



TBM

Solutions for Underground Construction



Master Builders Solutions from BASF

The Master Builders Solutions brand brings all of BASF's expertise together to create chemical solutions for new construction, maintenance, repair and renovation of structures. Master Builders Solutions is built on the experience gained from more than a century in the construction industry.

The know-how and experience of a global community of BASF construction experts form the core of Master Builders Solutions. We combine the right elements from our portfolio to solve your specific construction challenges. We collaborate across areas of expertise and regions and draw on the experience gained from countless construction projects worldwide. We leverage global BASF technologies, as well as our in-depth knowledge of local building needs, to develop innovations that help make you more successful and drive sustainable construction.

The comprehensive portfolio under the Master Builders Solutions brand encompasses concrete admixtures, cement additives, solutions for underground construction, waterproofing solutions, sealants, concrete repair & protection solutions, performance grouts, performance flooring solutions.





Global Underground Construction Team
BASF, with its global underground construction team, is a world leader in the provision of reliable, customer-oriented solutions focused on your needs in the tunneling and mining industries. We recognise that your success is underpinned by our ability to deliver solutions that meet or exceed your critical needs. By accompanying

you from the start of your project and understanding the issues that are important to you, we can contribute to your success. We support you with product training and quality control, and our professional technical services team is on hand around the clock, helping you with specialist technical advice and trouble shooting.





Specialty chemicals for safe and efficient TBM tunneling

Mechanized tunneling is the safest and quickest way of tunneling especially under difficult geological conditions and in urban areas. The optimum TBM (Tunnel Boring Machine) performance is achieved by combining both mechanical and chemical engineering.

Soil Conditioners

EPB (Earth Pressure Balance) tunneling requires the correct use of soil conditioners to reduce cutterhead torque and tool abrasion and increase advance rates. A selection of leading technology foams, polymers and anti-clay agents provide the solution for every geological situation.

Anti-Wear & Anti-Dust

Hard rock TBMs as well as soft ground TBMs may experience excessive wear and high temperatures of the cutting tools. Newly developed anti-wear agents ensure a longer cutter life and a dust-free working environment, especially for hard rock TBMs.

Tail Sealants

The TBM tail shield needs to be sealed against water, soil and annulus grout ingress. Tail sealants have been developed to ensure reliable sealing together with the brush system - the largest TBM diameter being 17 meters to date.

Main Bearing Greases

Every main bearing needs to be protected and lubricated as this is the most costly part of the TBM. Sealing and lubrication greases are also available in a renewable raw material version, leading the industry towards the highest environmental standards.

Annulus Grouts & Concrete Segments

Safe and reliable annulus grout applications require a specific selection of accelerators, retarders and stabilizers. High early strength development is of key importance for concrete segment manufacturing. A wide range of concrete admixtures is available for both technologies.

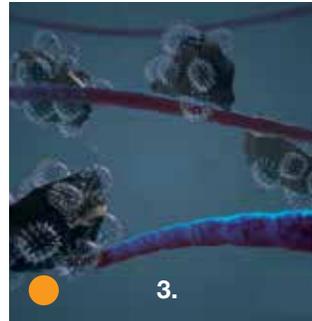
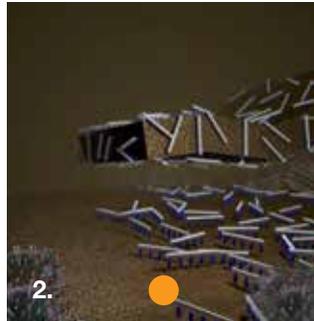
Injection, Stations, Cross Passages & Cutterhead Intervention

To strengthen geological fault zones and prevent water ingress, a comprehensive range of injection products is available, especially suited to pre-injection. Sprayable membranes enable a cost efficient composite shell lining for cross passages, access and escape routes and utility caverns. They can also be used for cutterhead interventions, providing an effective barrier against compressed air loss.



Soil Conditioners

Earth Pressure Balance (EPB) tunnel boring machines require the use of soil conditioners which must be adapted to the geology to ensure the safe advance and maximum efficiency of the TBM. Of increasing importance are the cost effective soil disposal and even the re-use of the excavated material. BASF offers competent service and expert support backed up by newly developed testing devices such as the modified shear vane tester and the soft ground abrasion tester (SGAT) which have been developed together with the renowned universities ETH in Zurich, Switzerland and NTNU in Trondheim, Norway.



1. Foams – MasterRoc SLF 41 and 47

Torque and wear reduction are the key to achieving safe and economical TBM tunneling. MasterRoc SLF foams ensure maximum performance and can be adapted to the geology encountered.

2. Anti-Clay Additives – MasterRoc ACP 127, 130 and 143 (formerly RHEOSOIL®)

MasterRoc ACP anti clay additives are the worldwide leading technology for powerful and cost-efficient EPB tunneling in clayey soils. BASF ensures a continuous development of this innovative technology.

3. Polymers – MasterRoc SLP 1 and 2

Stabilizing polymers are used to combat high water content or pressure, instable ground conditions and sharply graded soils. These unique polymers have a low impact on the environment and are also safe for the foaming system.

4. Laboratory testing & expert support

Safe and efficient tunneling already starts at the planning stage. Detailed laboratory tests of soil from the project location prior to excavation are essential. The newly developed SGAT device simulates a cutterhead advancing in consolidated ground with the possibility to add soil conditioners at the cutterhead level.



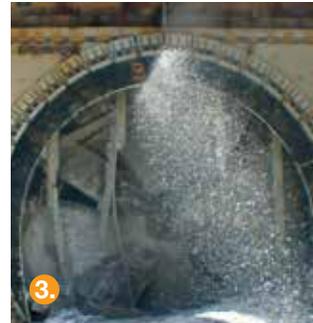
Challenging Project Solutions



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1. Galleria Sparvo, Italy

The world's largest EPB TBM to date (2013) with a cutterhead diameter of 15.55 m advanced through clay, claystone and sandstone geology which partly contained gas. The key success factor for the soil conditioning was the efficient reduction of torque even under mixed face conditions and EPB pressure of up to 3.5 bar using MasterRoc SLF 41 and MasterRoc ACP 143 (RHEOSOIL).

2. Madrid M30, Spain

The two 15m diameter TBMs worked predominantly in "penula" clay geology. Using MasterRoc ACP 143 (RHEOSOIL), only one third of the installed cutterhead torque was used throughout the whole project. No clay stickiness was observed even working under 3.5 bar earth pressure. Both TBMs achieved record advances of more than 2500 m in less than 28 weeks.

3. Toronto Metro Extension, Canada

A total of 4 TBMs were launched, with MasterRoc SLF 47 and MasterRoc ACP 127 and 211 (RHEOSOIL) being the key factor for success in difficult high clogging clay conditions. The TBMs advanced over 80 mm/min, achieving high production levels of more than 30 m/day steady advance.

The cutterhead torque was maintained well under the installed level, reducing energy consumption considerably. The EPB pressure reached 2-2.5 bar, and very low to no settlement was recorded.

4. Delhi Metro Extension, India

Numerous TBMs from various machine manufacturers (Robbins, Herrenknecht, Terratec) were working for the Delhi Metro project in sand to stiff clay geology. MasterRoc SLF 30 and 41 ensured a quick and steady advance with minimum surface settlements.



Anti-Wear & Anti-Dust

In hard rock tunneling as well as soft ground tunneling, the TBM often experiences excessive wear. BASF was one of the first companies to specially develop new solutions against wear and dust on tunnel boring machines. It is of great importance to identify these project challenges as early as possible to implement efficient counter measures to reduce the wear at the cutterhead and at the screw conveyor level. To apply the MasterRoc ABR additives in the most efficient way, a semi-automatic foam system is available, specially designed for use on hard rock TBMs.



1. Anti wear – MasterRoc ABR 5 / Anti dust – MasterRoc ABR 7

Tunneling efficiency is improved by protecting the steel tools, reducing cutter blocking and tool temperature during boring. Current site results show a wear reduction of roughly 25% and a dust free working environment for the personnel.

2. Anti clogging - MasterRoc ABR 5 and 7

The water sprinkler system typically used to decrease the cutter temperatures and the dust level often leads to clogging of the fine soil particles and blocking of the cutters. MasterRoc ABR prevents the fine particles from clogging and keeps all steel surfaces clean.

3. Wear prediction

Until the development of the SGAT testing device, wear prediction of compacted soft grounds was not possible. Now, the effects of varying moisture contents of the soil, the use of anti-wear agents as well as soil conditioners can be studied in detail. These results are used to optimize TBM performance on site.



Challenging Project Solutions



1. Guadarrama, Spain

Two shielded hard rock TBMs bored through extremely abrasive granite with a Cerchar Abrasivity Index (CAI) of 5.66 and rock strengths of 100-200 MPa. The use of MasterRoc ABR 5 led to significantly reduced abrasion, no cutter blockages and a reduced inspection time due to less wear and lower tool temperatures.

2. Faroe Islands

One Robbins main beam hard rock TBM was used in the Faroe Islands for the Eidi water transfer project in granite formations. MasterRoc ABR 5 was predominantly used to reduce the dust level inside the tunnel to improve the working conditions.



3. AMR, India

The AMR water transfer project in India used two shielded hard rock TBMs in hard and abrasive granite reaching strengths of 100-275 MPa with a quartz content ranging from 35-70%. This resulted in a very low Cutter Life Index (CLI) of 3.8-5.5. MasterRoc ABR 5 was used to reduce the wear, tool temperature and dust level.

4. Sochi, Russia

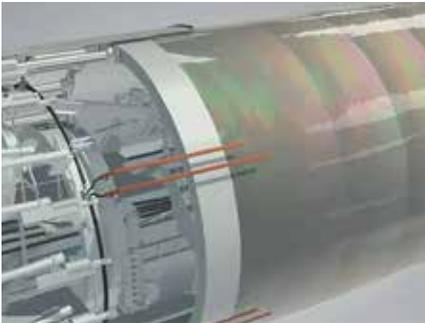
Several TBMs were used for the 2014 Sochi Winter Games transportation scheme. High tool wear was experienced, and where water ingress occurred, the crushed rock paste plugged the cutter housing, blocking the disk. MasterRoc ABR 5 was used to reduce the tool wear and clogging effect. The geology consisted mainly of hard fractured limestone and porphyry with difficult fault zones.





Tail Sealants

Reliable and cost efficient sealing of the TBM tail shield is essential for a smooth tunneling operation. Regardless of the soil conditions and the annulus grout type used, the MasterRoc TSG tail sealants effectively prevent not only water but also soil and annulus grout from entering the TBM. BASF offers an inert tail sealant that does not produce any negative side effects for the concrete and the EPDM gaskets.



1.

1. Driving grades – MasterRoc TSG 6 and 16

Both products have excellent adhesion to metal and concrete surfaces, even under water. To seal the complete circumference of the shield, the driving grade must flow well between the injection points. The consumption of MasterRoc TSG depends on numerous factors such as the roughness of the concrete segment and condition of the brushes, normally reaching 0.8-1.2 kg/m² of the segment surface.

2. First fill grade – MasterRoc TSG 7

The specially designed first fill sealant is of significant importance: once applied into the newly installed brushes, it protects them by preventing the penetration of water, soil and annulus grout. Additionally, it ensures the flexibility of the brushes which is necessary to follow the movements of the tail shield.

3. Product design and performance

MasterRoc TSG is made from high-molecular polymers, natural fillers and fibers. Important typical properties are a water spray off (ASTM D 4049) of below 5%, and a sealing capacity above 34 bar (Matsumura sealing test). It has been successfully used worldwide on Herrenknecht, Robbins, Lovat/Cat, Hitachi, Mitsubishi and Kawasaki TBMs - sealing diameters of up to 15.5 meters to date.



Challenging Project Solutions



1. Galleria Sparvo, Italy

The worlds largest EPB TBM to date (2013) with a cutterhead diameter of 15.55 m advanced through clay, claystone and sandstone geology which partly contained gas. The 2-component annulus grout reached the 4.5 bar maximum pressure. MasterRoc TSG 6 and 7 sealed the TBM successfully through its 2500 m long advance.

2. Toronto Metro Extension, Canada

Several EPB TBMs used the MasterRoc TSG 6 driving grade as well as the TSG 7 first fill grade during their advance in Toronto. The 2-component annulus grout pressure reached 4.5 bar. A special challenge was the very low temperatures at the start shaft.

3. Saverne, France

The convertible TBM used the TSG 6 driving grade during both the EPB and hard rock modes. Consumption values reached around 1.2 kg/m² of segment surface during EPB mode and around 0.5 kg/m² during hard rock mode. The TSG 7 first fill grease ensured brush protection during the 3800 m advance.

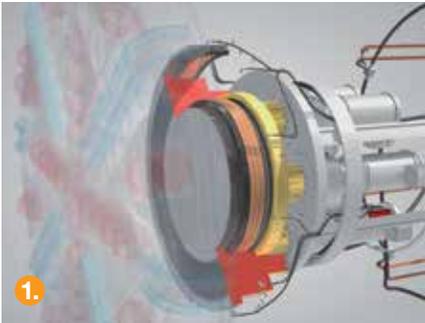
4. Hamburg U4 HarbourCity, Germany

The slurry TBM advanced through sand and clay geology with up to a challenging 5 bar saline water pressure below Hamburg Harbour. The MasterRoc TSG 6 and TSG 7 first fill secured a perfect sealing of the TBM over 3000 m between two stations.



Main Bearing Greases

The most costly part of the TBM is the main bearing, which therefore has to be well maintained. For this reason, BASF ensures highest raw material and production quality by only producing the greases at a few well selected sites around the world. All MasterRoc EPB and BSG greases have Merkel certification. Apart from the standard greases (EPB/BSG 11), highly biodegradable greases made from renewable raw materials (EPB/BSG 1) have been developed.



1. Protection of the main bearing

Generally, there are two different types of greases used together: main bearing lubricants (EP greases) and main bearing sealants. The main bearing sealants have a stronger adhesion to metal surfaces and higher wash-off resistance than EP greases, but less lubrication properties. The consumption level of both greases depends on the recommendation of the TBM suppliers.

2. Main bearing lubrication - MasterRoc EPB 1 and 11

The lubricants contain antioxidants, corrosion inhibitors and EP/AW additives. They offer excellent mechanical stability, load carrying capacity and corrosion protection, which makes them suitable for heavy loaded bearings as well as wet environments. Important typical properties are a 4-ball wear (DIN 51350:5) of around 0.5 mm and a water spray off (ASTM D 4049 @ 25°C) of below 15%.

3. Main bearing sealing - MasterRoc BSG 1 and 11

The sealants are excluder greases that effectively protect the main bearing by preventing water and soil from entering into the sealing system. They are formulated to resist high water and ground pressure and have good lubrication and pumping properties with excellent adhesion to all surfaces. Important typical properties are a 4-ball wear (DIN 51350:5) of below 0.9 mm and a water spray off (ASTM D 4049 @ 25°C) of roughly 3%.

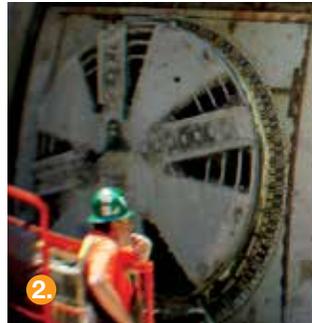


Challenging Project Solutions



1. Moscow Metro Extension, Russia

MasterRoc BSG 11 was used in combination with MasterRoc EPB 11 on 8 EPB TBMs to date, manufactured by CAT, NFM and Robbins. The EPB pressure reached 1-3 bar with high ground water flow, reaching at up to 20 m³/h at some sections.



2. Toronto Metro Extension, Canada

Several EPB TBMs in Toronto used the MasterRoc BSG 1 main bearing sealing grease. It was chosen due to its renewable raw material content. A special challenge was the very low temperatures at the start shaft.



3. Sochi, Russia

MasterRoc EPB 11 was used on 3 TBMs: 6 m Lovat EPB TBM at Tunnel 3 North (pressures reached 0.8-4.0 bar), 6 m Lovat/Selli double shield hard rock TBM at Tunnel 3 South and 10 m Lovat hard rock TBM at Tunnel 3 South.



4. Istanbul Metro, Turkey

Several EPB TBMs used the MasterRoc BSG 1 main bearing sealing grease for the entire project. The EPB pressures reached 1-4 bar.



Annulus Grouts & Concrete Segments

When the segmental lining is installed inside the TBM, the space between the ground and the segments – the annulus gap - must be filled in an efficient and reliable way to prevent settlements. In most cases, this space is filled by a cementitious grout, for which BASF provides a full range of admixtures.

Concrete quality is a very important aspect for segment production, especially as tunnels today have a designed lifetime requirement of 100 years. High performing concrete additives are necessary to ensure not only durability but also efficient production.



1. Segment concrete

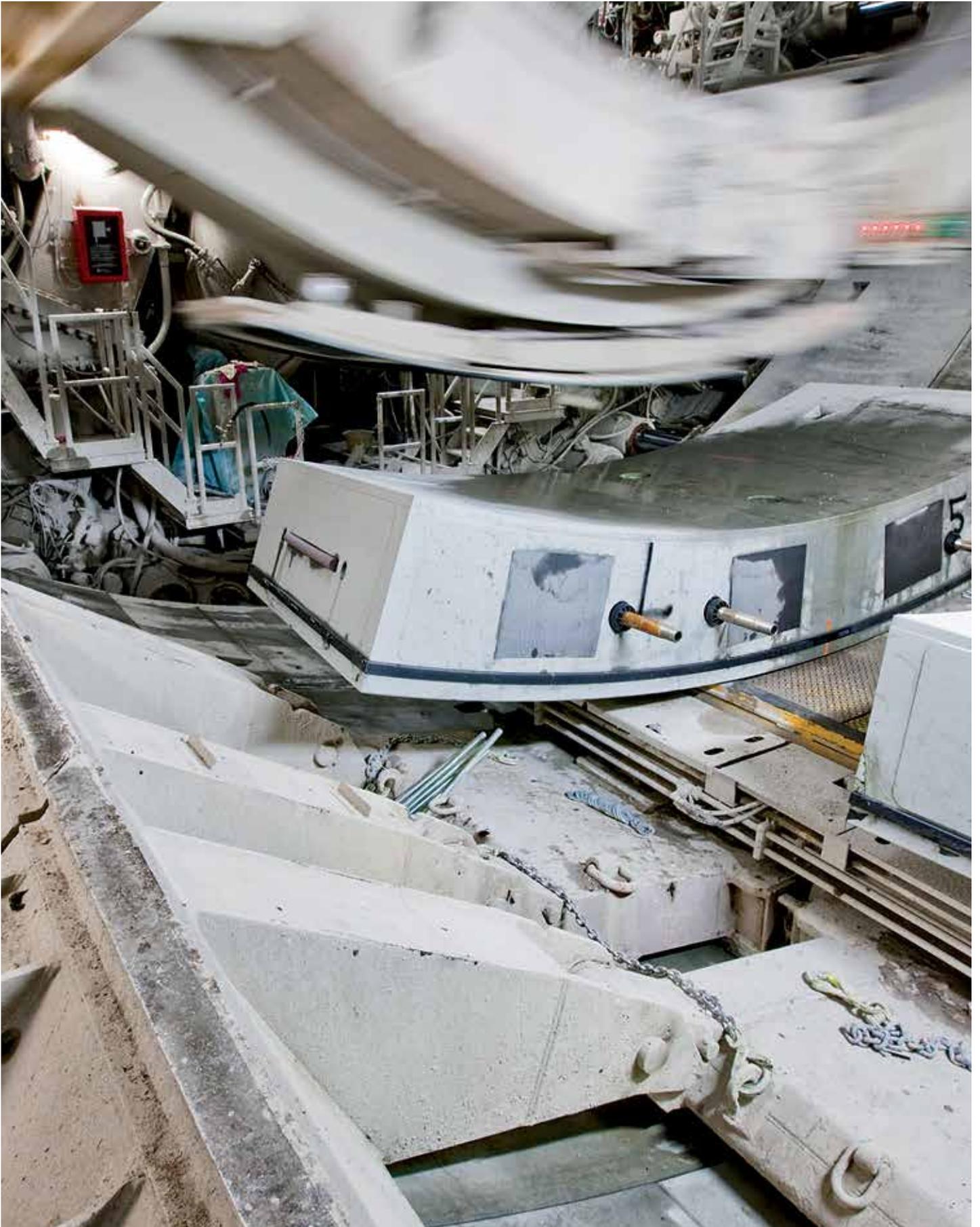
MasterGlenium Superplasticisers and MasterFinish Form Release Agents reduce the curing time of the concrete and allow earlier demoulding, leading to shorter production cycles. This reduces energy consumption while increasing productivity and improving work safety. Furthermore, the durability of the concrete itself is enhanced.

2. Annulus grout additives

The main goal of annulus grouts is to minimize surface settlements. Furthermore, the annulus grout protects both the outside surface of the segments and the EPDM gaskets and finally supports the segments to prevent floating. The use of retarders, accelerators, superplasticizers or air entrainers ensures a reliable and easy to handle grout formulation.

3. Shield stabilization and lubrication

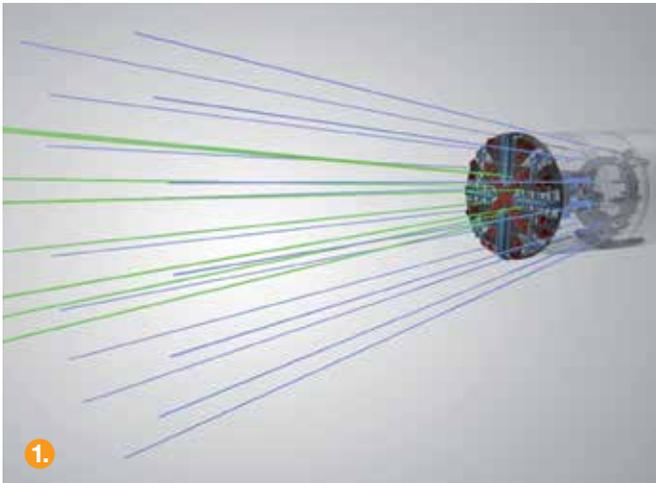
In projects with a big TBM diameter or very unstable ground conditions, shield stabilization grout can reduce surface settlement and prevent the shield from becoming blocked. For this application the use of polymerized bentonite or sand suspensions is ideal. MasterRoc SLP Polymers can also be used for clay swelling inhibition and to lubricate the shield.







Injection



1. Pre-injection

Pre-injecting the ground is an important measure to stabilize fractured rock and to prevent water ingress, especially in geological fault zones. It is essential that the TBM already has all the necessary equipment installed prior to commencing the tunneling operation, as retrofitting is costly, time consuming and quite often only partially possible. This includes drilling and mixing equipment as well as the drill jigs which go through the shield, and if necessary through the cutterhead. BASF offers microcements and colloidal silica to penetrate low permeable ground. The most economical and technically suitable product can be provided for each geological situation. This proven concept also fulfills environmental standards for drinking water, which was for example required by the Arrowhead project in the USA.



2. Post-injection

Post-injection on a TBM can be used for void filling, water stopping and concrete repair. The polyurea silicate MasterRoc MP 367 Foam is excellent for void filling (less adhesion to the metal TBM parts), the polyurethane MasterRoc MP 355 for water stopping, and the acrylic resin MasterRoc MP 307 CE for concrete repair.

More details are available in the Master Builders Solutions Injection brochure.

Mastering underground construction challenges requires the right partner. Continuous innovation and customized solutions ensure that customers using Master Builders Solutions operate successfully, and to the highest safety standards.



Stations, Crosspassages & Cutterhead Intervention



Stations and Cross Passages

BASF offers a unique solution with its MasterSeal 345 sprayable waterproofing membrane, allowing design flexibility for difficult geometries such as tunnel intersections, and also for station and access tunnels and cross passages. When placed in a sandwich structure between two sprayed concrete layers, MasterSeal 345 also offers design optimization, creating a double bonded composite shell lining. Special design guidelines are available to support all projects. Selected references are the Singapore and Sofia Metro projects.



Cutterhead intervention

Safe and efficient cutterhead intervention is one of the key success factors in TBM tunneling. MasterSeal 345 offers a quick and reliable way of sealing the face to prevent compressed air loss for a secure intervention even in highly permeable ground conditions.

More details about the MasterSeal 345 sprayable membrane are available in the Master Builders Solutions Sprayed Concrete brochure.



Training and Education

BASF brings extensive know-how gained through worldwide experience in solving challenging situations in mechanized tunneling. In addition, support is offered frequently for clients, contractors, TBM manufacturers and consultants by offering technical training courses and specialized seminars. Whenever required, and especially in the case of large projects, tailored on-site training can be organized.

Technical Services

BASF supplies more than just specialty products for TBM operations, but also assists in the selection of the most suitable combination of products for each project specific geology or TBM, as well as providing start-up supervision and site support.

More brochures on our underground construction solutions are available at www.ugc.basf.com

Documentation available on request:

- Reference list
- Project reports
- Technical data sheets
- Design guidelines
- Method statements

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Master Builders Solutions products from BASF for the Construction Industry:

MasterAir®

Solutions for air-entrained concrete

MasterBrace®

Solutions for concrete strengthening

MasterCast®

Solutions for manufactured concrete products

MasterCem®

Solutions for cement manufacture

MasterEmaco®

Solutions for concrete repair

MasterFiber®

Comprehensive solutions for fiber reinforced concrete

MasterFinish®

Solutions for formwork treatment

MasterFlow®

Solutions for precision grouting

MasterGlenium®

Solutions for high-performance flowing concrete

MasterInject®

Solutions for concrete injection

MasterKure®

Solutions for concrete curing

MasterLife®

Solutions for enhanced durability

MasterMatrix®

Advanced rheology control solutions for self-consolidating concrete

MasterPel®

Solutions for watertight concrete

MasterPolyheed®

Solutions for moderate slump concrete with superior finishability

MasterPozzolith®

Solutions for conventional slump concrete

MasterProtect®

Solutions for concrete protection

MasterRheobuild®

Solutions for high slump concrete

MasterRoc®

Solutions for underground construction

MasterSeal®

Solutions for waterproofing and sealing

MasterSet®

Solutions for set control

MasterSure®

Solutions for workability control

MasterTop®

Solutions for industrial and commercial floors

Ucrete®

Flooring solutions for harsh environments

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