Sprayed Concrete

Solutions for Underground Construction

A brand of
MBCC GROUP

Master Builders Solutions

The Master Builders Solutions brand brings all of our 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 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 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 and protection solutions, performance grouts, performance flooring solutions and solutions for on- and offshore wind energy.

Our Comprehensive Portfolio

- Concrete admixtures
- Cement additives
- Chemical solutions for underground construction
- Waterproofing solutions
- Sealants
- Concrete repair and protection solutions
- Performance grouts
- Wind turbine grouts
- Performance flooring solutions

Sprayed Concrete

Sprayed concrete technology has revolutionized tunnel construction and mining operations since the middle of the 20th century. The development of material science and performance together with advances in spraying equipment technology have made sprayed concrete the building material of choice for today's underground construction projects.

Due to its nature as a spray-applied material, sprayed concrete offers excellent surface sealing and ground strengthening as it perfectly fits the excavation contour, hardening and gaining strength in a remarkably short time frame. It has allowed the construction of underground subsurface structures that were not possible before.

The development of modern wet-mix sprayed concrete in particular has contributed considerably to this eff ort. Furthermore, the proven quality of sprayed concrete has led to it being used more and more as a permanent support solution, replacing the traditional cast in-situ inner concrete lining.

Expert Know-How

Master Builders Solutions provides technical consulting expertise at every project stage from start to finish, covering issues such as geo-technical challenges and design and time constraints. Our underground construction specialists bring long-term experience in sprayed concrete application, and work together with laboratory resources to choose the correct product selection. They take a consultative approach to help solve the challenges ahead.

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.

Benefits at a glance:

- Comprehensive portfolio including a wide range of admixtures and fibers
- Robust and safe application for initial and final support
- Solutions for durable and permanent applications
- Structural fibers for advanced support design
- Know-how and expert advice for sustainable construction

Sprayed Concrete from Start to Finish

Sprayed concrete applications must ensure safety and be formulated to last. Master Builders Solutions offers a wide range of admixtures for addition during concrete batching and on-site.

At the Batching Plant

Superplasticizers

Sprayed concrete mixes that combine low water/cement ratios with superior flow and workability deliver concrete with excellent early strength development, high long-term strength and improved durability. MasterGlenium® is a high performance water-reducing superplasticizer for reduced accelerator consumption, reduced bleeding and lower levels of segregation. While the MasterEase® range provides superior rheological properties (good pumpability, low viscosity), the MasterSuna® range is specifically designed to work with manufactured sands with high fines, clay minerals, or both.

Hydration Control

Our hydration control system MasterRoc® HCA can maintain an open time of up to 72 hours, offering greater flexibility of site logistics.

Pumping Aid

Improving the thixotropy of a mix and eliminating the risk of segregation, improves pumpability. The MasterMatrix range allows the modification of rheological properties to prevent segregation. MasterRoc TCC 780 is a pumping aid for sprayed concrete mixes which contain difficult or poorly graded aggregates.

Concrete Improvement

MasterRoc TCC 735 is a chloride-free concrete-improving admixture which enhances the quality of sprayed concrete in both plastic and hardened states. Its unique composition ensures better hydration of the cement. As a result, initial shrinkage is substantially reduced, bonding characteristics are enhanced, and density and compressive strength are increased.

Microsilica

MasterRoc MS microsilica improves the pumpability and workability of sprayed concrete mixes in the fresh state, while reducing permeability and increasing density and long-term strength in the hardened state. It is available in both densified powder and liquid formulations.

Colloidal Silica

MasterRoc MS colloidal silica is an amorphous precipitated silica suspension (liquid) designed to improve the properties of sprayed concrete in both the plastic and hardened states. It improves pumpability and sprayability and reduces rebound, at the same time reducing permeability and improving durability in the hardened state.

Structural Plastic / Steel Fibers

MasterFiber structural reinforcing fibers greatly improve the load absorption capability and cracking resistance of sprayed concrete and are available in both steel and polymer (typically polypropylene) versions. They are easy to dispense and use, giving even distribution throughout the mix to ensure uniform results.

On-Site

Pump Lubrication Aid

MasterRoc LUB 1 powder is specially formulated for lubricating concrete pumps, hoses and pipelines prior to concrete pumping or spraying.

Set Accelerators

MasterRoc SA alkali-free accelerators are added at the nozzle and accelerate the setting and hardening of the sprayed concrete. They provide high early strength gain and long-term strength development, as well as enhanced durability. Furthermore, they reduce dust and rebound levels.

Admixture type	Product line	Application example	Flowabilty	Open time	Segregation prevention	Low viscosity	Manufactured sand/clay	Strength/ Durability	Waterproofing
Plasticizer	MasterGlenium	Standard superplasticizer	●	●				●	
	MasterEase	Solution for low viscosity / easy pumpability	●	●		●		●	
	MasterSuna	Special solution for manufactured sands and clay	●	●				●	
Hydration control	MasterRoc HCA	Extended workability for sites with long availability or difficult logistics		●					
Viscosity modifying admixture	MasterMatrix	Overcome lack of fines within sieve grade			●				
	MasterRoc MS	Colloidal silica (e.g., MS 675 - 695)			●				
Concrete improvement	MasterRoc MS	Microsilica as powder or slurry (e.g., MS 610 - 660)			●			●	●
	MasterRoc TCC	Internal curing, permanent sprayed concrete linings						●	
	MasterKure	External curing						●	
	MasterLife	WP 1000 or 300D for waterproofing						●	●
	MasterLife SRA	Shrinkage reduction						●	
Alkali-free accelerator	MasterRoc SA	Accelerator for sprayed concrete for fast buildup and early re-entry						●	

Mix Design & Durability

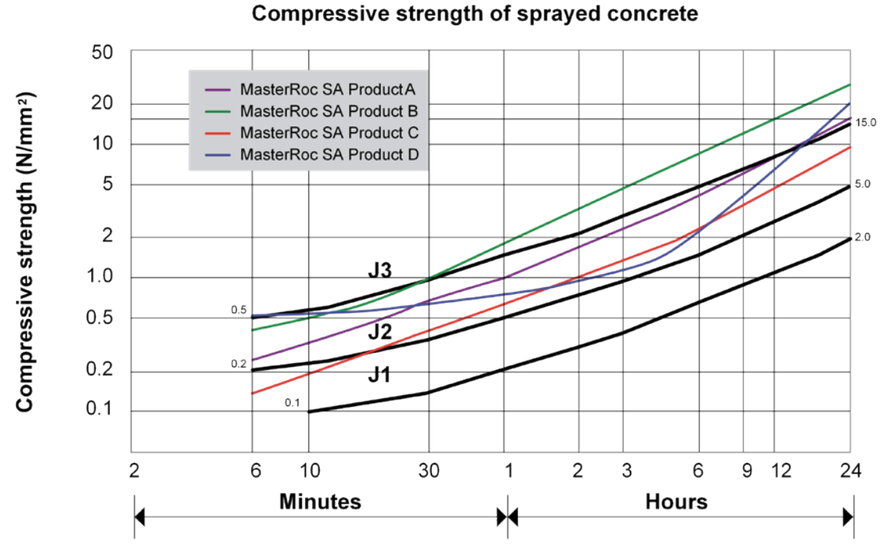
Mix Design

Creating the optimal concrete solution requires experienced concrete knowledge. Suitable materials for the mix (cement, aggregates, superplasticizer, etc.) and the correct alkali-free accelerator must be chosen to optimize pumpability and spraying performance. Furthermore, project limitations such as transport restrictions and badly graded aggregates, as well as specific project requirements, such as very high early strength to minimize settlement in urban tunneling and faster re-entry in mining, require the variety of admixtures. Master Builders Solutions offers to solve these specific challenges.

Durability

A durable sprayed concrete lining is defined as one that performs in the working environment for the duration of its expected service life. Achieving good durability depends on a variety of factors, especially density and water/cement ratio. Each project requires an adapted solution based on customer requirements and local building material, and Master Builders Solutions' underground construction specialists are here to propose the right chemistry for a successful result. As a consequence of the growing use of sprayed concrete as a permanent construction material for tunnel linings, demands on its durability have increased likewise. It offers more flexibility in terms of the geometry and space requirements. Permanent sprayed concrete is a requirement for the innovative composite shell lining design. See also our brochure on permanent sprayed concrete linings.

Sprayed concrete quality testing



Recorded compressive strength developments by selected alkali-free set accelerators in comparison with J1, J2 and J3 standard requirements based on the Austrian Guideline for sprayed concrete

Alkali-Free Accelerators

The MasterRoc SA series of alkali-free accelerators was developed to meet industry demand for durable, high-quality sprayed concrete that also minimizes environmental risks. Master Builders Solutions offers a wide range of accelerators to suit local cements, conditions and site needs.

- High performance with relatively low dosages
- Fast setting and constant early strength development, allowing fast application and high build rates
- Ability to spray in areas with moderate water ingress
- Sprayable in ground-freezing projects
- Effective embedment of steel reinforcement for concrete with lower initial strength
- Enables a dense concrete structure with high final strength
- Highly durable sprayed concrete for permanent support
- Non-aggressive properties (pH around 3) provide improved working safety, reduced environmental impact and lower handling costs
- Low dust and rebound for a healthier working environment

It is essential to use automated spraying equipment with an integrated dosing system to ensure accurate dosage control.

Master Builders Solutions strives to offer innovative solutions for the tunneling and mining sectors through continual product development. Our research and development community includes a team dedicated to optimizing the properties of sprayed concrete for underground construction.

Permanent Sprayed Concrete

Permanent Sprayed Concrete (PSC) has, in principle, the same composition as temporary sprayed concrete, however it must last for the same lifetime as the structure (e.g., tunnel) where it is applied. Therefore, durability requirements should be similar to those for other permanent concrete structures. Durability in civil engineering is the resistance of materials to outside influences like moisture or water, temperature (hot or cold), frost, chemical or bacterial attack.

The main influencing factors for durability and life span of PSC are:

- Design
- Concrete technology
- Material parameters
- Process and application parameters

The concrete technology parameters do depend on the normative requirements in the relevant countries. In a nutshell, they can be summarized as the requirement for a dense structure and the selection of PSC constituents according to the exposure. So, a low water/binder (cement+additions) ratio and suitable strength development for the spray application is of major importance.

The chosen set accelerator (alkali-free) should give a suitable early strength development – as low as feasible – and provide a good final strength together with high density and low porosity.

Adding microsilica or nanosilica influences the density in a positive way. Admixtures should be selected to achieve the necessary fresh concrete properties and to improve hardened properties like shrinkage or water tightness.

As well as the typical admixtures used in sprayed concrete, the following should be considered for PSC:

- Internal/External curing
- Admixtures to improve watertightness (e.g., MasterRoc WP)
- Anti-shrinkage admixtures (MasterLife® SRA)
- Microsilica/Nanaosilica (MasterRoc MS)
- Fibers: MasterFiber® micro- or macrofibers for shrinkage control or structural support

For further details refer to our brochure "Composite Shell Linings" as well as the "ITA Working Group 12" and ITA tech report “Permanent Sprayed Concrete Linings.”

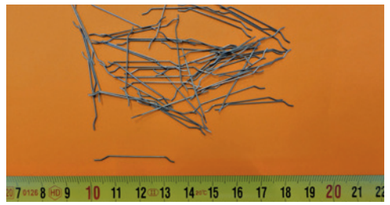
Fiber-Reinforced Sprayed Concrete

The addition of structural fibers in sprayed concrete, improves the structural performance in the early ages and once hardened. The fibers control plastic and drying shrinkage and improve the structural response to tensile, bending and shear providing a ductile failure. They also improve fatigue and impact resistance, with high impact absorption capacity. These improvements are achieved with a polymer fiber technology of different natures, completely corrosion-free, non-magnetic, and 100% alkali resistant.

The dispersion and three-dimensional distribution of the fibers guarantee a sewing throughout the mass of concrete, without the existence of weak planes. Due to the specific elasticity of the polymer, a very high compatibility and bonding between the concrete and the fiber is obtained in all stages of concrete hardening.

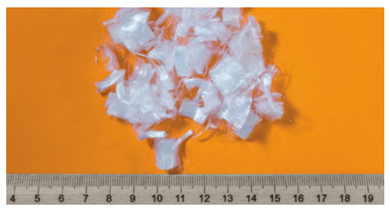
Our knowledge of concrete technology and chemistry allows us to design the concrete mix by combining a perfect application process (pumping, spraying, etc.) with a maximum structural response. In the field of reinforced sprayed concrete, the main requirement is to maintain a certain level of ductility under high deformation conditions. Strength and age of the concrete matrix as well as fiber design have to be considered to achieve the desired performance.

Types of Fibers



Steel Fibers

Steel fibers with a length of 30-35 mm and a diameter of around 0.5 mm provide high initial stiffness and good performance in low deformations. Under adverse conditions, corrosion can be an issue.



Microsynthetic Fibers

Polymer fibers with a length of 6-18 mm and a diameter of 15-30 microns provide specific properties to sprayed concrete. They give fire protection by preventing explosive spalling in the case of a fire due to their low melting point. They also reduce plastic shrinkage cracks and provide better durability.

Macrosynthetic Fibers

Polymer fibers with a length of typically 25-65 mm and a diameter of at least 0.3 mm. Due to their high ductility, they deliver good performance under higher deformation conditions. They are available with different surface structures (e.g., flat, crimped or embossed) to suit specific requirements.

Fiber Reinforced Sprayed Concrete

Design and Testing

For stiff underground structures, like shallow tunnels in weak ground, the design is typically done according to Eurocodes or the fib Model Code, based on residual strength, determined by beam testing. For hard rock tunneling and mining, the energy absorption of the sprayed concrete is used. Tests can be conducted on either square panels according to EN 14488-8 with 25 mm deflection or on round determinate panels (RDP) with 40 mm deflection. The results from one test can be converted to the other, using a factor of 2.5 (see table below).

Energy Class	EN Square Panel (60 x 60 x 10 cm)	RDP Round Plate (80 x 7.5 cm)
E 500	500 J	200 J
E 700	700 J	280 J
E 1000	1000 J	400 J

Application of FRSC Underground

Fiber-reinforced sprayed concrete is a widely used rock support measure which replaces the conventional mesh reinforcement and can be applied safely, fast and highly mechanized. The structural synthetic macrofibers from the MasterFiber product range form an internal network and add superior tensile properties to the sprayed concrete system.

MasterFiber structural reinforcing fibers greatly improve the load bearing capability and cracking resistance of sprayed concrete. In comparison to steel fibers, the synthetic fibers are not prone to corrosion and show a better CO_2 footprint.

The use of synthetic fibers guarantees a very ductile behavior of the concrete structure, which ensures very big deformation before failure. Effective surface support and protection against weathering of rock and strata are critical to the safety, efficiency and longevity of any mining operation. Master Builders Solutions provides systems for supplementary surface support to strategic areas of a mine, thus increasing safety for people and infrastructure.

Know-how and Service

Training and Education

Master Builders Solutions brings extensive know-how gained through worldwide experience in solving challenging situations in tunneling and mining. In addition, support is offered frequently for clients, contractors 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

Master Builders Solutions supplies more than just specialty products for underground construction and mining, assisting in the selection of the most suitable combination of products for each project specific geology, as well as providing start-up supervision and site support.

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

Documentation available on request:

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

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