



TBM

Solutions for Underground
Construction



Master Builders Solutions®

The Master Builders Solutions® brand brings all of our expertise together to create chemical solutions that inspire people to build better. Master Builders Solutions® is built on the experience gained from more than a century in the construction industry.

Our know-how and experience as a global community of 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 Master Builders Solutions® technologies, as well as our



front cover photo: © The Robbins Company

Global underground construction team

Master Builders Solutions®, with its global underground construction team, provides reliable, customer-oriented solutions focused on your needs in the tunneling and mining industries all over the world. We recognize 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.

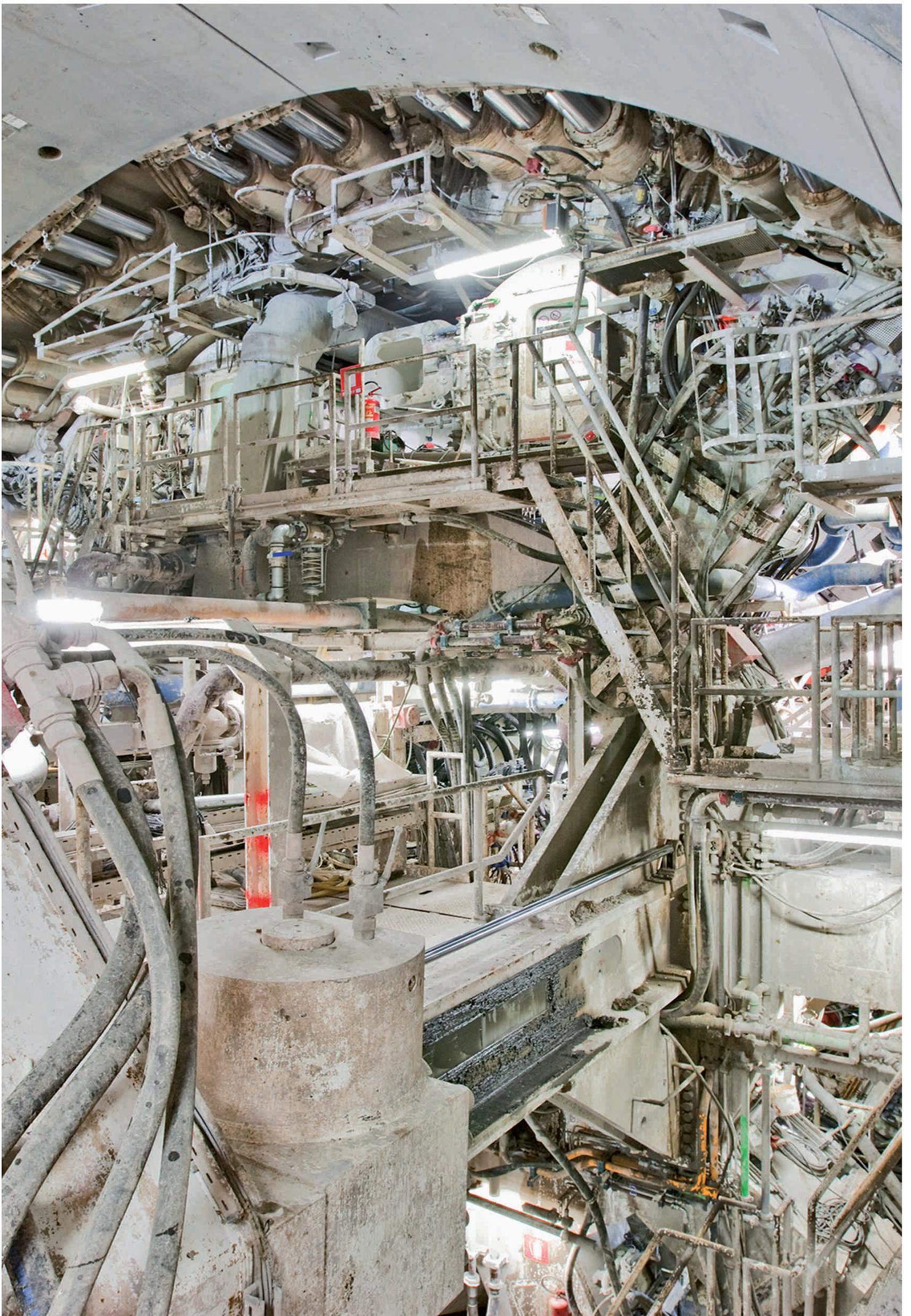
Our comprehensive portfolio

- Concrete admixtures
- Cement additives
- Chemical solutions for underground construction



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, and chemical solutions for underground construction.





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 17.6 meters to date.

Main Bearing Greases

Every main bearing needs to be protected and lubricated as this is the costliest 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. The Master Builders Solutions® team offers competent service and expert support backed up by local lab facilities.



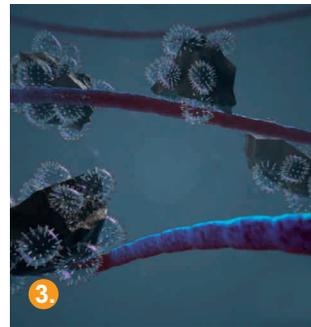
1. Foams – MasterRoc® SLF 30, 32, 34, 41, 47, 50, and recent introductions 325, 419, and 543

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, 147, 143, 211, and 214

MasterRoc® ACP anti clay additives are the worldwide leading technology for powerful and cost-efficient EPB tunneling in clayey soils. The portfolio includes pure anti-clay additives or formulated products based on foams and polymers. Master Builders Solutions® ensures a continuous development of this innovative technology.



3. Polymers – MasterRoc® SLP 1, SWA 710, and 750

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 they can be used through the foaming system or injected by separate lines in the chamber or screw.



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. Based on these laboratory tests, the contractor is able to judge the use of the best suitable product and it provides him with the necessary information for the setup of the foam parameters on the TBM.



Challenging Project Solutions



1. Galleria Sparvo, Italy

An EPB TBM 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.



2. Alaskan Way Viaduct Replacement Tunnel, Seattle/WA (USA)

One of the world's largest EPB TBM (Ø 17.5 m) was utilized to construct a double deck road tunnel underneath the city of Seattle. The majority of the alignment consisted of cohesion less, poorly graded sand and gravel with stretches of cohesive clay and silt. Both conditions were challenging especially due to the large diameter and required exceptional performance of the soil conditioning products. The extremely high half-life of the MasterRoc® SLF 50 maintained consistent characteristics of the treated bsoil throughout the excavation chamber and screw



conveyor. The MasterRoc® ACP 147 was successfully utilized to manage the cohesive clay sections.

3. Toronto Metro Extension, Canada

A total of 4 TBMs were launched, with MasterRoc® SLF 47 and MasterRoc® ACP 127 and 211 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. MasterRoc® ACP 143 was used when sticky clay was encountered.



Anti-Wear & Anti-Dust

In hard rock tunneling as well as soft ground tunneling, the TBM often experiences excessive wear. The Master Builders Solutions® team was one of the first 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 needed, specially designed for use on hard rock TBMs.



1. Anti-wear and anti-dust – MasterRoc® ABR 5 / Anti-dust – MasterRoc® ABR 2 and 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 Soft Ground Abrasion Tester (SGAT) 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. Westery Tunnel – Cleveland, Ohio, USA

The Westery Tunnel is a sewer tunnel part of the Project Clean Lake, is using a Lovsun Single Shield TBM in its way through the Chagrin Shale. The Chagrin shale consist of siltstone, silty gray shale and soft gray clay shale. The Chagrin Shale is classified as a weak to medium-strong rock, with a compressive strength from 34 Mpa to 100 Mpa. ABR 7 is mainly used as a dust suppressant.



2. Faroe Islands, Denmark

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

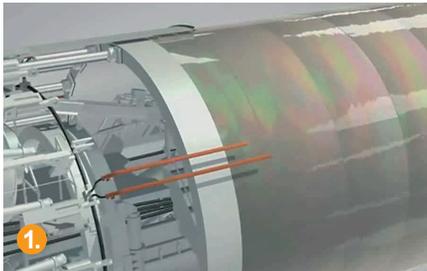
Several TBMs were used for the 2014 Sochi Winter Games transportation scheme. High tool wear was experienced, and where water ingress occurred, the crushed rock paste plugged the cutter housing, blocking the disk. MasterRoc® ABR 5 was used to reduce the tool wear and clogging effect. The geology consisted 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. Master Builders Solutions® offers an inert tail sealant that does not produce any negative side effects for the concrete and the EPDM gaskets.



1. Driving grades – MasterRoc® TSG 6 and 800

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, tunnel lay out and condition of the brushes, normally reaching 0.8-1.2 kg/m² of the segment surface.

2. First fill grade – MasterRoc® TSG 7 and 870

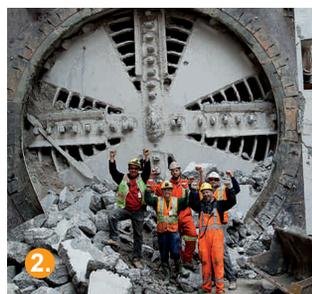
The specially designed first fill sealant is of significant importance: once applied into the newly installed brushes, it protects them by preventing the penetration of water, soil

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) and a sealing capacity above 34 bar (Matsumura sealing test). MasterRoc® TSG 800 and TSG 870 are fire resistant giving optimum safety during tunnel excavation. MasterRoc® TSG has been successfully used worldwide on Herrenknecht, Robbins, Lovat/Cat, Hitachi, Mitsubishi and Kawasaki.

Challenging Project Solutions



1. Galleria Sparvo, Italy

An EPB TBM 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.

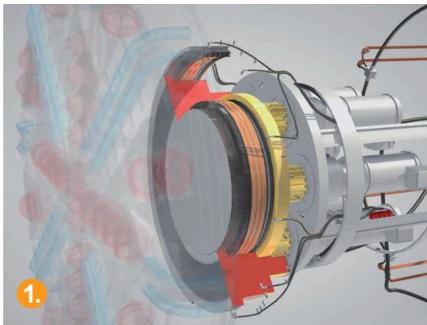
4. Moscow metro, Russia

The fire resistant MasterRoc® TSG 800 was used in the new metro ring line in Moscow. The 6.25m diameter TBM excavated in clay conditions and the MasterRoc® TSG 800 sealed the TBM effectively against any ingress from water or grout.



Main Bearing Greases

The costliest part of the TBM is the main bearing, which therefore has to be well maintained. For this reason, Master Builders Solutions® 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.

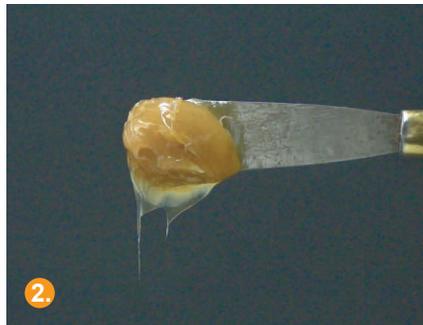


1. Protection of the main bearing

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.

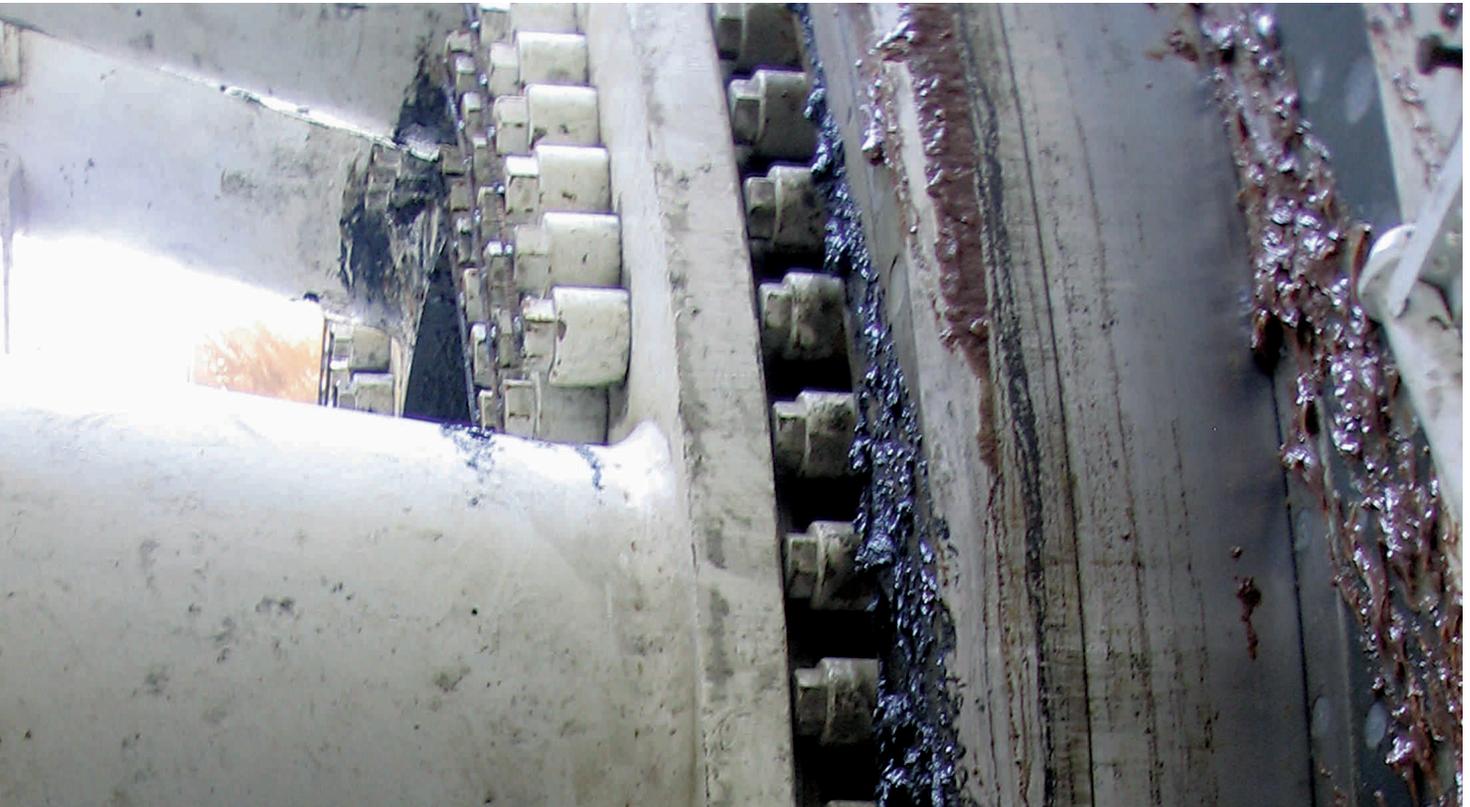
2. Main bearing lubrication – MasterRoc® EPB 1 and 11

The lubricants based on synthetic or vegetable oil 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 based on synthetic or vegetable oil 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.



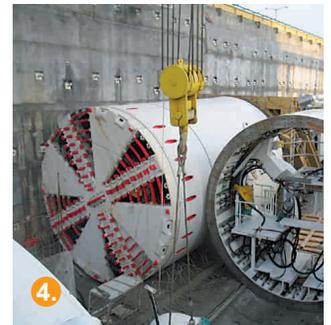
2. Toronto Metro Extension, Canada

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 Master Builders Solutions® 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. 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.

2. 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

3. Segment concrete

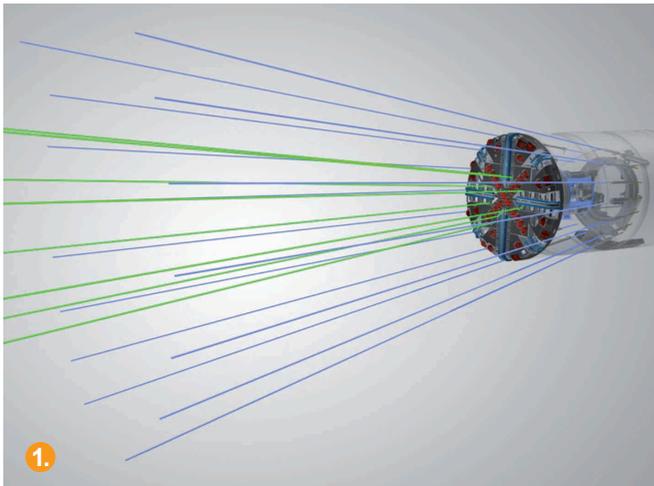
MasterGlenium® superplasticizers and MasterFinish® form release agents reduce the curing time of the concrete and allow earlier demolding, leading to shorter production cycles. This reduces energy consumption while increasing productivity and improving work safety. Furthermore, the durability of the concrete itself is enhanced.







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. Master Builders Solutions® 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 & Cross Passages



Stations and Cross Passages

Master Builders Solutions® offers a unique solution with its MasterRoc® MSL 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, MasterRoc® MSL 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.



Know-how and Service



Training and Education

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More brochures on our underground construction solutions are available at <https://ugc.master-builders-solutions.com>.

Documentation available on request:

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



Master Builders Solutions® for the Construction Industry

MasterAir®

Complete solutions for air entrained concrete

MasterCast®

Solutions for the manufactured concrete product industry

MasterCem®

Solutions for cement manufacture

MasterCO₂re™

Solutions for low-clinker concrete

MasterEase®

Low viscosity for high performance concrete

MasterFinish®

Solutions for formwork treatment and surface improvement

MasterFiber®

Comprehensive solutions for fiber reinforced concrete

MasterGlenium®

Solutions for high performance concrete

MasterKure®

Solutions for concrete curing

MasterLife®

Solutions for enhanced durability

MasterMatrix®

Advanced rheology control for concrete

MasterPel®

Solutions for hydrophobization, anti-efflorescence and surface protection

MasterPolyheed®

Solutions for mid-range concrete

MasterPozzolith®

Solutions for water-reduced concrete

MasterRheobuild®

Solutions for high strength concrete

MasterRoc®

Solutions for underground construction

MasterSet®

Solutions for set control

MasterSphere®

Solutions for guaranteed freeze-thaw resistance

MasterSuna®

Solutions for sand and gravel in concrete

MasterSure®

Solutions for extraordinary workability retention

Master X-Seed®

Advanced accelerator solutions for concrete



QUANTIFIED SUSTAINABLE BENEFITS ADVANCED CHEMISTRY BY MASTER BUILDERS SOLUTION

Let the numbers do the talking: We have portrayed some of our most eco-efficient product solutions for concrete and precast production, construction, and civil engineering.

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