



# Tunnels excavated with traditional methods

## Tunnel portal

The initial engineering works for the construction of a tunnel transform a mountain slope into a vertical wall, thereby forming the tunnel portal. These works are wide ranging and may be subdivided between structural works, consolidation works, finishing and protection works; these stages employ materials of different types and characteristics.



### Reinforced soil

These are structures for the containment, stabilisation and renaturalisation of slopes and embankments at tunnel portals.



### Rockfall barriers

The protection works against falling rocks represent a fundamental aspect in the design of tunnel portal works, having a direct effect on the safety of the overall works.



### Soil nailing and surface reinforcement

The stability of the slope is controlled during construction of the portal by means of surface reinforcement consisting mainly of

steel mesh and anchors (high strength steel bars, self-drilling bolts, fibreglass nails), sometimes coated with shotcrete.

### Micro-piles

Micro-piles are fixed into the ground by drilling of holes. They form a vertical wall from which the excavation of the tunnel will be started.



### Drainage

In order to avoid instability problems caused by inflowing water, drainage pipes made of synthetic materials are used to collect groundwater from the deepest layers and carry it outside.



### Fibreglass reinforcement for foundation piles

If foundation piles are used instead of micropiles, the traditional steel concrete reinforcement is replaced by fibreglass elements which guarantee the same mechanical strength, enabling fast progress in the excavation of the heading face.



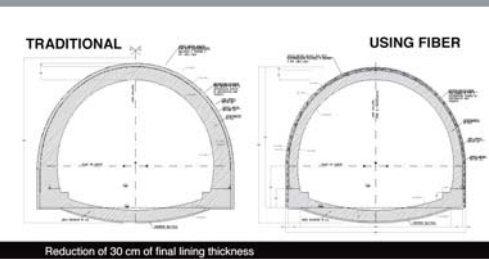
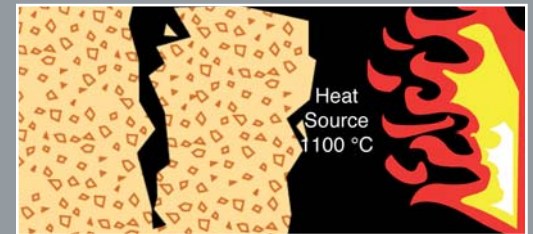


# Final lining

The final lining is the most important stage in the construction of a tunnel. It represents the final reinforcement which determines the durability and structural strength of the underground works, as well as being the support for the service installations such as final ventilation, aeration and lighting. There are a series of technical solutions for this stage, with special attention paid to an increase of the final quality, durability, safety and appearance; also from an architectural point of view.

## Polypropylene fibres for passive fire protection

The use of Fibromac® polypropylene fibres permits the construction of a homogeneous material which forms an effective passive protective element against fire, thereby reducing spalling phenomena.



## Concrete reinforcement using Wirand® steel fibres

The final fibre-reinforced concrete lining uses Wirand® steel fibres for the construction of the structural parts (invert and upper final lining) of tunnels excavated with traditional methods.



## Ceramic linings

High quality and large-sized ceramic linings are fixed by adhesive to the inner face of the concrete by means of mechanised installation methods. This solution provides greater durability of the side walls, better luminosity and safety, and fast and cost-effective maintenance. Various types of finish may be planned, depending on the architectural requirements.





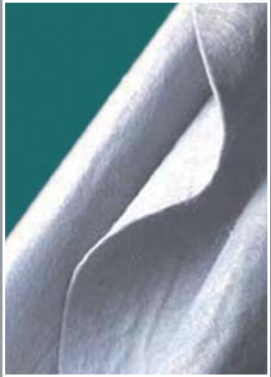


# Drainage

The durability of the final lining depends on the drainage works which enable any water tables to be collected and drained through channels and pipes. This avoids infiltration of water into the concrete and, therefore, limits problems linked to freezing and thawing cycles.

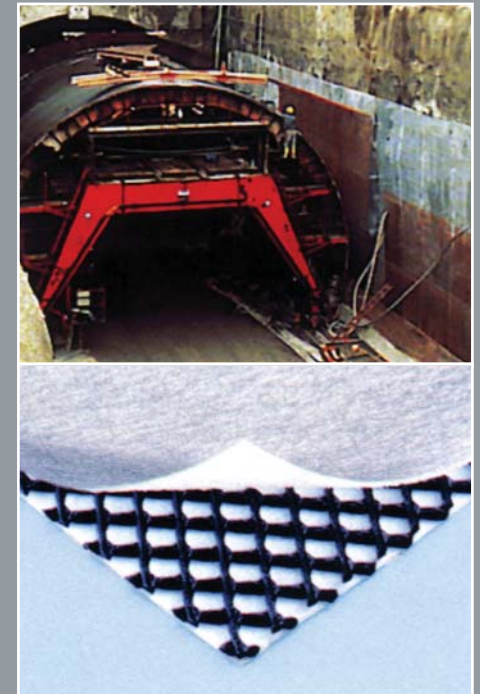
## Drainage

Drainage pipes are used, sometimes in combination with flat drainage composites, in order to quickly lower the groundwater level in the deep rock masses.



## Geotextiles

The MacTex® family of geotextiles represents an excellent solution to protect the waterproofing of the tunnel formed by HDPE or PVC sheeting.



## Drainage geocomposites

The MacDrain® drainage geocomposites reduces pore water pressures and thereby reduce the threat of saturated ground conditions.





# First lining

The first lining is applied immediately after excavation of the heading face. This temporary support lining is commonly made of steel fibre reinforced shotcrete. If structurally required, this phase also comprises the installation of reinforcement elements consisting of steel sections that are deformed to the contour of the tunnel. For example steel ribs or lattice girders that are longitudinally connected together to form the support reinforcement. These are quickly incorporated into the sprayed steel fibre reinforced concrete to form a tough structure enabling absorption of the first deformation forces of the tunnel. Where necessary, additional radial reinforcement in the form of various types of steel anchors is installed.



## Wirand® steel fibres

Wirand® steel fibres give a combined compressive and bending strength to the shotcrete lining, increasing substantially the toughness of shotcrete, improving the reinforcement performance and increasing the work safety. Specialised Maccaferri dosage equipment is provided to add the exacting quantity of steel fibres during the batching operation in the mixing plant.



## Steel arches

These consist of pre-shaped steel sections, to provide first stage support. Variations have also been implemented in order to improve the installation, with the use of parts of the arches that are extendable PMET, thereby making the installed rib immediately active. Textile sacks, known as BIM BAGS, are also placed behind the arches and when they are inflated, using the same mortar as the shotcrete, they fill perfectly the spaces behind the arches.

## Self-drilling bolts and steel anchors

These solutions are used to control and/or reduce convergence of the excavated tunnel section. The reinforcement range comprises steel anchors, self-drilling rock bolts and high-strength steel bars



## Plasticising and accelerating admixtures

The superplasticisers maintain the workability of shotcrete, preserving the quality and characteristics during transport and pumping. Rocksil® (silicates) and Apral® (alkali free) admixtures accelerate the setting time by reducing the consistency during spraying and hence, improving grip to the substrate or previous layers.







# Consolidation of excavation face

The adoption of this method is increasing worldwide and is used mainly to reinforce and consolidate the soil mass in front of the excavation face, thereby enabling fast progress with large-sized excavations. It tends to be used in particular geological conditions and in soils considered to be difficult to excavate. The method consists in reinforcing the excavation face by

installing fibreglass elements in sub-horizontal holes, which are then grouted to form a set of micro-piles around the entire section. This contains the stresses induced by the excavation and stabilises any thrusts. Approaches such as ADECO-RS (Analysis of Controlled Deformation in Rocks and Soils) are used to prepare the final designs for such techniques.



## Fibreglass reinforcement elements

These are extruded elements formed by glass filaments and polyester resin that are manufactured with various cross-sections, from hollow to solid; the latter having a high mechanical strength, which may be compared with steel, whilst maintaining its lightness and versatility. Required characteristics to make the excavation.



## Polyurethane resin

These are chemical products that are mixed before the grouting stage to create a lightweight and expansive closed cell foam. When it comes into contact with water it forms a foam that blocks any accidental inflow of water. It is also widely used to fill the cavities that sometimes form or which are encountered during tunnel excavation work.



## Special expansive mortars

These are dry ready-mixed products that are added to water and injected in holes at the excavation face. Due to their expansive characteristics they compress the soil around the drilled hole, thereby guaranteeing a better adherence between the reinforcement element and the soil itself.



## Drainage

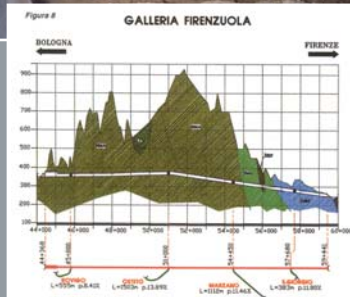
Drainage pipes are used in order to quickly lower the groundwater level in the deep rock masses.



# Projects and works

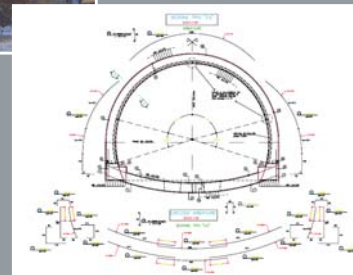
## High-Speed Railway Line Milan-Naples

Construction of the section between Bologna and Florence (Italy)



## A3 Motorway Salerno-Reggio Calabria

Modernisation and upgrading of the section between Salerno and Reggio Calabria (Italy)

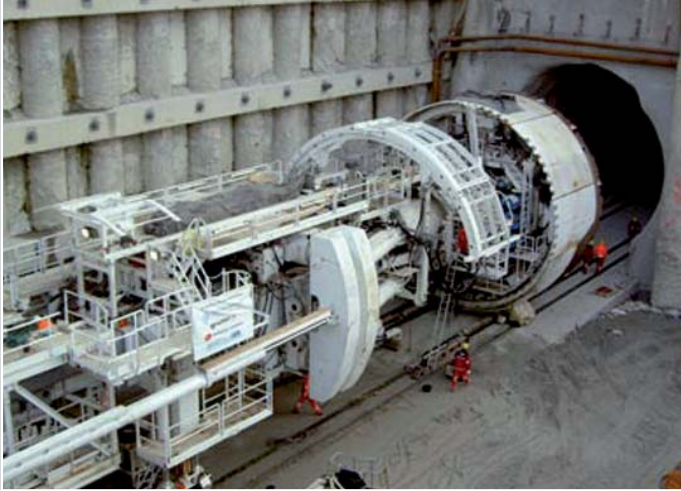


## A1 Motorway Milan-Naples

New Variante di Valico motorway section. Upgrading of the Apennine section between Bologna and Florence (Italy)



# Tunnels excavated with TBM



## Access shafts - Stations

TBM driven tunnels often require the construction of access shafts or trenches through which the TBM is lowered down to the level at which the excavation starts. The shafts are formed by constructing reinforced concrete walls down to the ground level, sometimes to considerable depths and with large dimensions. Water tables may be encountered during the construction of these shafts or trenches. The appropriate means to keep the work environment dry are consolidation and waterproofing grouting. The various work stages include: steel or fibreglass reinforcement of the concrete, pipes fitted with valves for consolidation grouting, chemical consolidation mixes.

## Chemical Consolidation Mixes Groutmaster

These are ready made products with "Groutmaster" granules that contain both the active part and its reagents. Simply by adding water and mixing, it transforms into a low viscosity solution, that enables it to permeate into soils even with a low permeability. Soils grouted with this chemical mix acquire impermeability characteristics and the compressive strength of the soils are increased.







## Precast segments

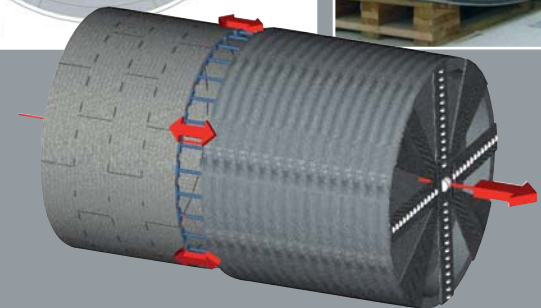
The final lining consists of precast concrete segments. These segments can be reinforced solely with Wirand® steel fibres or in combination with conventional steel reinforcement. In order to reduce concrete spalling Fibromac® polypropylene fibres can be added to achieve an efficient passive fire protection.



## Barcelona Line 9

Line 9 is 43 km long and runs from the El Prat airport in two different directions, with 43 stations. The final lining for the tunnel is made of precast concrete, with a combination of conventional steel reinforcement and Wirand® steel fibres (FF1 and FF3).

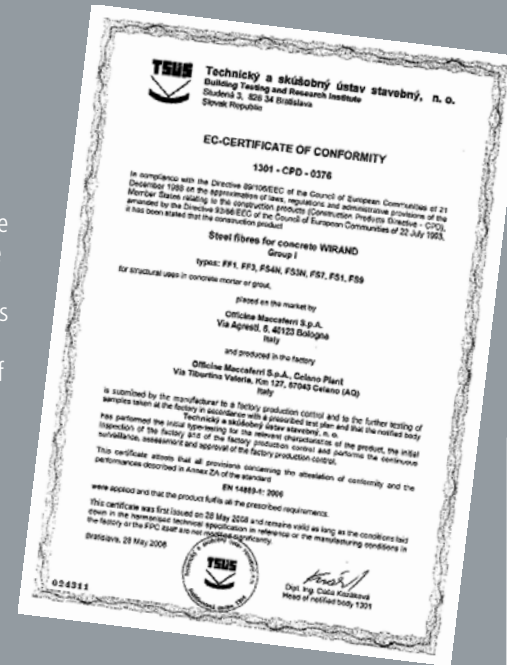
The total production quantity amounts to 450,000 m<sup>3</sup> of fibre reinforced concrete. Maccaferri dosing systems have been especially designed and installed in order to ensure precise fibre quantities and quick batching.



# Research and Development

Maccaferri and Elas promote and carry out continuous research within the tunnelling sector in collaboration with universities, government bodies and research institutes. This aptitude for technical innovation is the result of continuous dedication, which, alongside experience and technical know-how, has enabled us to reach high levels of efficiency. Concepts are developed into versatile solutions to meet market specific requirements.

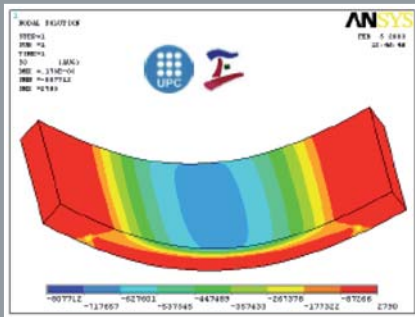
The entire range of products complies with the highest standards of quality at both a national and international level and they constantly undergo tests to prove their performance. All new products are patented in the main countries. Our technical staff has prepared numerous technical papers over the years and is often called upon to join with groups of experts for projects and technical committees.



## CE Marking



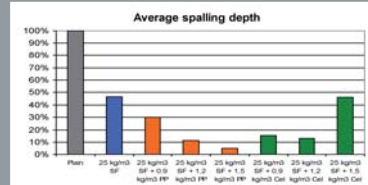
## Fibres as only reinforcement



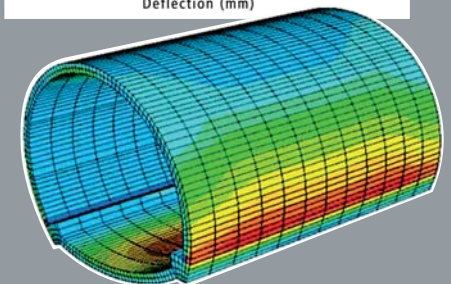
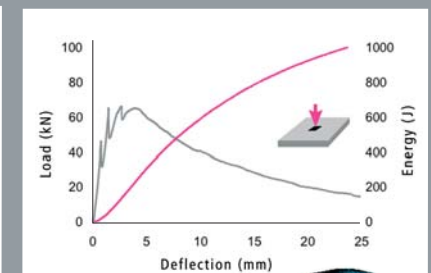
# Fire resistance tests



PP fibre  
reinforced  
concrete



## Panel tests





# Technical Support

We recognize the importance of world-class technical support. Our goal is that every support interaction strengthens our clients' overall satisfaction and reinforces our relationship with them. We are able to provide a full technical service to our customers. Not merely a simple collaboration but a true partnership from design

stage over job start until the end of the project, providing consultancies, training, and allowing all our customers to benefit from our worldwide experience.

Our technical service provides:

- Product selection according with the specific requirements

- Project consultancy and analysis
- On site tests and assistance
- Research and development with universities and research institutes
- Worldwide presence with more than 40 operating companies
- Fibre dosage equipments.

## Big bags batching systems



## Carton boxes batching system



## MACCAFERRI

Founded in 1879, Officine Maccaferri was soon to become a reference worldwide in the design and development of advanced solutions for erosion control and reinforcement structures. Over time, however, the company has innovated and evolved so that today it is also a reliable partner for complex civil and

environmental engineering applications, with specific focus on the underground works.

Maccaferri's presence throughout the world allows the company to deal with problems which results in new know-how that, in turn, feeds into further innovation for other solutions offered on the market.

As well as the parent company in Italy and subsidiaries in France, Britain, Russia, Spain and Portugal, the company is also active in all five continents, with 46 operating companies such as Latin America, New Zealand, USA. Where there is no internal sales force, there are distributors in all the continents.



Elas, for more than ten years now, has been supplying the construction market with exclusive, highly innovative and distinctive products for underground building projects, which are customised and applied in accordance with the specific technical requirements. Our skilled, experienced team provides the

customer with specialist technical consultancy, ranging from an analysis of the project, the identification of the product and their installation, paying particular attention to the specific application processes.

Research and development occupancy a position of primary importance, with a

view to ensuring the continuous improvement and development of the products and their performance features. These operations take place on site and by means of university laboratories, and are tailor-made to guarantee maximum operating efficiency and complete customer satisfaction.

## MACCAFERRI

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