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HIGHER PERFORMANCE IN ROCK-BOLTING TECHNOLOGY BY USE OF IMMEDIATE-BEARING GROUTED BOLTS

Abstract

Efficient support technology and in particular rock-bolting systems are increasingly important under ever more difficult working conditions. Recognised worldwide as an efficient, innovative and highly automated mining company, RAG relies on high-quality, economical support concepts for one of the most demanding coal deposits in the world. Two new methods for setting immediate-bearing bolts with the use of a highly reactive bolt resin and prospects of replacement of wire mesh by a spray-on system in roadway supports are described in this contribution.

Minova CarboTech GmbH, Essen has been developing and manufacturing products for rock control in the mining industry and tunnel construction for almost 40 years at various locations in Europe and the CIS.

In addition to grouting systems and the associated processing technology such as grouting equipment and grouted bolts, packers and the like the products also include cavity backfilling systems, support bolts, resin cartridges and special mining mortars and cements.

The economical extraction of raw materials is highly important in particular in the current financial and economic crisis. This requires increasingly more effective aids for efficient and safe establishment of mine layouts. In particular the drivage and support of roadways must be carried out on schedule and economically with simultaneous high quality. The methods and supports used for this purpose must be efficient and ensure or improve safety.

With increasingly difficult working conditions at greater depths, high rock pressure and extensive working of the deposit rock control is becoming the important question in practice. High-quality support sections are combined with modern rock-bolting technology.

Two different bolt support systems are currently used by RAG Deutsche Steinkohle AG (RAG), Herne. Both systems are characterised by the immediate-bearing property of the bolts. An immediate-bearing bolt must already be able to absorb high forces in the rock a few minutes after introduction into the borehole. The most diverse types of polyester resin cartridges – adapted to the special operating conditions in each case – have been successfully used worldwide for this purpose for several decades. A distinction is made between rod-type bolts in conjunction with polyester resin cartridges introduced separately into the borehole and self-drilling bolts with cutting edge and integrated polyester resin cartridge.

The cartridge method is characterised by the fact that it can be easily adapted to different bolt types borehole lengths and diameters. Full embedding in resin taking into account the fissure volume can be achieved by selection of the suitable cartridges both with regard to setting times and the resin volume to be introduced. This method has its limits in the case of collapsing or unstable boreholes and/or rock, in which the fissure volume along the borehole is so large that even stemming of the borehole as far as the mouth is inadequate for full embedding of the bolt in resin.

In the case of self-drilling bolts with integrated polyester resin cartridge the drilling and setting process is performed in one step. It can be used in the case of rock compressive strengths up to 60 MPa and in particular in unstable boreholes. Rapid adaptation to changing fissure volumes and rotary percussive drilling are currently not possible.

The disadvantages and system-induced restrictions of these two methods should be eliminated by new methods. The new One- and Two-Step methods developed by Minova in collaboration with Friedr. Ischebeck GmbH, Ennepetal offer an opportunity to increase the drivage rate. The individual components and both methods are described below.

Bolt resin

An important component of these two methods is a reactive bolt resin, which ensures an immediate-bearing effect of the resin-embedded bolt. A quickly reacting two-component resin was unavailable until development of this resin by Minova. In addition to the properties such as high reactivity, high reaction rate and the insensitivity to water or moisture the resin must exhibit thixotropic behaviour. This allows boreholes drilled at an angle of 100 gon to be filled

with resin without the material dripping out. In addition the resin can be transported in reusable containers and processed via the well-proven pumping technology of Minova. A high quality standard and a clear improvement in safety are additional features of this new resin. The efficiency of this resin is proved by bolt tensile tests conducted by DMT GmbH & Co. KG, Essen (Table 1).

Grouted bolts of the type Wiborex T 30/11 of Friedr. Ischebeck GmbH were used in these tensile tests. With a bonded length of 2000 mm the bolt can already be stressed after 45 s to the breaking load of almost 400 kN.

A resin, which can bond a bolt in the rock quicker than a polyester resin cartridge, has thus been successfully developed to a stage where it can be used in practice for the first time.

Table 1. Tensile tests with Geothix, mixing ratio 1:2

Tested length [mm]	bonded	Setting time	Max tensile force [kN]	Tensile distance [mm]	Cause of failure
600		60 min	385	25	Bolt fails due to fracture in the fissure
600		240 min	338	21	Bolt fails due to fracture in the fissure
600		240 min	335	19	Bolt fails due to fracture in the fissure
600		28 d	393	19	Bolt fails due to fracture in the fissure
2000		45 s	391	35	Bolt fails due to fracture on bolt head
2000		1 min	354	41	Bolt nut sheared off
2000		2 min	387	46	Bolt fails due to fracture on bolt head

Bolt

In addition to this special liquid resin a further component of both methods is a grouted bolt with an integrated mixing element. Fig. 1 shows the Two-Step-Bolt (TSB) of type T30/11 TS made from steel. As the construction of the bolt with integrated mixer differs only internally from the standard bolt, all standard system components such as spherical collar nuts can be used. Basically both hollow glass fibre-reinforced and steel bolts can be used in the One- and Two-Step methods. Correct selection of the mixer type adapted to the grouting material is important. Fixed at the borehole mouth end of the bolt, it ensures adequate introduction of the necessary mixing energy and prevents dripping of the resin after removal of the grouting head.

Fig. 1 TSB with integrated mixer,
Wiborex T30/11TS



Fig. 2 Drilling and grouting adapter on drilling feed unit



One-Step method

In the One-Step method the operations

- drilling,
- introduction of bolt and
- grouting

are combined in one step. It is thus ideally suitable for use in friable rock with collapsing boreholes. Equipped with bolt plate and nut the bolt can be introduced by rotary percussion or rotation. For this purpose the hammer drill is equipped with the drilling and grouting adapter, through which the water of the drilling mud initially flows during the drilling process (Fig. 2). After completion of drilling the two components of the bolt resin are fed through the adapter to the bolt. After the two components have flowed through the mixer the resulting bolt resin forces the water out of the bolt and the surrounding annular gap and bonds the bolt in the borehole. As a result of its thickening behaviour the bolt resin flows only as long as the two components are still conveyed. Dripping of the resin from the borehole is thus avoided. The bolt set in this way can absorb its full load capacity immediately after release of the drilling and grouting adapter.

Two-Step method

In the Two-Step method the individual operations are performed separately from each other in contrast to the One-Step method. The drilling technology can thus be optimised to the operating conditions in order to drill the boreholes quickly and economically.

After the borehole has been drilled the bolt is introduced into the borehole and the grouting carried out in the next step. This can be performed manually or mechanically. In the case of manual setting a grouting adapter is screwed on to the bolt after the bolt is in the borehole. The two components of the grouting medium are subsequently conveyed separately into the bolt, mixed there and the bolt set.

A special Two-Step Bolt feed unit (TSB feed unit), which is currently being developed in collaboration with GTA Maschinensysteme GmbH, Hamminkeln, is used for the mechanical

Two-Step method. In Fig. 3 the TSB feed unit is shown with a drill rod, but without a bolt. This feed unit offers the possibility of combining the well-proven efficient drilling technology with the automated bolt setting with the aid of the hydraulic grouting adapter. It consists essentially of two slides movable independently of each other, which are mounted on a common feed unit. The feed unit is designed in such a way that after drilling of the borehole it brings the bolt to be set into the same position previously occupied by the drill rod in order to set the bolt.

The TSB feed unit is movable in all three axes like conventional feed units and can be equipped with the usual hammer drills. The other drilling equipment such as drill rod and bit does not differ from the normally used materials. This offers the advantage that special materials are not required and the already existing efficient drilling technology in the mines can be used. The Wiborex T30/11 TS, for example, can be used as grouted bolt to be set with the TSB feed unit. The properties of this well-proven bolt, which offers a good close fit with the grouting medium as a result of its external trapezoidal thread, do not differ from those of the standard bolt T 30/11.

The entire drilling and bolt setting process takes place as follows: the TSB feed unit is brought into the operating position and fixed on the rock with the aid of the setting mandrel. After the borehole has been drilled and the hammer drill with the drill rod returned to its initial position, the bolt is brought into position. For this purpose the TSB feed unit swivels the drilling slide hydraulically out of the drilling position and at the same time the setting slide into the operating position. The setting slide with the grouting adapter (Fig. 4) and inserted bolt is brought accurately by the kinematics of the feed unit into the axis previously occupied by the drill rod. While the bolt is hydraulically fixed in the grouting adapter the setting slide advances and pushes the bolt with the attached hemispherical plate and spherical collar nut into the borehole. The contact force of the slide is sufficient to force lagging mats with the bolt against the rock if necessary. The grouting medium is subsequently conveyed through the bolt with the aid of the grouting adapter. As soon as the annular gap is filled and the bolt fully embedded in resin, the grouting adapter is released after a short holding time and the setting slide returns to its initial position. The bolt set with Geothix (mixing ratio 1:2) can be subject to its full load immediately after the grouting adapter is released.

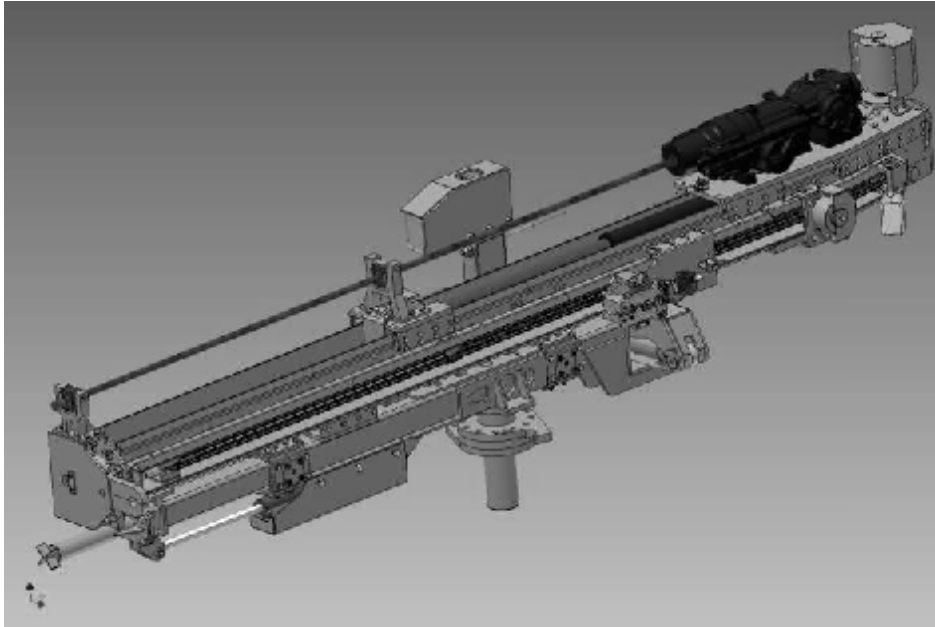


Fig. 3. TSB feed unit with drill rod and grouting adapter

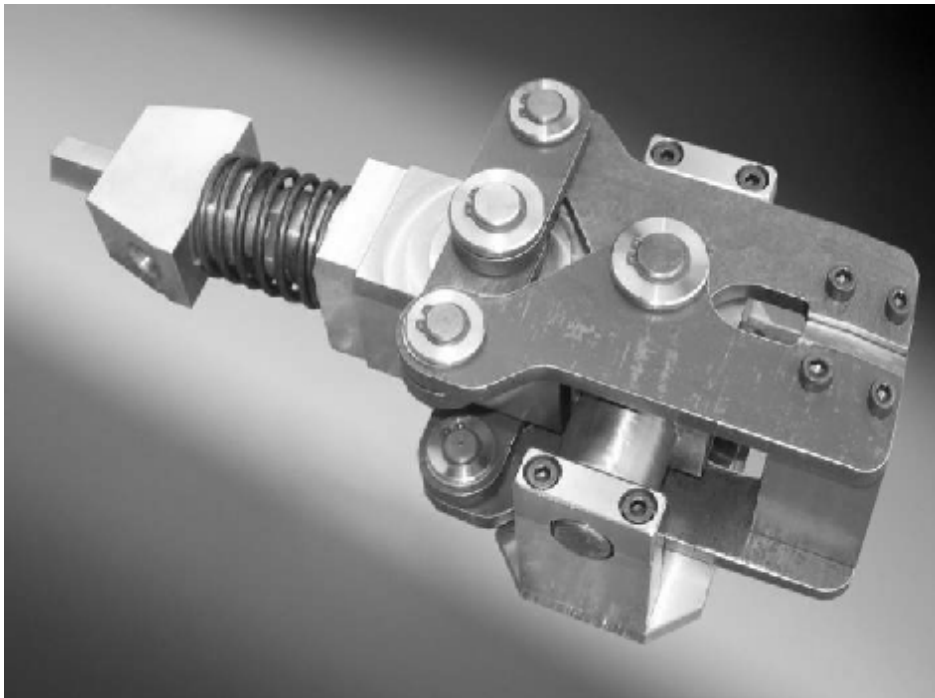


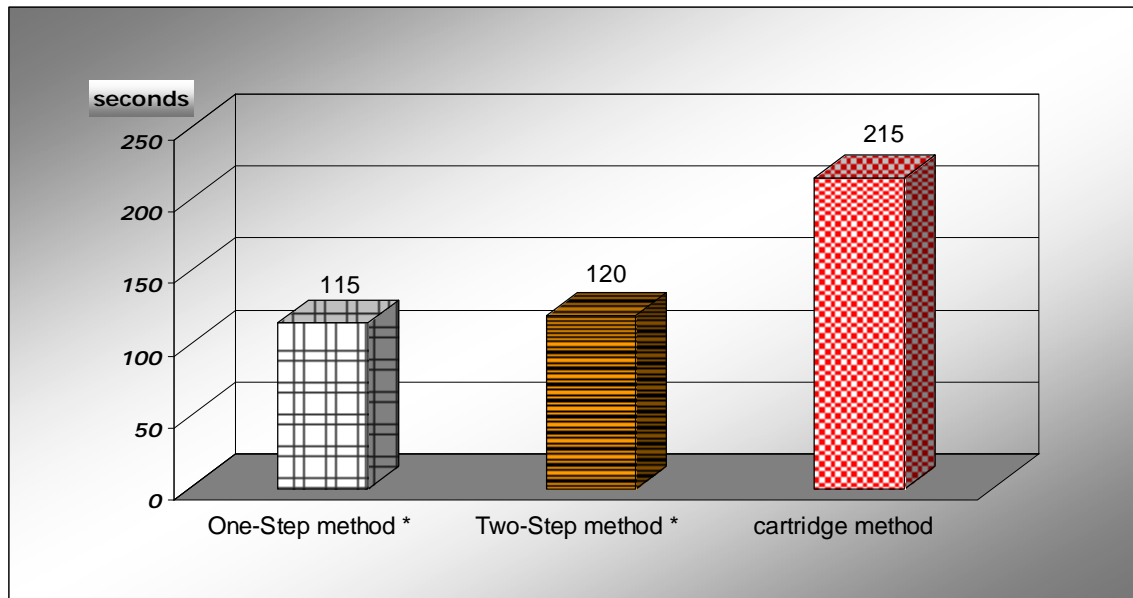
Fig. 4. Grouting adapter

Efficiency

In Fig. 5 the aims of the development with regard to the bolt setting times are compared with the results obtained for the One- or Two-Step method from experience acquired in initial field

tests. The time advantages of the One- and Two-Step method over the conventional cartridge method can be seen.

The efficiency of roadway drivage can be clearly increased by this time advantage in the following way: with use of a single-arm drilling jumbo, a bolt density of 20 bolts/m, for example, and 10 m drivage a 100 s time advantage produces a time saving of more than 300 min, which is available for the increase in efficiency of the drivage.



Basis: drill hole Ø 32 mm, 2,4 m; GEWI bolt 25 mm, 2,5 m

Fig. 5. Comparison of bolt setting times

Grouting technology

The grouting equipment used for conveyance of the two components of the grouting medium is based on the well-proven standard equipment used by RAG.

Both pneumatic units with piston technology (Fig. 6) and electric long-distance feed pumps with radial piston technology (Fig. 7) can be used. Distances of several hundred metres to several kilometres between the pump station and the site of use can be realised in this way. A common feature of all installations is the high metering accuracy with simple operation and maintenance. In conjunction with the re-usable containers likewise used successfully for many years a complete system, which also includes monitoring of operation from a central control room, is available.



Fig. 6. Pneumatic piston pump PHP

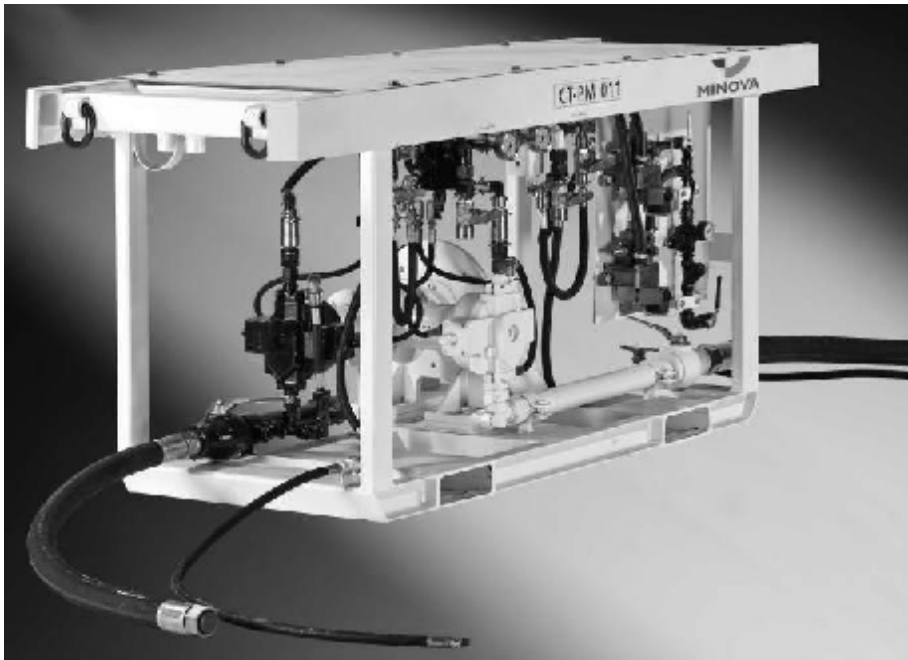


Fig. 7. Electric grouting equipment for long-distance conveyance

Prospects

If the bolt setting times can be reduced by the described One- and Two-Step methods, further potential exists for an increase in efficiency in road drivage when introducing the lagging. The lagging secures the area between the already set immediate-bearing bolts and stabilises the rock by counteracting further loosening. As an important safety element it already prevents rock and coal falls between the bolts before installation of the arch supports.

The lagging is introduced manually and is therefore time-consuming. The lagging mats are initially pre-hung – i.e. secured to the mats already introduced in the out by area – before they are brought into contact with the rock by the bolts.

The rock must first be loosened at the points, at which the mats do not rest against it, so that a supporting effect is ensured. Hence the lagging installed in this way acts passively and with a late-bearing effect.

These disadvantages should be avoided by a mechanically sprayable coating (“Thin spray-on liner” (TSL). Hence for several years a plastic/cement mixture (Tekflex) of Minova has been used as a TSL in the ore mining industry. Tekflex takes over tasks, which have previously been performed by a spray-on mortar in conjunction with lagging, e.g. protection of the rock against loosening, weathering and gas emission.

On the basis of this experience sprayable reactive resins on a different chemical basis, e.g. silicate resin, are currently being developed with the aim of replacing the currently used wire lagging of the bolt support. For this purpose calculations with conservative assumptions are undertaken to define mechanical requirements on a system of this type. The values for modulus of elasticity, tensile strength and permissible deformation in particular are important in this respect.

The combination of the bolt set by the One- and Two-Step method and a TSL thus makes a further contribution to an increase in safety and efficiency underground.