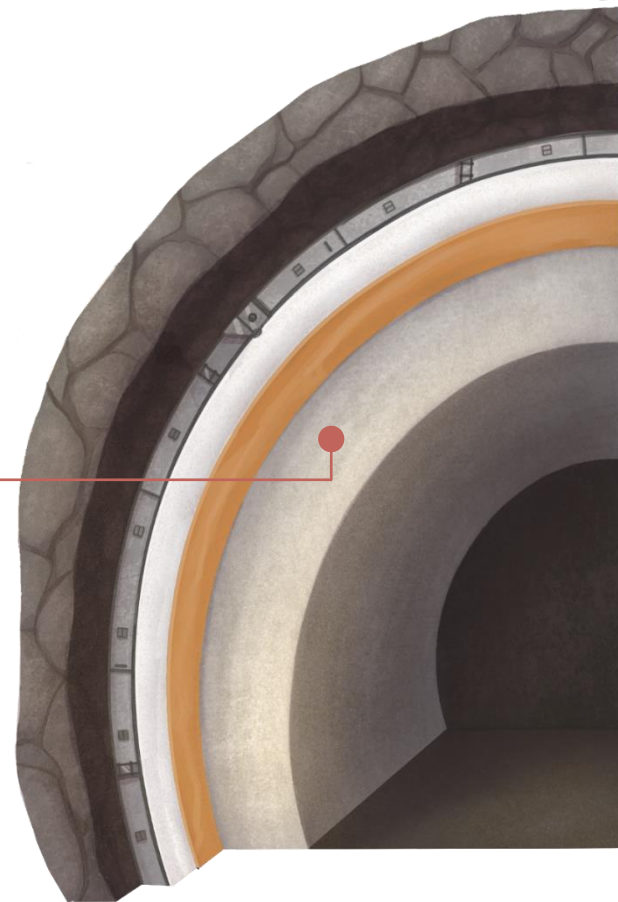
The Maccaferri portfolio

FINAL LINING



STEEL FIBERS (SFRC)

Our steel fibers for fiber-reinforced concrete provide an uniformly and intimately distributed reinforcement within the final concrete lining, preventing micro-cracks.



OUR SOLUTIONS

MACCAFERRI

The Maccaferri portfolio

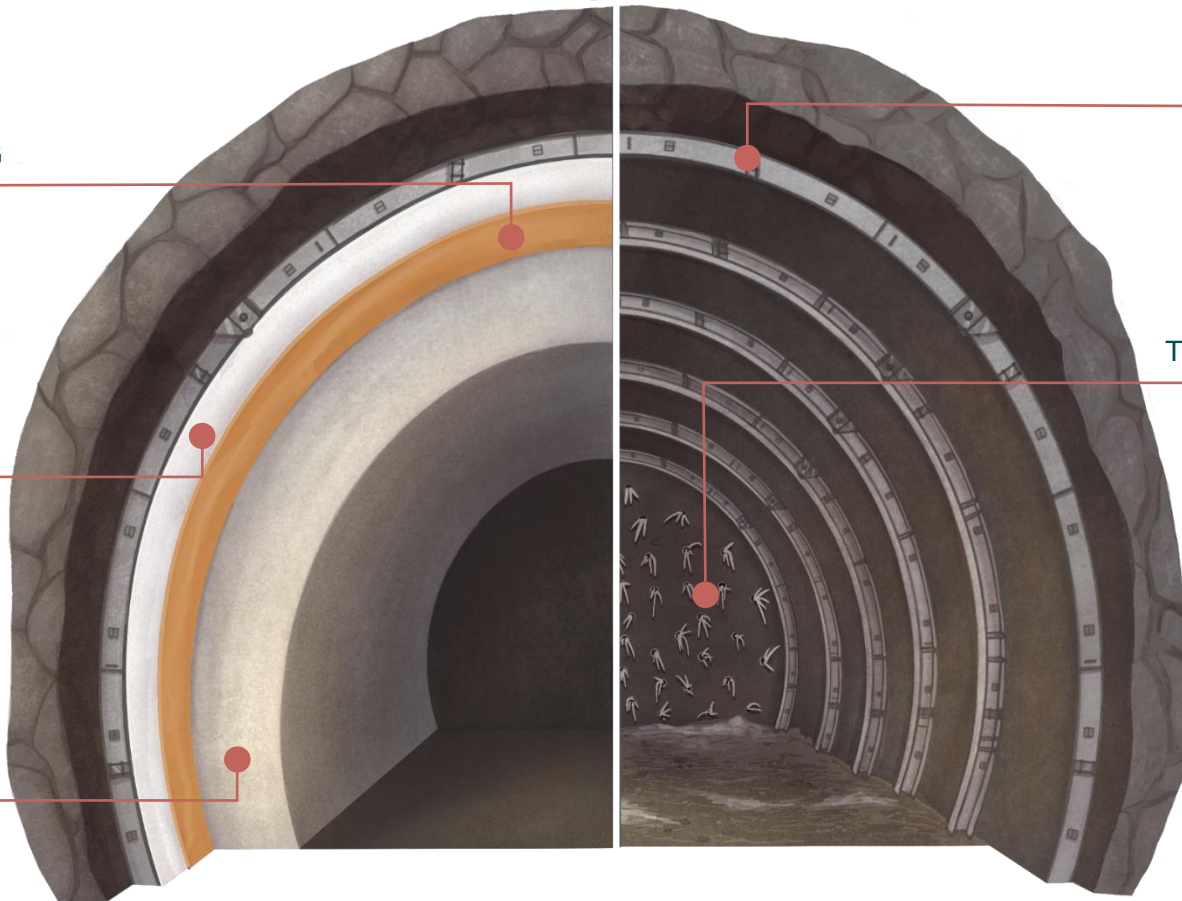
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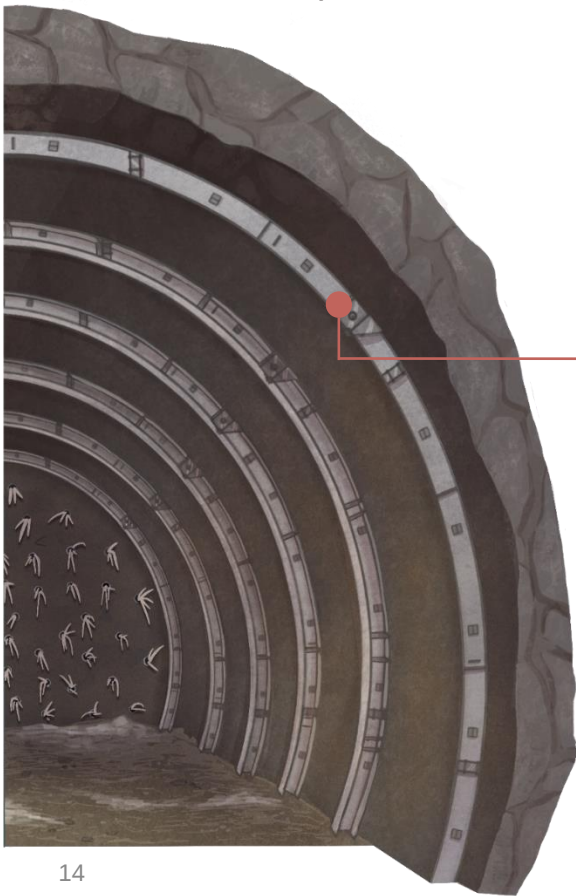
DRAINAGE AND
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PRIMARY LINING

AUTOMATED TUNNEL RIBS



Both H-Beam and Round Tubular ribs are designed to achieve the highest performance and withstand the highest lithostatic pressures.

In the final phase of primary lining, shotcrete reinforced with steel fibers is used.

The primary lining typically involves the assembly and installation of tunnel ribs.

The traditional procedure requires **intensive manual work**, and often these operations take place at very close distances from the excavation face.



«Technical and technological progress does not concern the mined tunnel engineering in an extensive way, so much so that there are still some work phases that require the presence of workers close to the excavation face.»



Nota interregionale “Lavori a ridosso del fronte”

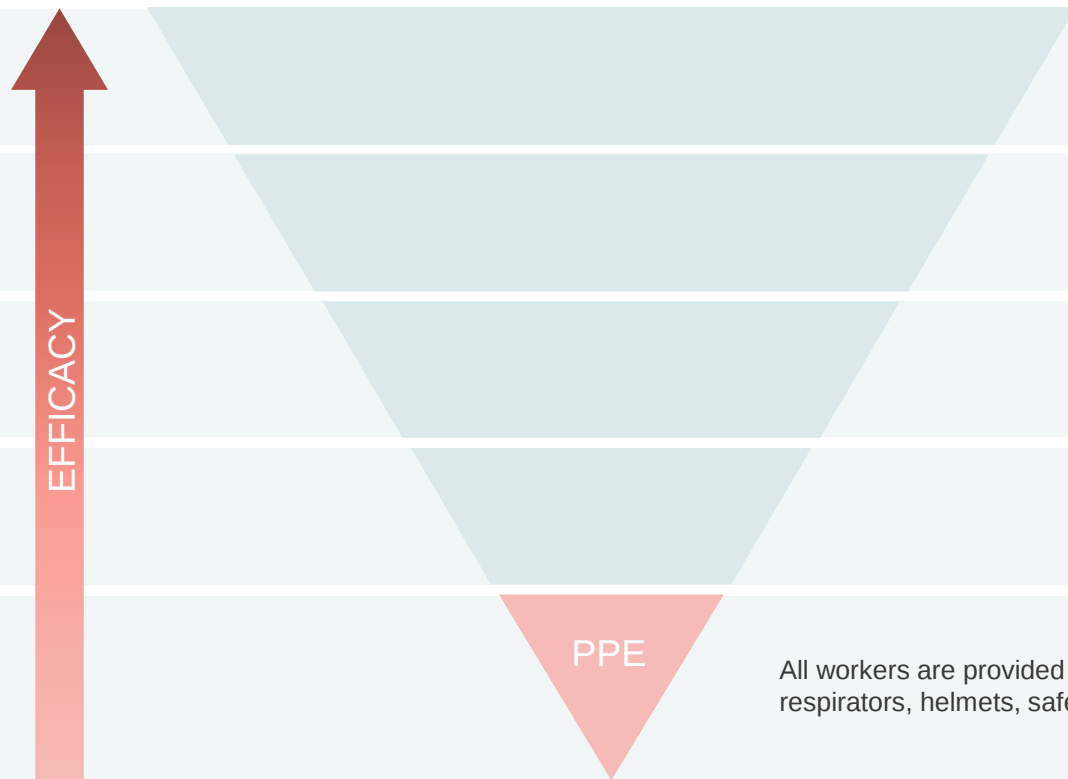
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27/11/2009

Hierarchy of risk control

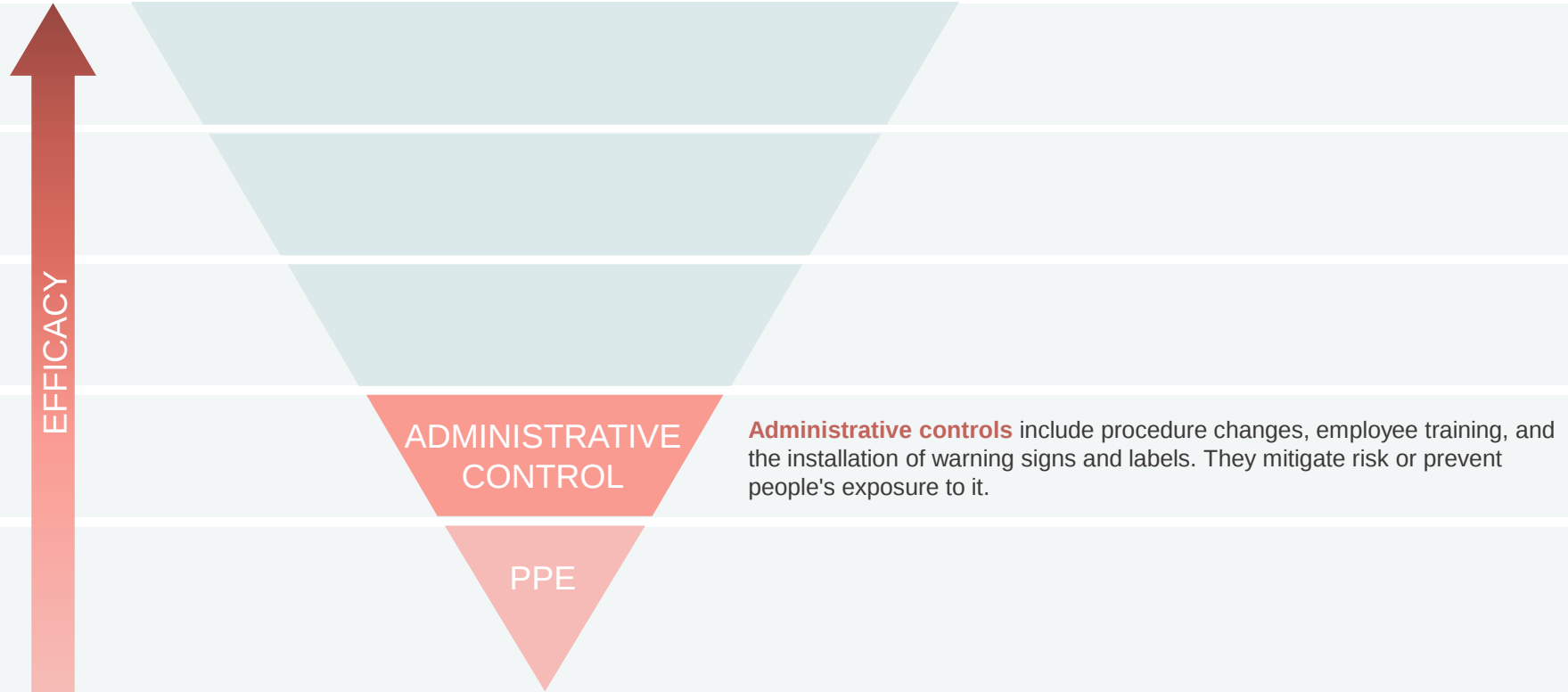


Hierarchy of risk control

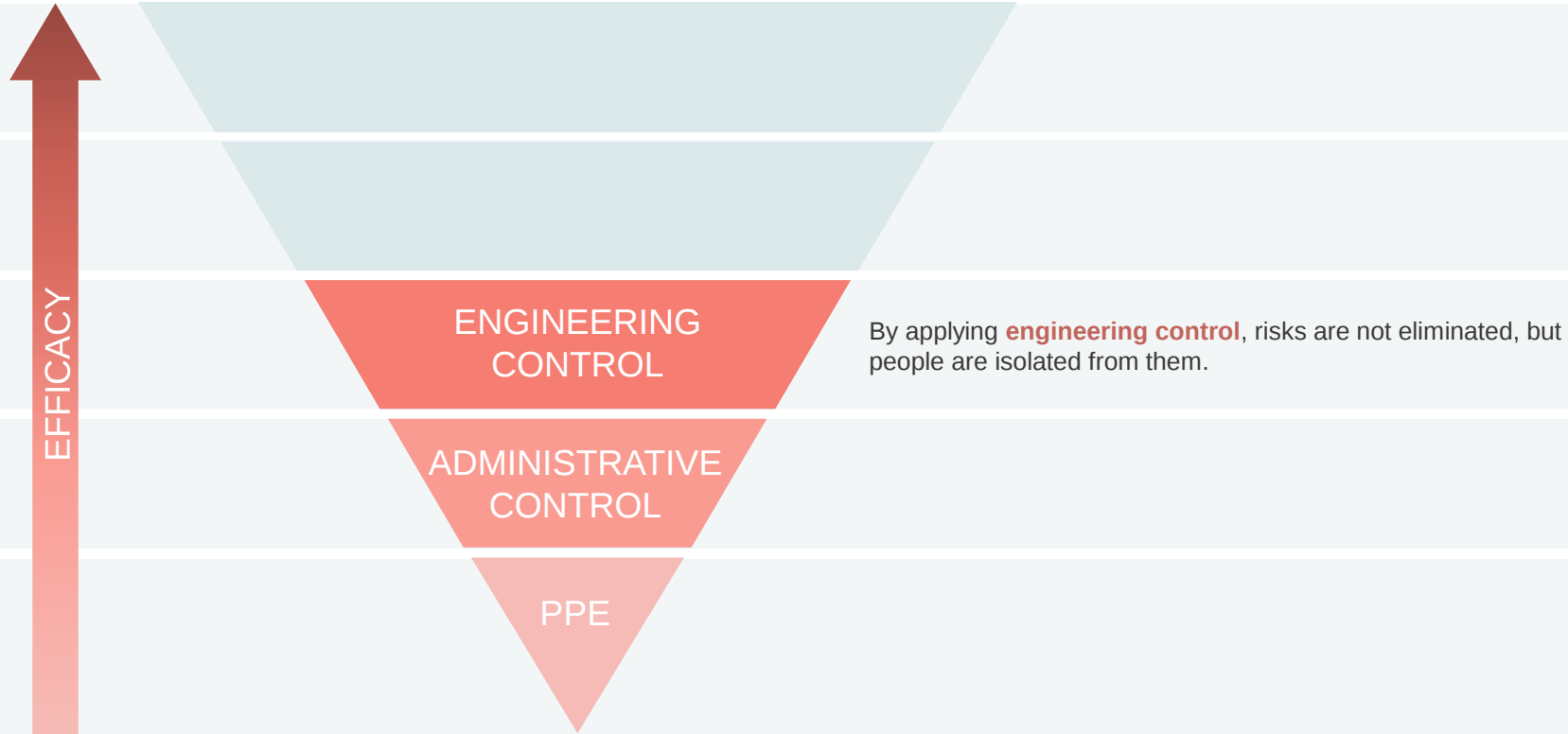


All workers are provided with **personal protective equipment**, such as gloves, respirators, helmets, safety glasses, high-visibility clothing, and safety footwear.

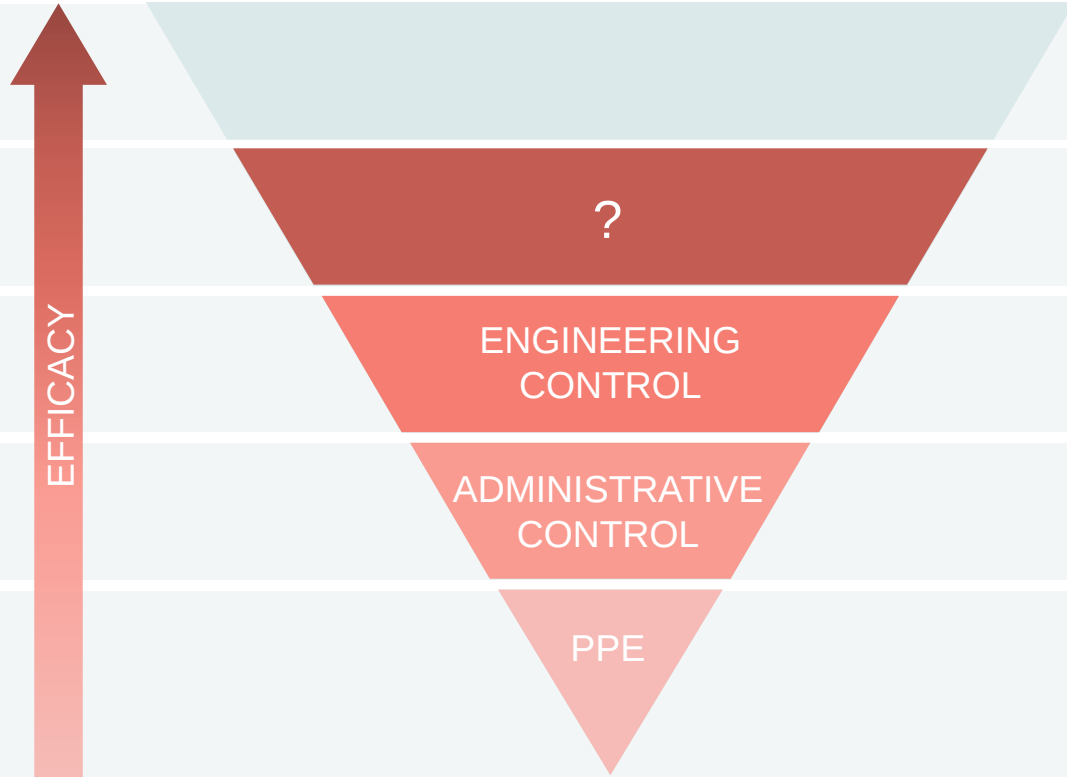
Hierarchy of risk control



Hierarchy of risk control



Hierarchy of risk control





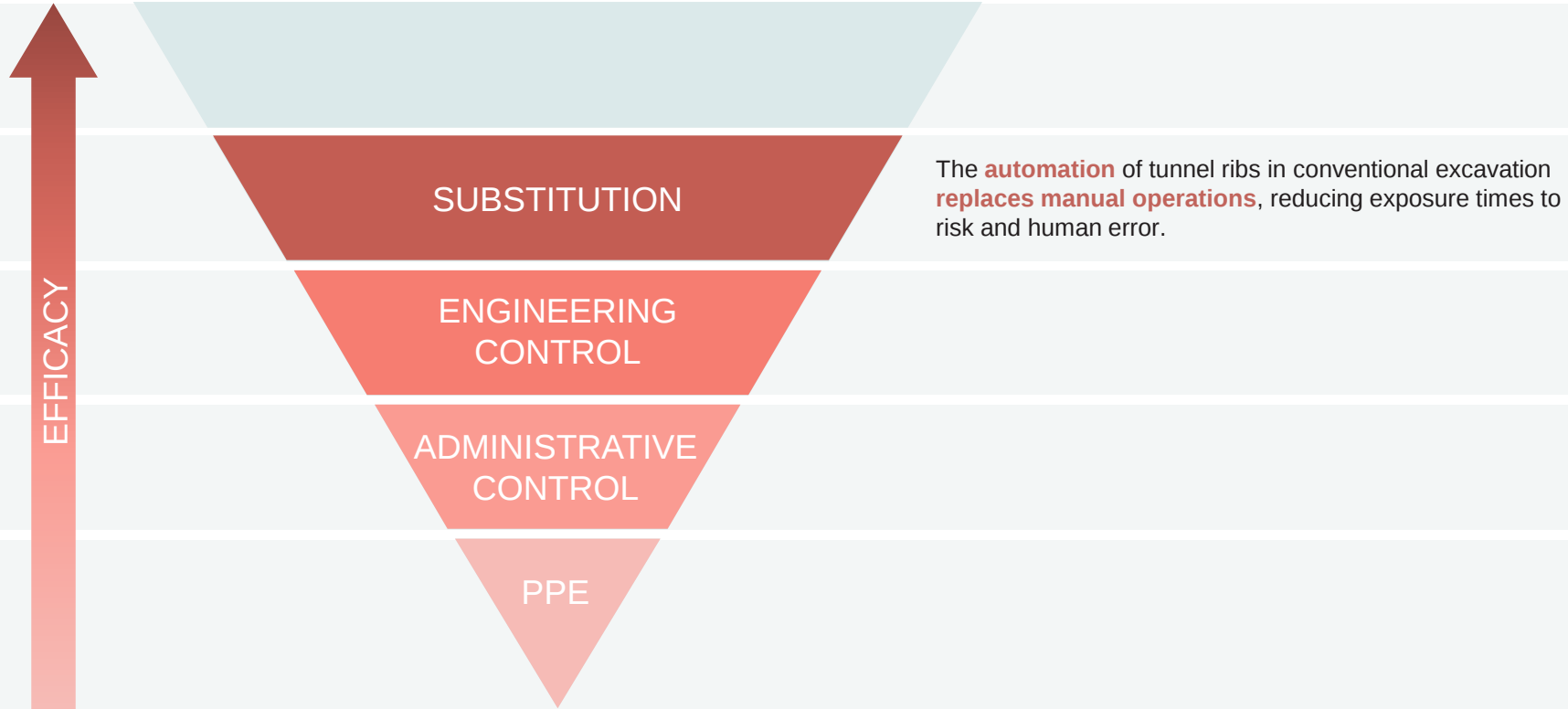
«[...] the safeguard of worker safety requires that resources and energy be urgently directed towards identifying technical solutions, possibly already available on the market, which make it possible to replace manual work activities with **mechanized** and/or **robotized solutions**.»

Nota interregionale “Lavori a ridosso del fronte”

Reg. PG 2009 272843

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Hierarchy of risk control



Automated tunnel rib

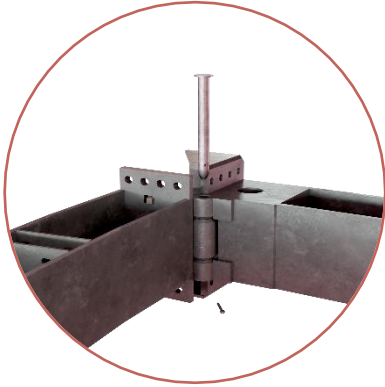
H-BEAM PROFILE

The H-Beam automated tunnel rib represents the perfect combination of past experience and the innovation of automation, developed to increase **safety** and **productivity**.



SUBSTITUTION OF MANUAL OPERATIONS

Automated tunnel rib



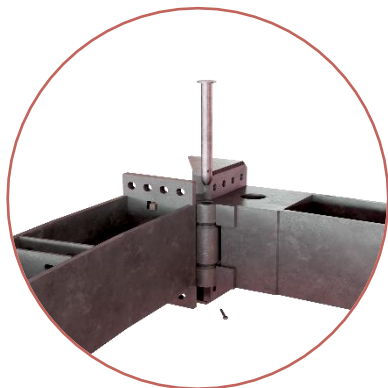
The Automated Tunnel Rib's crown and shoulder sections are **pre-assembled** with the **hinge** which is integrated within the automated locking pin mechanism.



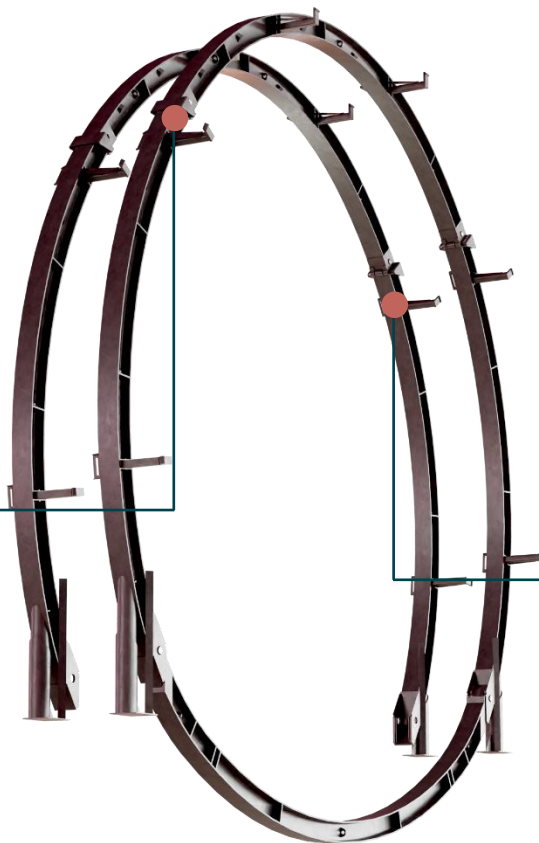
SUBSTITUTION OF MANUAL OPERATIONS

MACCAFERRI

Automated tunnel rib



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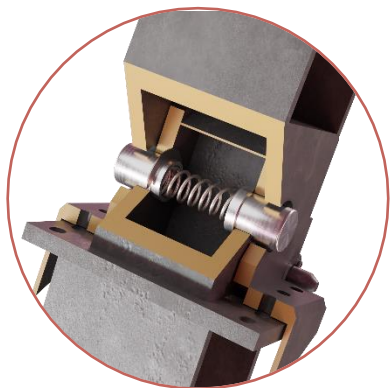


The **automated links** are assembled to the rib safely away from the excavation face, before the rib installation.

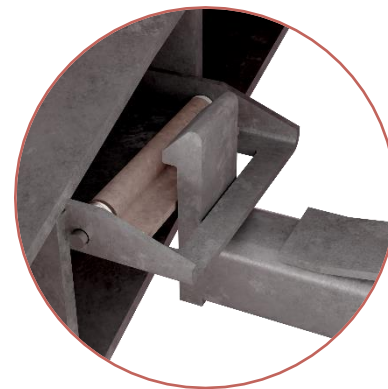
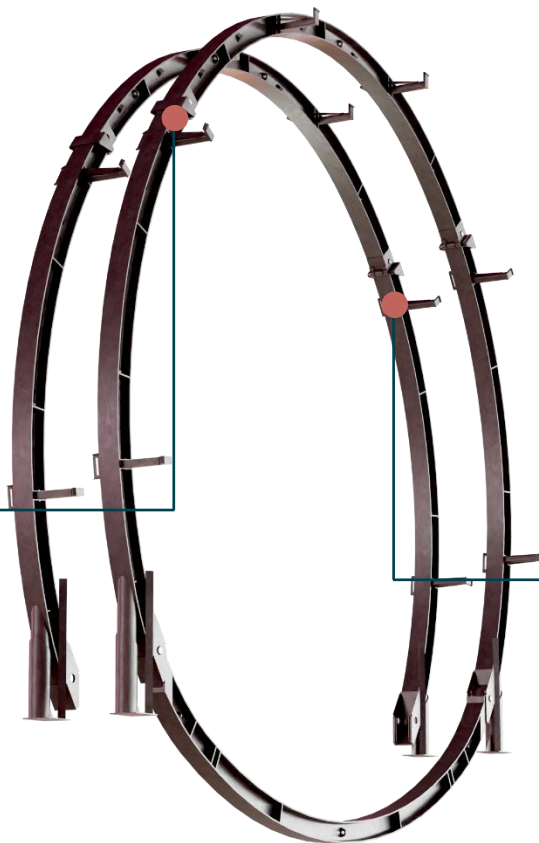
SUBSTITUTION OF MANUAL OPERATIONS

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Automated tunnel rib



Locking of the hinge by the automated pin mechanism, to secure the rib in **open position**.

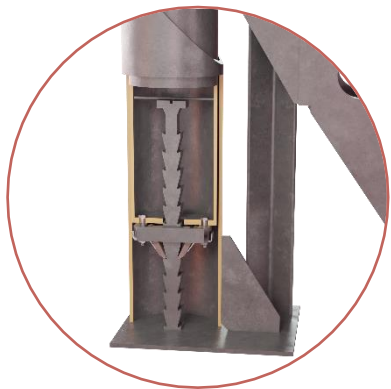


The spring lock mechanism allows the automated **fixing** of the links to the last previously installed rib.

SUBSTITUTION OF MANUAL OPERATIONS

MACCAFERRI

Automated tunnel rib



The **foot** is extendable with a double-sided linear ratchet mechanism. The rib's **correct position** can be attained allowing for the irregularity of the excavation level, without the use of wooden shims and wedges.



The **invert strut** is connected by its automated pin mechanism. The installation can be carried out at the same time as the rib.

Automated tunnel rib

ROUND TUBULAR PROFILE

Thanks to its circular shape and the shotcrete filling, the automated Round Tubular tunnel rib ensures **greater structural strength** and a significant **reduction in shotcrete spray** during processing.

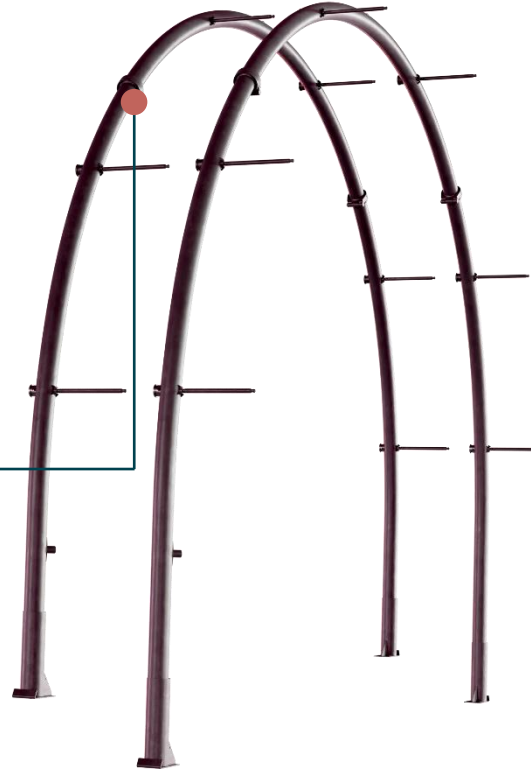


SUBSTITUTION OF MANUAL OPERATIONS

Automated tunnel rib



The Automated Tunnel Rib's crown and shoulder sections are **pre-assembled** with the hinge which is integrated within the automated **tubular locking** mechanism.



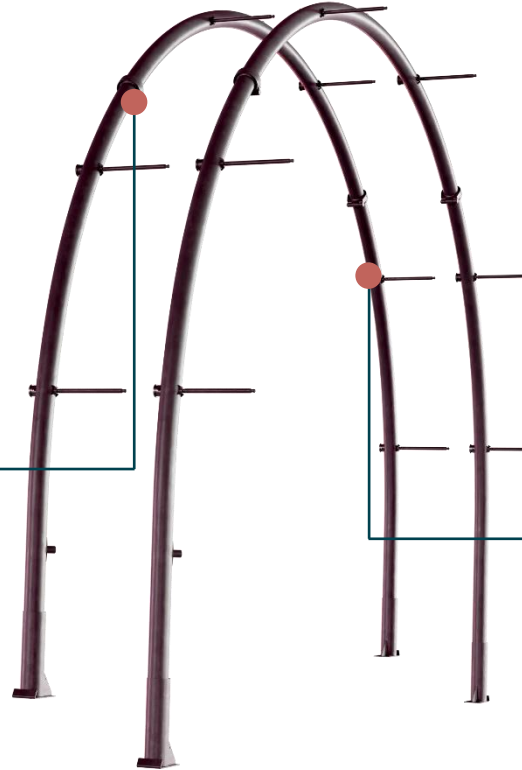
SUBSTITUTION OF MANUAL OPERATIONS

MACCAFERRI

Automated tunnel rib



The Automated Tunnel Rib's crown and shoulder sections are **pre-assembled** with the hinge which is integrated within the automated **tubular locking** mechanism.



The **automated link** is of the "Boscaccio" type. The **assembly** of the link to the rib is done by means of a threaded bushing.

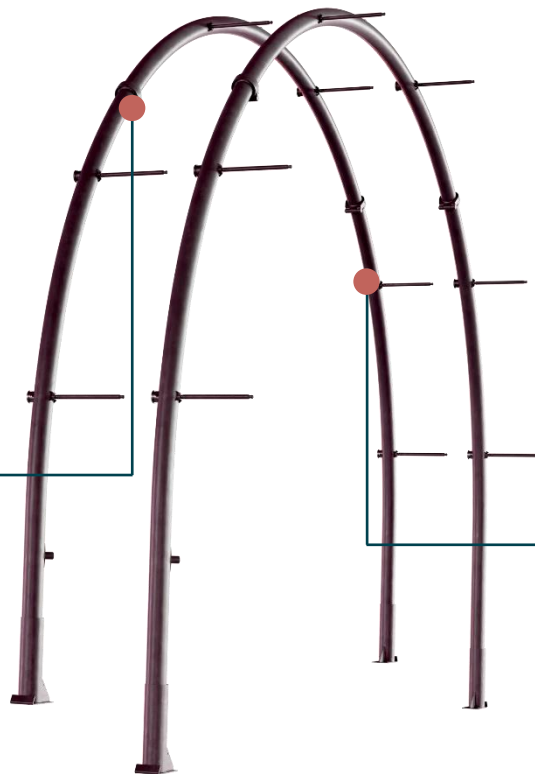
SUBSTITUTION OF MANUAL OPERATIONS

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Automated tunnel rib



Locking of the **tubular joint**: male-female **automated locking** mechanism with axial securing ring, to fix the rib in open position.



A “Belville” type **spring joint** allows the **automated fixing** of the links to the last previously installed rib.

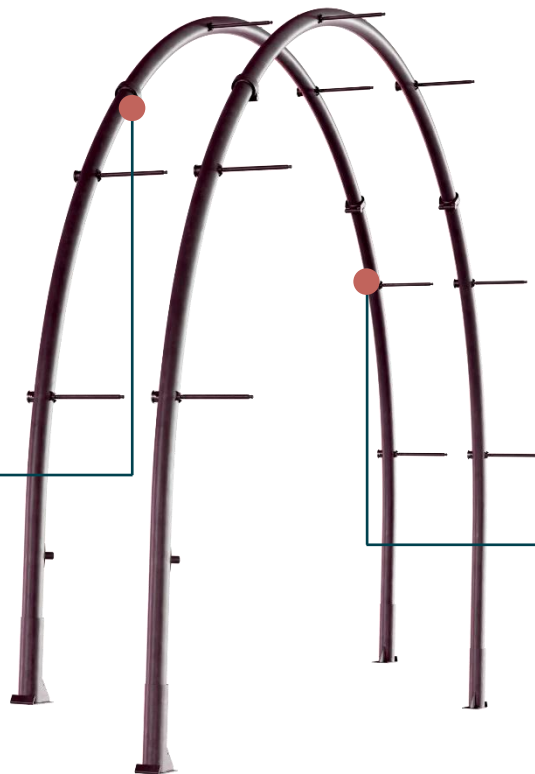
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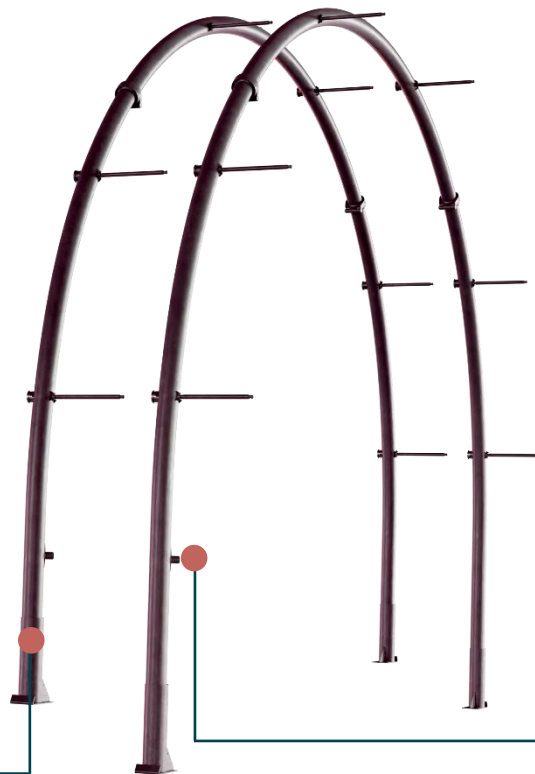
SUBSTITUTION OF MANUAL OPERATIONS

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Automated tunnel rib

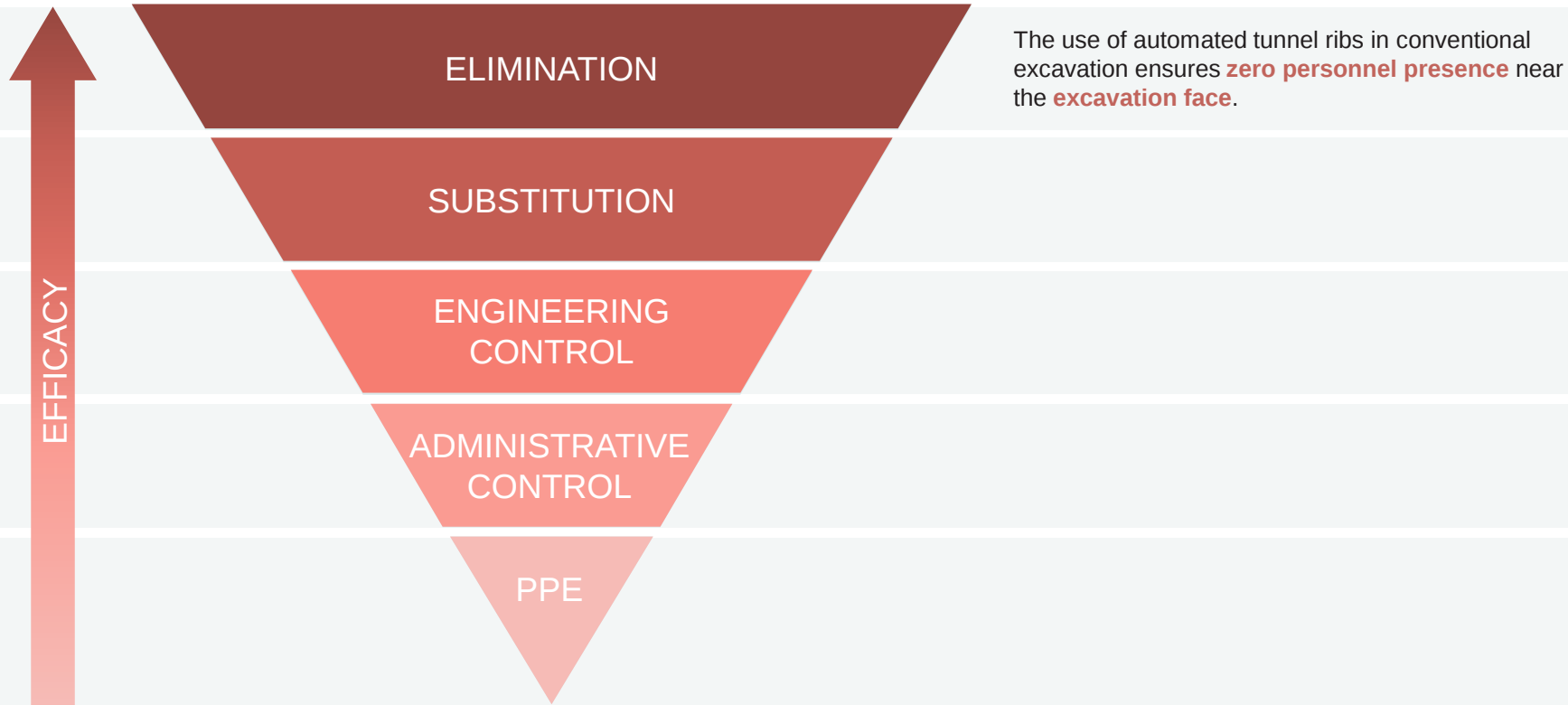


The **foot** is extendable with a double-sided linear ratchet mechanism. The rib's **correct position** can be attained allowing for the irregularity of the excavation level, without the use of wooden shims and wedges.



The shotcrete **self-sealing injection** nozzle is made of plastic material. When the shotcrete injection stops, the spout closes again.

Hierarchy of risk control



NO PERSONNEL NEAR THE EXCAVATION FACE

MACCAFERRI

Installation of automated tunnel ribs

The use of automated tunnel ribs in conventional excavation allows for the **elimination of personnel near the excavation face**, the most at-risk zone.



1

PRE-ASSEMBLY

Automated joint connections and links are safely carried out away from the excavation face.

NO WORKERS
NEAR THE
EXCAVATION
FACE



NO PERSONNEL NEAR THE EXCAVATION FACE

MACCAFERRI

Installation of automated tunnel ribs

The use of automated tunnel ribs in conventional excavation allows for the **elimination of personnel near the excavation face**, the most at-risk zone.



2

OPENING

The rib is unfolded and locked in open position by the automated pin mechanism integrated with the hinge. The operator carries out the entire operation by operating the machine from a safe distance from the excavation face

NO WORKERS
NEAR THE
EXCAVATION
FACE



NO PERSONNEL NEAR THE EXCAVATION FACE

Installation of automated tunnel ribs

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3

ADJUSTING

The extensible telescopic foot, manoeuvred through the use of machinery, allows the perfect adjustment of the rib to the tunnel's excavation.

NO WORKERS
NEAR THE
EXCAVATION
FACE



NO PERSONNEL NEAR THE EXCAVATION FACE

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4

CLOSURE

The installation of the invert strut is carried out at the excavation face, using machines only, improving accuracy and increasing the speed of operations.

NO WORKERS
NEAR THE
EXCAVATION
FACE



The advantages of automated tunnel ribs

NO WORKERS
NEAR THE
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FACE



- 50%
INSTALLATION
TIME

- 14%
SHOTCRETE
CONSUMPTION*

OUR SOLUTIONS

MACCAFERRI

The Maccaferri portfolio

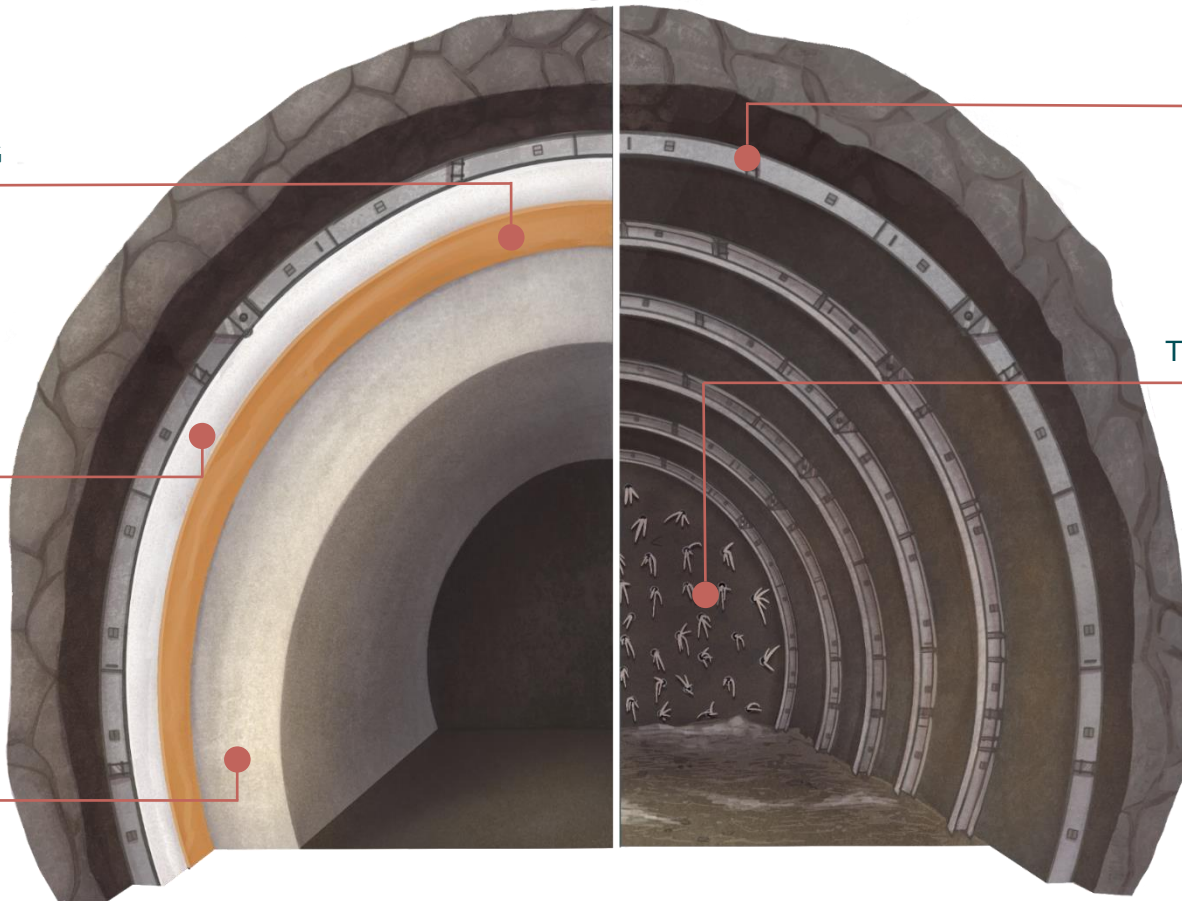
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CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

Our fiberglass (**GFRP**) solutions guarantee the improvement of the mechanical characteristics of the soil or rock, increasing the global stability of the excavation face and optimizing the consolidation and reinforcement process.

To effectively deal with excavation conditions in particularly adverse terrain, the fully customizable anchoring systems of the P.E.R. Ground System series can perform multiple functions. **P.E.R. Ground Drain**, for example, simultaneously guarantees the reinforcement and the drainage of the excavation face.



Maccaferri fiberglass solutions' range:

- M** Profiles and elements in fiberglass of different section
- M** The customizable anchoring systems P.E.R. Ground
- M** Glass fiber reinforcement nets
- M** Glass fiber reinforcing bars





Applications of Maccaferri's fiberglass solutions:

- M** Consolidation and reinforcement of the excavation face
- M** Soil nailing
- M** Soft eye
- M** Concrete reinforcement

What drives innovation?



Operational safety

A solution that can reduce the time spent at the excavation face



Engineered safety

A solution that allows for precise consolidation control

Corrugated fiberglass hollow sections

Corrugated fiberglass hollow sections

The corrugated fiberglass hollow sections are made of a polyester resin matrix reinforced by continuous unidirectional glass fibers (E-Glass type GFRP).



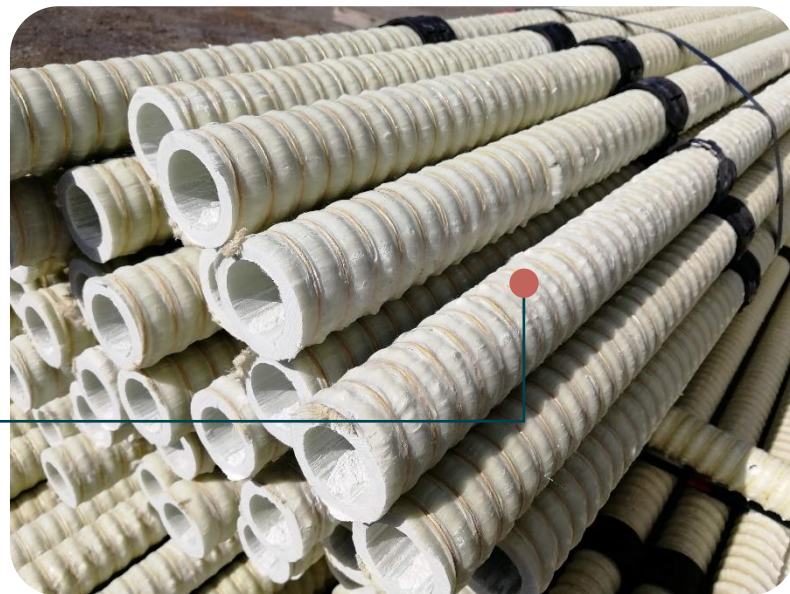
CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

MACCAFERRI

Corrugated fiberglass hollow sections

The corrugation process does not affect the **integrity of the glass fibres** and the profile has an uninterrupted fibreglass' reinforcement, along all its length.

The full efficacy and collaboration of all the fibers allows a significant improvement in the overall tensile strength with an enhanced **pull-out resistance**.



CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

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Corrugated fiberglass hollow sections

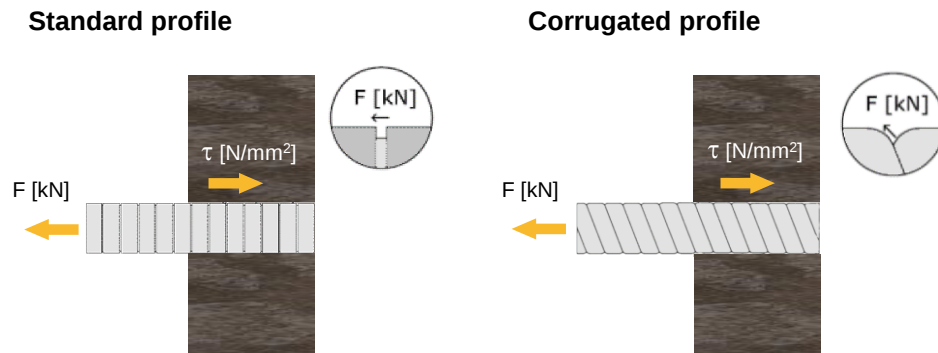


The **corrugated profile** improves the adhesion strength which, combined with the high tensile capacity of the tube, provides reliable stabilization of the excavation face.

CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

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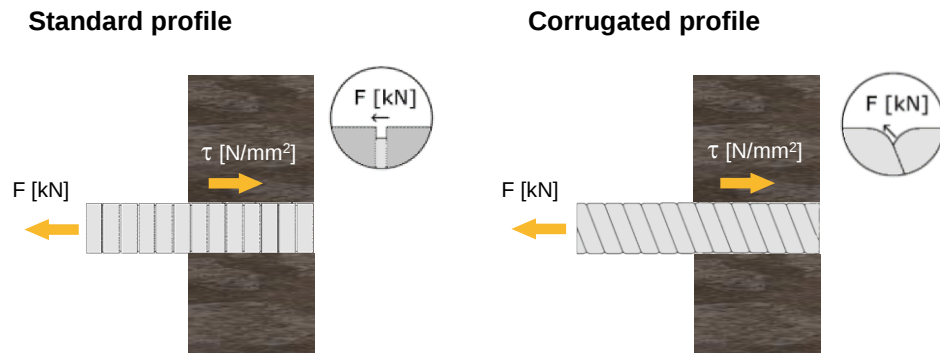


As opposed to the standard profile, the corrugated one produces compression actions in the injection mortar which actively participate in the process of resistance to pull-out, increasing the overall performance.

CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

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Corrugated fiberglass hollow sections



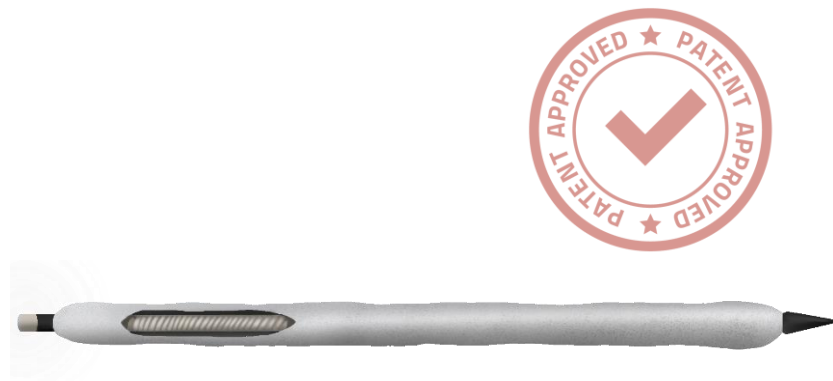
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What can be further improved?

To successfully address excavation conditions in particularly challenging soils, further process optimization is required to enhance consolidation control while simultaneously reducing the time spent at the excavation face.

P.E.R. Ground System

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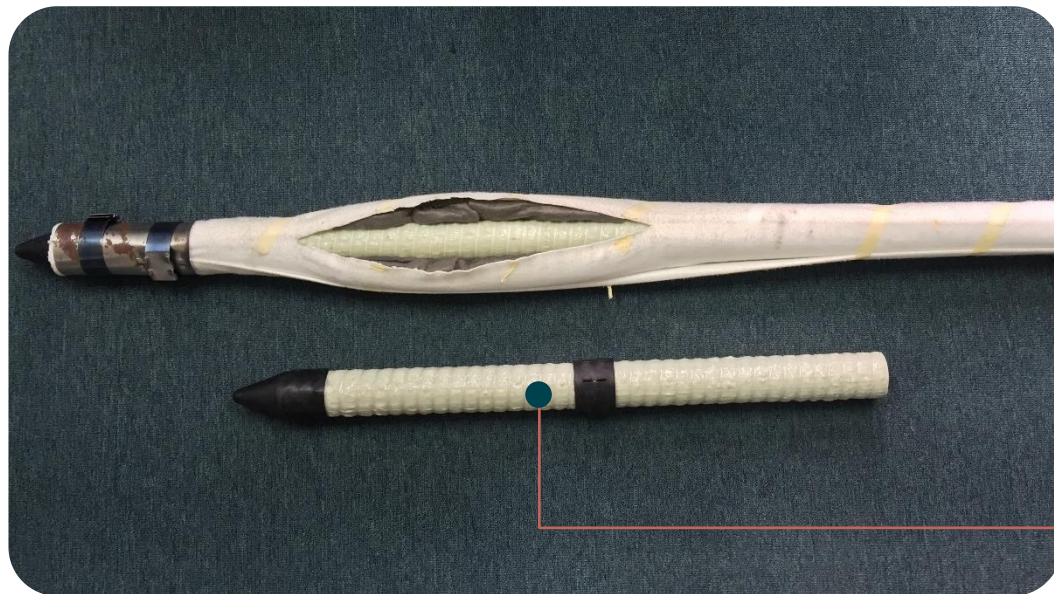


The **P.E.R. Ground System** (Pressurizing Element for Reinforcement of the Ground) series has been specifically designed to tackle these adverse excavation conditions.

CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

MACCAFERRI

P.E.R. Ground System

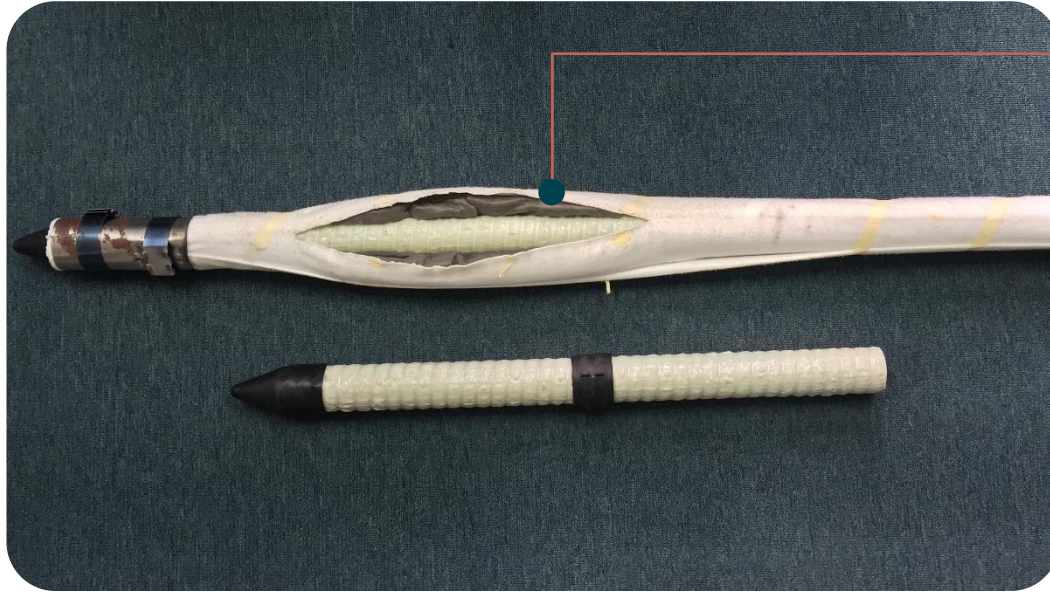


The reinforcing element is made of
fiberglass reinforced polyester resin

CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

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P.E.R. Ground System



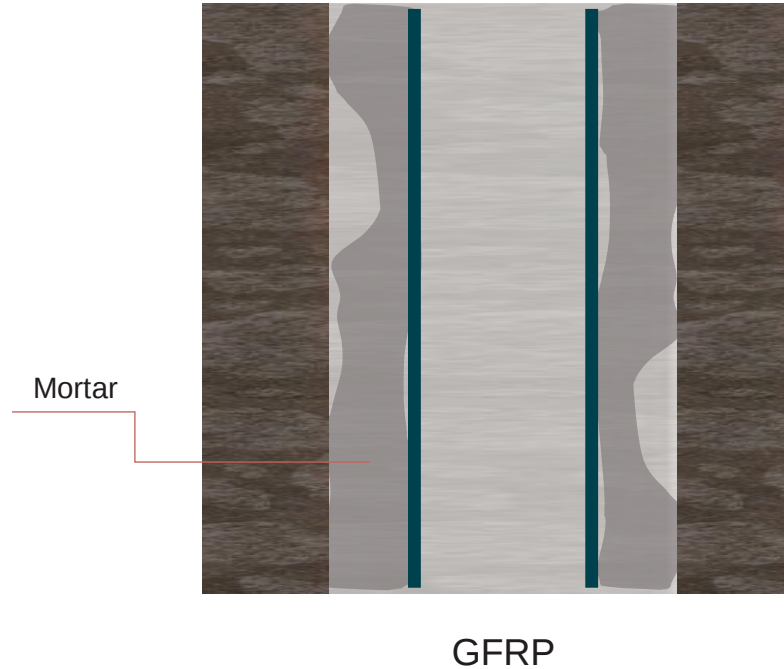
Once inserted into the borehole, the **integrated expandable sheath** is filled with mortar under pressure.

CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

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P.E.R. Ground System

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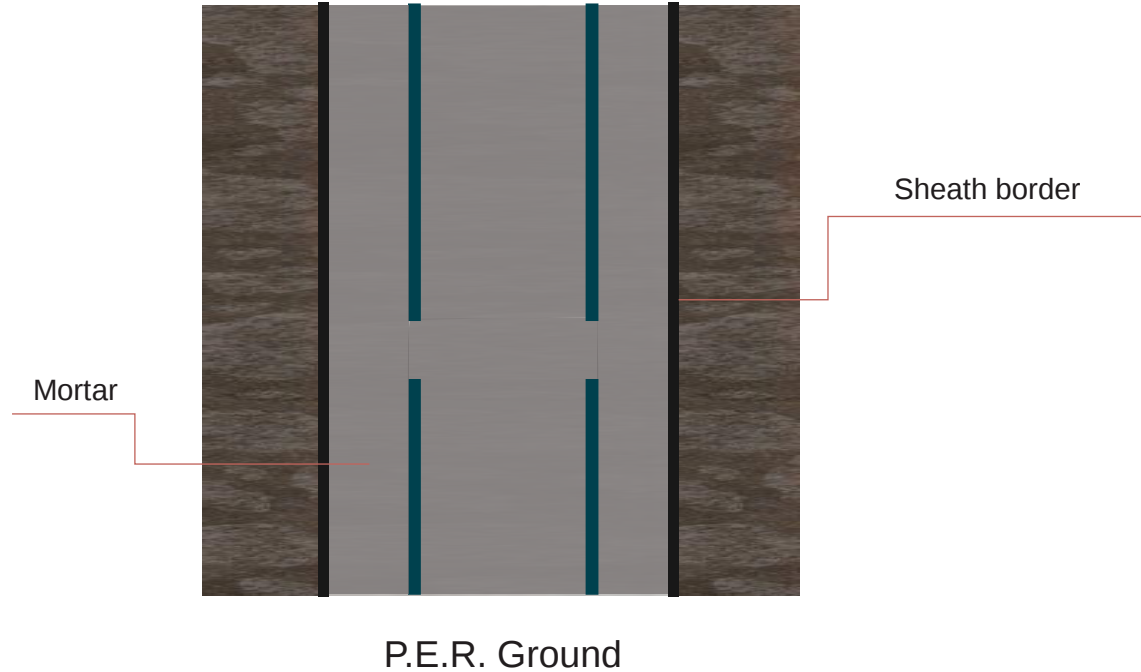


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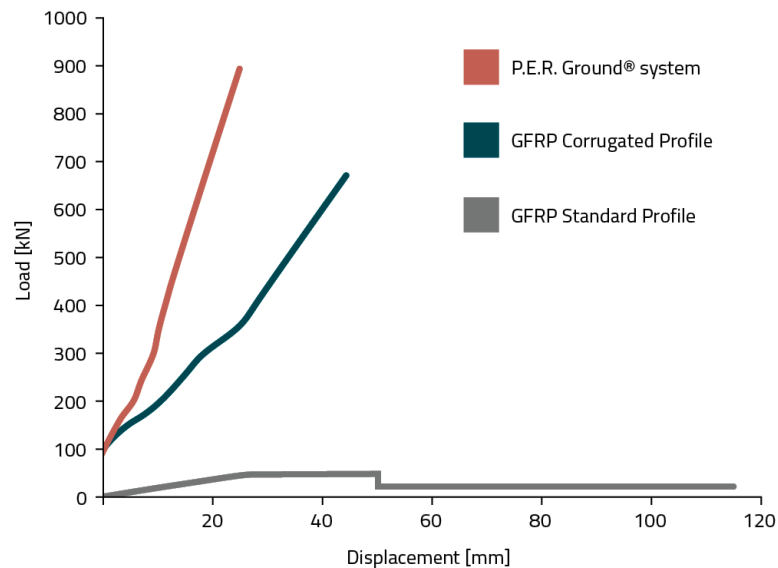


What are the benefits?

The **confinement of the mortar** produces a larger bond area, and a better pull-out resistance result.



Consolidation control



What are the benefits?

The **compaction** of the surrounding soil due to the expansion of the sheath.



Consolidation control



What are the benefits?

P.E.R. Ground System enables precise consolidation control, contributing to higher **engineered safety** while also reducing the number of perforations at the excavation face.



Consolidation control

-45%

NUMBER OF
REQUIRED
PERFORATIONS



Process optimization

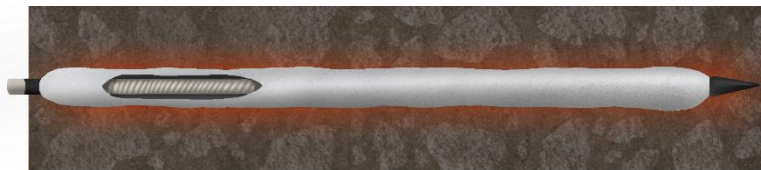
What are the benefits?

The P.E.R. Ground System is **customizable** in various combinations, allowing multiple functions to be performed simultaneously.

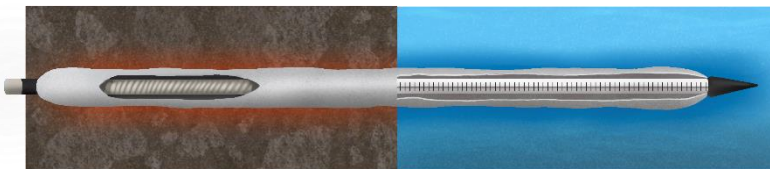


Less time at the excavation face

P.E.R. GROUND SYSTEM



P.E.R. GROUND SYSTEM DRAIN



CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

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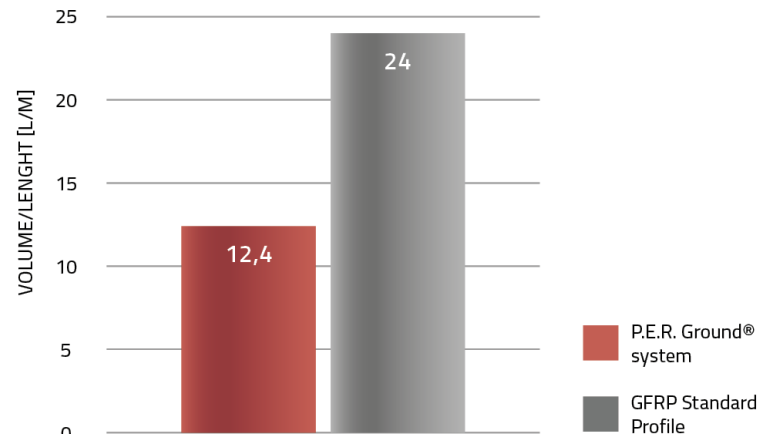
P.E.R. Ground System

What are the benefits?

The injected mortar **volume** inside the sheath is precisely **controlled**, preventing washout or excess usage.



Process optimization

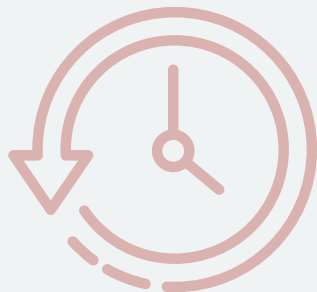


Volume of injected mortar (l) per metre of perforation (m)

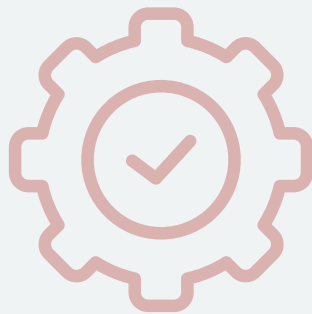
CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

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Advantages of P.E.R. Ground System



LESS TIME AT THE
EXCAVATION FACE



IMPROVED CONSOLIDATION
EFFICIENCY



PROCESS
OPTIMIZATION

*We are constantly striving to
ensure a safer working
environment for everyone.*

