THE FUTURE OF ROCK BOLTING

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evaluates new opportunities in rock bolting based on pumpable resin and hollow bar.

The technical development of rock reinforcement constantly pursues increased operational safety and improved productivity to achieve a sustainable, economic excavation cycle. This article presents rock bolting solutions for challenging rock conditions based on a combination of innovative bonding resins and mining hollow bar rock bolts that

Table 1. Post-grouting offers a higher degree of safety at increased operational efficiency. These positive results can justify a moderate increase in material costs per unit.

Feature	Pre-grouting		Post-grouting	
	Cement	Resin capsules	Cement	Pumpable resin
Adequate quantity of grout in the hole	Questionable in broken rock		Good in all conditions	
Full encapsulation	Questionable		Good	
Immediate rock support	No	Yes	No	Yes
Mechanised cycle time	Good	Good	Poor	Excellent
Long term efficiency	Poor	Acceptable	Acceptable	Good

Figure 1. Post-injected resin gives clear evidence that rock bolt is fully encapsulated, and the two components (A + B) are perfectly mixed.

Figure 2. Test of mineral bolt.

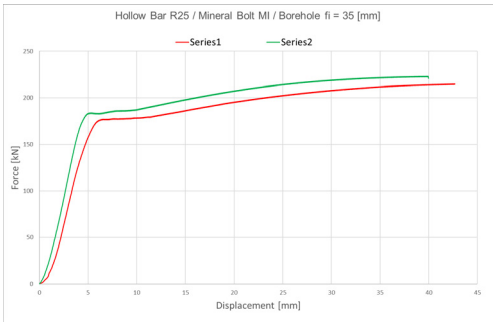

Figure 3. Load/displacement curve for mineral bolt.

can be installed by a new generation of highly mechanised bolting rigs.

System description

The traditional grouted rock bolt sequence fills the drilled hole with cement-based material or resin capsules before a solid bar rock bolt (pre-grout) is installed. Hollow bars and self-drilling anchors facilitate the injection of bonding grout after installation (post-grouting), with bonding materials flowing from the bottom to the surface.

Such a system allows the pumping adjusted volume of bonding material, compensating for geometrical irregularities of the drilled hole and filling voids created by cracks and joints in the rock. As soon as the bonding medium is visible, the hole is filled, and the rock bolt is embedded.

Post-grouted hollow bar/self-drilling anchors have been used in tunneling and geotechnical applications for decades, though always in combination with cement-based bonding materials. However, the manual solution was not particularly appealing for mining. It was only with the introduction of reliable and affordable thixotropic organo-silicate resins that it piqued the interest of innovators and major drill rig manufacturers began exploring how to mechanise this system. The organo-silicate resin is characterised by low viscosity to achieve high flow rates with relatively small pumps, making injection time fast and reliable. Gel and curing time are short and fully compatible with reducing the overall installation cycles. Unlike conventional rebar bolt and resin capsules, the self-drilling anchor installation sequence is simple: drill and inject. But even the hollow bar sequence is straightforward: drill, insert the bolt, inject – and nut tightening is not strictly required either.

Thixotropic properties of the organo-silicate resin – mineral bolt

Thixotropic liquids show lower viscosity until shear forces are present in their flowing, though they rapidly increase viscosity in static conditions.

After mixing the two components, mineral bolt becomes a highly thixotropic liquid with pseudoplastic behavior, reaching high viscosity almost immediately after stopping its flow. During the flow, the resin fills nearby voids and cracks. Once the pump stops, however, it turns into a toothpaste-like texture, minimising spillage.

Local mining conditions, bolt geometry, resin flow, and installation procedures require an adequately balanced thixotropic effect (from strong to weak). Therefore, cooperation between all process stakeholders in the project's initial phase is essential to arrive at an efficient, customised solution.

Table 2. Typical hollow bar diameter for mining – the load-bearing capacity, displacement requirements, and energy absorption depend on rock type, depth, and stress field.

	Inner/outer diamter	Loading capacity class	Elongation	Drill bit	Self-drilling anchors option
	[mm]	[kN]	A_5%	[mm]	
R18-140	18-9	140	6 – 8%	31	Soft rock
R22-180	22-11	180	6 – 8%	33	Soft rock
R25-200	25-12	200	8 – 10%	33 – 35	Soft, medium
R25-200 (DU)	22-12	200	15 – 18%		
R28-220	28-17	220	8 – 10%	35 – 38	Soft, medium, hard
R28-220 (DY)	27-17	220	15 – 18%		
R28-220 Dynamic Bolt					
R32-250	32-20	250	16 – 20%	38 – 45	
R32-280	32-18	280	14 – 20%		

Figure 4. The bonding capacity of mineral bolt resin allows full utilisation of steel ductility.

Figure 5. Sandvik DS412i-R is equipped with a double bolting turret and complete injectable resin systems, ready for hollow bar/self-drilling anchors.

Bonding strength, setting time, and installation cycle performance

Silicate resins develop bonding strength much faster than the usual cement grouts. Initial strength develops within minutes, and maximum mechanical strength is achieved in hours. The load/displacement curve shows excellent bond strength after five minutes, exceeding the strength of steel. The shape of the curve reflects the bolt's steel properties, with no sign of failure or slippage in the bonding resin.

Many lab tests have shown mineral bolt performance to be much less sensitive to the bolt-to-borehole-diameter ratio and water presence, eliminating an existing problem when using resin capsules.

Self-drilling anchors and hollow bar bolts feature 'R'-type threads (rope cross-section), which fit tunneling organo-mineral resins and develop a strong bonding effect.

Short encapsulation tests conducted in a lab and under actual mine conditions have shown that maximum tensile strength in the steel cross-section can be achieved at a bonded length of 30 – 50 cm, depending on the hollow bar type.

'Setting time', referring to the minimum time needed to retain the bolt in the hole, is easily controlled by adjusting the formula. For manual installation or long bolts, miners prefer a longer setting time measured in minutes. In contrast, it is essential to speed up the installation cycle for high-performance, fully mechanised bolting systems, so the mineral bolt has an adjustment time of just a few seconds. A modern bolting system equipped with a fast rock drill, a pumping time of 10 – 15 seconds, and a set time of 20 – 30 seconds, can install a 2.4 m bolt in less than four minutes (approximately 10 – 15 bolts per hour/rock drill installed).

Typical hollow bar diameter for mining

The load-bearing capacity, displacement requirements, and energy absorption depend on rock type, depth, and stress field. Typical parameters are listed in Table 2.

Performance of ductile R25-12 hollow bar bolt embedded in mineral bolt resin

The Norwegian University of Technology in Trondheim uses a proven method to

test the combined tensile and shear strength at a joint or concrete block and simulate joint displacement.

Comparing this system (hollow bar and mineral bolt) with more common solutions – in this case, a 20 mm bolt and polyester capsules – the results confirm the compatibility between the two systems, as shown in Table 3.

Table 3. Summary of the test results. The values presented are the average of two tests, except those marked with a ' * '.

Bolt type Resin type	Tests	Yield load [kN]	Ultimate load [kN]	Ultimate displacement [mm]
Hollow bar	Tensile test (0°)	163.9	231	35.4
2-component silicate resin	Shear test (90°)	57.2	214.9	43.5
	Combined (45°)	161.3	233	42.4
Rebar B500	Tensile test (0°)	173	205.1*	44.6*
FASLOC resin capsules	Shear test (90°)	70	184.6	34.9*
	Combined (45°)	127.1	204.8	32.7

*Results based on one test

Dynamic R28 bolt and organo-silicate resin

The risk of rock bursts and the presence of micro-seismicity have brought several mines to consider the utilisation of rock bolts that can absorb a sudden release of energy. DSI's research and development activities focus on combining rock bolts and chemical bonding resins. The design is a dynamic R28 with two bonded sections and a de-bonded area in the middle. Furthermore, the bolt features different ductility from the other parts. This design demands a rigid bonding material able to withstand the high-peak loads created during a rock burst. Extensive testing in dynamic drop tester has proven that this combination can absorb large deformations (up to 200 mm in a 2.4 m hollow bar bolt) and withstand a busy load of 34 kJ.

Conclusion

Injectable organo-silicate resins, associated with hollow bars and self-drilling anchors, represent the next generation with:

- Much faster installation cycles.
- Easier installation procedure.
- Higher cycle repeatability.
- Better bolt encapsulation.
- Safer and more constant rock support.
- Better corrosion resistance.

New fully mechanised bolting rigs capable of capitalising hollow bar/self-drilling anchors and injectable resin have been available for a few years. They feature resin tanks for the two components, pumps, flow and pressure meters, static mixer cleaning systems, and fully computerised control systems. The results are promising, and some major mining companies are currently testing this new system. GMR