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maccaferri.com

Engineering a Better Solution

Maccaferri's motto is **'Engineering a Better Solution'**; We do not merely supply products, but work in partnership with our clients, offering technical expertise to deliver versatile, cost effective and environmentally sound solutions. We aim to build mutually beneficial relationships with clients through the quality of our service and solutions.

GLOBAL ENGINEERS

In the second half of the 19th century, we invented Gabions and dramatically changed the civil engineering landscape. We are still changing today. We work every day to find better solutions for our clients at every degree of latitude and longitude. Our worldwide network grows through innovation and diversification of sectors of activity and through an increasing range of high quality and environmentally friendly products and applications.

OFFICINE MACCAFERRI GROUP PROFILE

Founded in 1879, our Group soon became a worldwide reference in the design and development of advanced solutions, with offices in over 70 subsidiaries and 20 factories worldwide.

Our mission is to pursue excellence through continuous improvement, while delivering to customers engineered solutions that are innovative, advanced and environmentally friendly. We are committed to outstanding safety, quality and sustainability, to create value for all stakeholders as well as our communities.

MACCAFERRI APPLICATIONS

- RETAINING WALLS & SOIL REINFORCEMENT
- SOIL STABILISATION & PAVEMENTS
- DRAINAGE OF STRUCTURES
- FENCING & WIRE
- HYDRAULIC WORKS
- BASAL REINFORCEMENT
- TUNNELLING
- AQUACULTURE NETS/CAGES
- ROCKFALL PROTECTION & SNOW BARRIERS
- COASTAL PROTECTION, MARINE STRUCTURES & PIPELINE PROTECTION
- LANDSCAPE & ARCHITECTURE
- CONCRETE FLOORING, PRECAST & OTHER USES
- EROSION CONTROL
- ENVIRONMENT, DEWATERING & LANDFILLS
- SAFETY & NOISE BARRIERS
- INDUSTRIAL MANUFACTURING

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TUNNELLING

TUNNELLING
HISTORY AND DEVELOPMENT

THE ANCIENT ERA

Our ancestors used caves as a means for protection against the dangers of wildlife and the natural environment; they were excavated for extracting valuable minerals, but also as storage spaces, tombs and sanctuaries.

FROM THE MIDDLE AGES TO THE 19th CENTURY

Tunnelling started for **mining** and military purposes in the Middle Ages. The 17th century saw the first major **canal tunnels** being built in France and England to meet transportation needs.

With the introduction of **railroads** in the 19th century, tunnelling increased significantly. Technology from the mining sector, such as timber support, was adopted.

THE INDUSTRIAL ERA

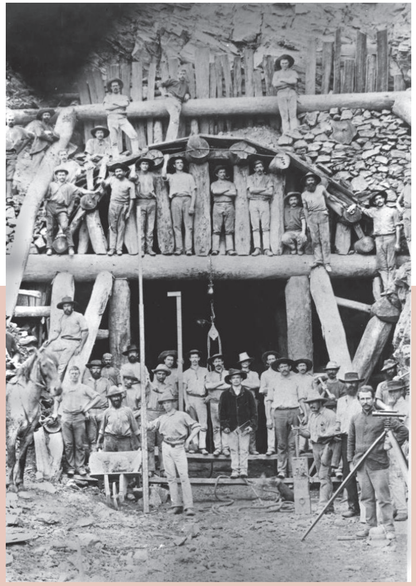
In the late 1920's and early 1930's, the use of **steel** for supports in tunnelling gradually increased, in order to face new challenges such as heavy soil pressure. Steel was stronger than wood, it greatly reduced the tunnel crosssection, and it could be encased in the final cast-in-place concrete lining.

THE MODERN ERA

A growing emphasis on key elements of tunnel support such as **safety**, speed, economy, **performance** and surface settlement had led to significant innovations during the late 1960's and 1970's with a rapid spread of sprayed concrete and the development of tunnel boring machines

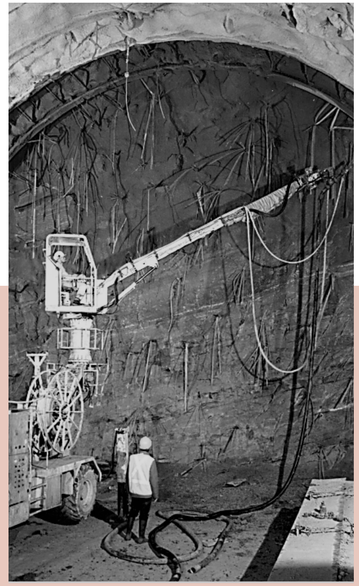
Ikuno Ginzan Silver Mine, Asago, Japan (active from 1592)

"For centuries, humans have had a longstanding practice of utilizing underground spaces"



Cairns Tunnel, Kuranda Railway, Australia (1890)

Piccadilly Line Extension, London, United Kindom (1920)



The "Tartaiguille" tunnel , France (1997)

TECHNOLOGICAL PROGRESS

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.

THE UTMOST SAFETY THROUGH INNOVATION

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

> "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.
>
> [...] 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 of 27/11/2009

OUR SOLUTIONS
THE MACCAFERRI PORFOLIO

Tunnel linings are highly complex structural systems, and their design must consider the high degree of interaction with the surrounding soil. In its portfolio, Maccaferri offers cutting-edge and innovative solutions to address multiple aspects of underground construction.

WATERPROOFING

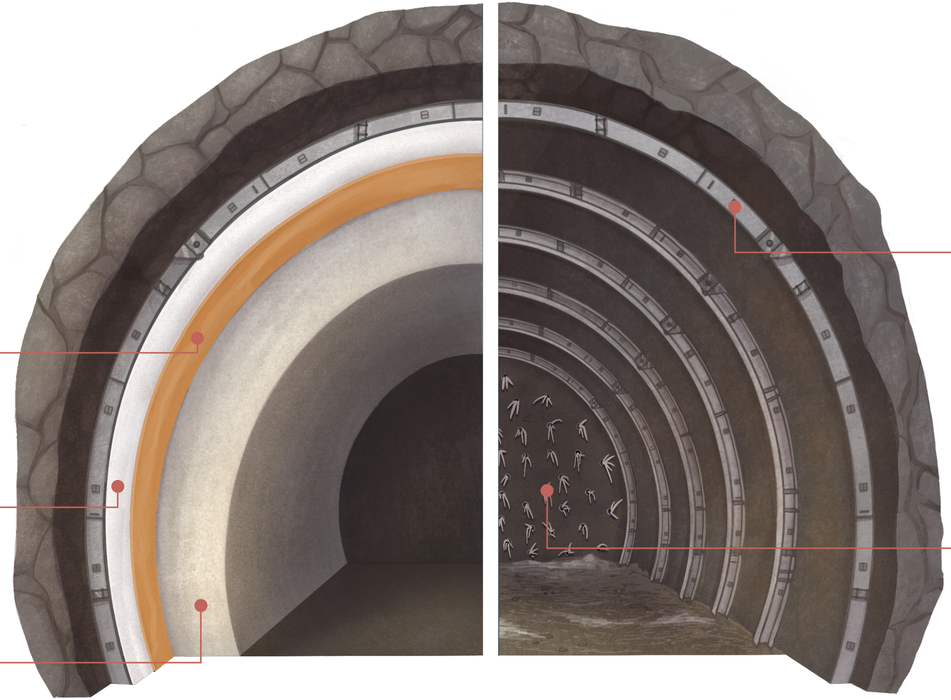
As part of the final lining of the tunnel, the **MacLine™** polymeric geomembrane guarantees an extremely low permeability, preventing any water ingress and infiltration. The waterproofing of the excavation perimeter is of fundamental importance to guarantee the structural stability of the tunnel and prevent deterioration that could represent a serious safety hazard.

DRAINAGE AND PROTECTION

The waterproofing layer must be adequately protected. The use of a drain then allows the water present around the excavation profile to be removed. **MacDrain™** is 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.

FINAL LINING

Our **steel fibers** for fiber-reinforced concrete provide an uniformly and intimately distributed reinforcement within the final concrete lining, preventing micro-cracks. In this way, a significant reduction and, sometimes, complete replacement of the traditional reinforcing bars can be obtained. Our fibers are also used to reinforce the shotcrete during the primary lining phase.



PRIMARY LINING

The primary lining consists of steel reinforcing elements (**ribs**) embedded in or filled with shotcrete.

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

All the operations that in the installation of traditional ribs were carried out manually by workers at the excavation face, are now automated. The **automation** of the ribs further improves the overall safety conditions.

CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

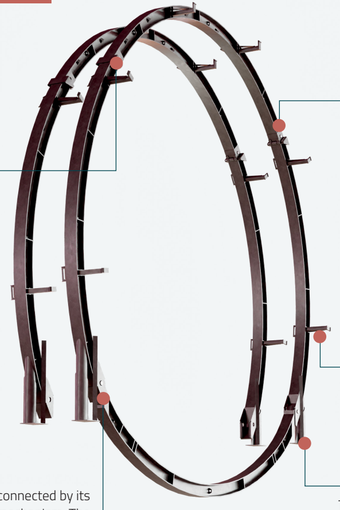
Our fiberglass (**GFRP**) solutions guarantee the improvement of the mechanical characteristics of the soil or rock, increasing the global stability of the excavation face and optimizing the consolidation and reinforcement process from both an operational and economic point of view.

The innovative **corrugated hollow profile** allows a significant increase in performance. To effectively deal with excavation conditions in particularly adverse terrain, the fully customizable anchoring systems of the **P.E.R. Ground System** series (Pressurizing Element for Reinforcement of the Ground) can perform multiple functions. **P.E.R. Ground Drain**, for example, simultaneously guarantees the reinforcement and the drainage of the excavation face.

AUTOMATED TUNNEL RIB
H-BEAM PROFILE

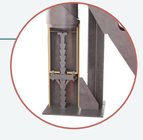
The H-Beam automated tunnel rib represents the perfect combination of past experience and the innovation of automation, developed to increase safety and productivity.

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



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

The automated links are assembled to the rib safely away from the excavation face, before the rib installation. The spring lock mechanism allows the automated fixing of the links to the last previously installed 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.

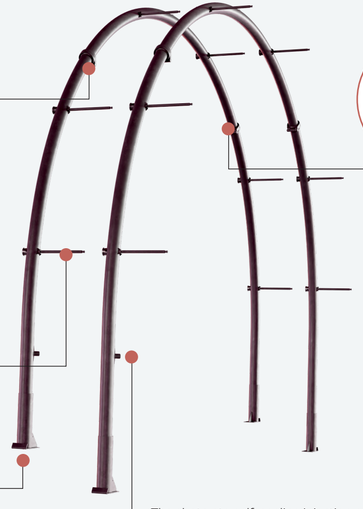
The invert strut is connected by its automated pin mechanism. The installation can be carried out at the same time as the rib.

-50%
INSTALLATION TIME

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 shortcrete spray during processing.

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

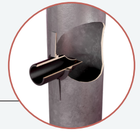


Locking of the tubular joint: male-female automated locking mechanism with axial securing ring, to fix the rib in open position.

The automated link is of the "Boscaccio" type. The assembly of the link to the rib is done by means of a threaded bushing. A "Belville" type spring joint allows the automated fixing of the links to the last previously installed 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.



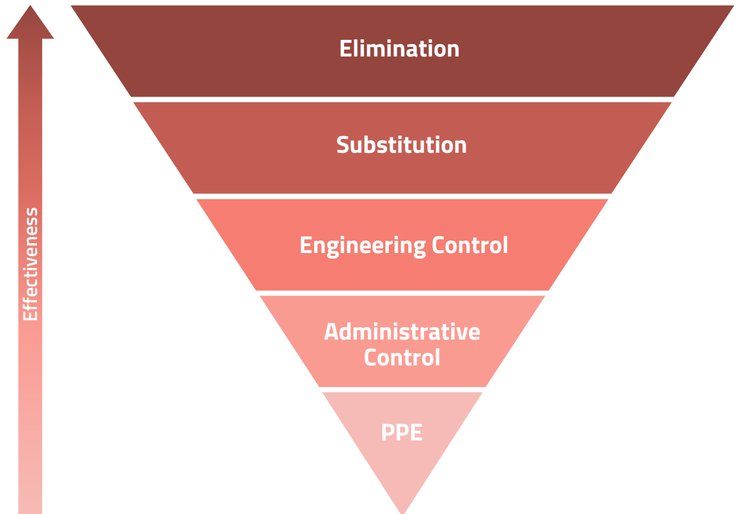
-14%
SHOTCRETE CONSUMPTION

PRIMARY LINING

The primary lining generally 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.

The hierarchy of risk control is a fundamental component of prevention through design, which is based on the application of methods to minimize professional risks right from the beginning of the entire process.

It is a widely accepted and promoted practice as a standard workplace procedure. **Technological advancement** has further improved risk control by the **substitution** of manual labor with automated solutions and ensuring **zero personnel** presence near the excavation face.



Hierarchy of risk control

The use of automated tunnel ribs in conventional excavation ensures zero personnel near the excavation face.

1 PRE-ASSEMBLY

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

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

3 ADJUSTING

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

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 in safer conditions.

NO WORKERS NEAR THE EXCAVATION FACE

CONSOLIDATION AND REINFORCEMENT OF THE EXCAVATION FACE

Our fiberglass reinforced solutions (**GFRP**) allow for the enhancement of soil characteristics, increasing overall stability and, thus, improving safety conditions.

In the presence of specific geological conditions and challenging soils to excavate, consolidation and reinforcement techniques of the excavation face provide **stabilization** and enable r**apid and secure progress**, even in large-scale tunnels.

The consolidation and reinforcement of the excavation face with fiberglass pipes have become a well-established method in underground construction. As **effective** and **adaptable** as these solutions are, they are also at the forefront of significant technological advancements.

MACCAFERRI FIBERGLASS SOLUTIONS' RANGE:

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

APPLICATIONS OF MACCAFERRI'S FIBERGLASS SOLUTIONS:

- Consolidation and reinforcement of the excavation face
- Soil Nailing
- Soft-eye
- Concrete reinforcement

WHAT DRIVES INNOVATION?

ENGINEERED SAFETY

A solution that allows for precise consolidation control.

OPERATIONAL SAFETY

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

PROCESS OPTIMIZATION

A solution that serves multiple functions and allows for material savings.

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).

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.

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

Consequently, 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

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.

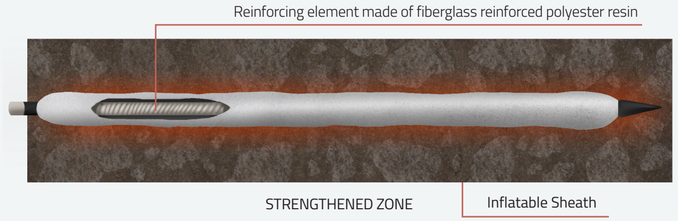
P.E.R. GROUND SYSTEM

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

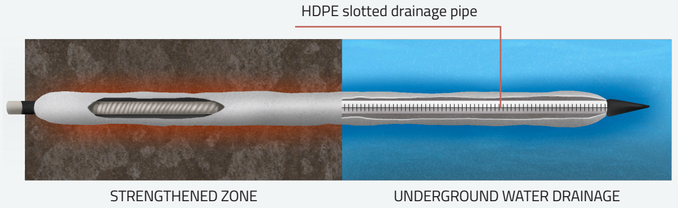
The reinforcing element is made of **fiberglass reinforced polyester resin**, with an integrated **expandable sheath**. Once inserted into the borehole, the sheath is filled with mortar under pressure. The advantages of this solution are multiple, and allow a considerable reduction in construction time.

PATENT APPROVED ★ PATENT APPROVED ★

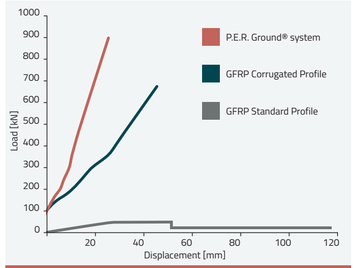
P.E.R. GROUND SYSTEM



P.E.R. GROUND SYSTEM DRAIN



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



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

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

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

P.E.R. Ground is a multifunctional system designed for maximum efficiency. It enables precise consolidation control, contributing to higher **engineered safety** while also reducing the number of perforations at the excavation face by **up to 45%**. As a result, operator time at the excavation face is minimized, enhancing **operational safety** conditions. Additionally, the consolidation **process is optimized**, leading to savings in both time and materials.

-45%
NUMBER OF REQUIRED PERFORATIONS