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RULES OF BOLTING WITH USE LOKSET RESIN CAPSULES

Abstract

The paper briefly presents offer of Minova Company with respect to application of resin capsules LOKSET, with specification of the manufacturing series, basic properties and some guidelines on application rules.

Introduction

Resin capsules are mostly offered as two-chamber packages of plastic foil or glass, with two mutually separated components, one per each chamber. Resin with admixture of fillers and modifying agents is usually used as one component that is capable to polymerize after mixing with a hardener, which fills the second chamber. Such capsules are used in the mining industry, civil engineering and construction of tunnels – whenever the need appears to fix anchors, bars, barriers, etc. in appropriately hard rock.

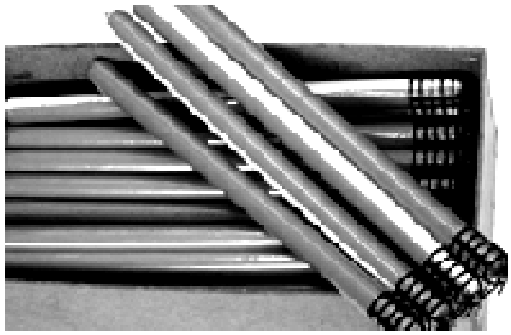

Fig.1 *View of LOKSET resin capsules*

Resin capsules LOKSET® represent the famous product of the Minova International, which is a part of Orica group. They are manufactured at the amount of more than 50 millions of resin capsules in production plants located worldwide: in Europe, the USA, South Africa, Australia, Russia and India. In Poland the resin capsules LOKSET are manufactured by the companies Minova Ekochem in Siemianowice Śląskie and Minova Ksante in Polkowice. Scope of customers that purchase capsules manufactured by Minova Ekochem include mines of hard coal, zinc and lead in Poland as well as mines of hard coal, metal ores, salt and tunneling companies in other European countries, such as UK, Ireland, Spain, Norway, Ukraine and Czech Republic. The Minova Ksante delivers its production chiefly to copper mines of the Polish copper company KGHM. Beside Polish enterprise, resin capsules LOKSET are also manufactured and marketed in Europe by Minova CarboTech from Essen (Germany).

Production line

Minova Ekochem offers a very wide production series of polyester-based resin capsules. The products vary in dimensions (diameter, length) and components that define their basic properties, as setting (gel) time, viscosity and mechanical parameters. The resin capsules are marked in the following manner:

Full name of the resin capsule: ***LOKSET SxL T-G***

S - diameter [mm]: it ranges from 14 to 40 mm.

L - length [mm]. may vary from 100 – 2000 mm.

T – chemical formula that determines chiefly viscosity and capability of material penetration. Here three types of capsules are distinguished: of high viscosity, marked as ST, of medium viscosity, with letter code ST1, HS1, HSF1, CP, AV, AV1, as well as of low viscosity: such as HS, SHS, AV2.

G stands for laboratory-measured, rated gel time at 20°C expressed in seconds. The Minova Ekochem manufactures resin capsules LOKSET with the gel time values from 10 to 600 [sec]. As a departure, for capsules that comply British Standard (type HS) the names are specified that denote gel time at 27°C: Fast (13-18 sec.), Medium (40-55 sec.), Slow (70-200 sec.), Ultra Slow (350 – 500 sec.).

For instance, the symbol LOKSET 24x600 ST-180 stands for the capsule with its diameter of 24 mm (deviation ±0.5 mm), length of 600 mm (+10, -5 mm), with high viscosity, rated gel time 180 (± 20) seconds.

A separate class of resin capsules manufactured by Minova Ekochem is represented by the material marketed as LOKSET PUR. Due to its unique properties, such as extremely low viscosity and controllable depth of resin penetration, they are particularly useful to fix strings, cables or bar anchors to large depths (~5 – 6 m), especially if the full-length anchoring is required.

Standards and requirements

All types of LOKSET capsules meet relevant standards, applicable to the end-client and user. For instance, according to standards that are in force in Poland the resin capsule for anchoring in the mining industry should present compression strength not less than 10 MPa after 2 hours. It should also guarantee sufficient loading capacity of anchors that is the subject of a separate standard that describes requirements to anchors. The minimum value of loading capacity for anchors dedicated for roof bolting in Polish coal mines is 120 kN.

Requirements to the coal mining industry in United Kingdom are different (UK Coal) and specified by the British Standard BS 7861 “Strata reinforcement support system components used in coal mines. Part1: Specification for rockbolting”. This standard assumes very high laboratory values of mechanical parameters exhibited by the resin capsules and measured after 24 hours after having the components mixed together: compression strength not less than 80 MPa, creep at compression: max. 0.12% and modulus of elasticity - min 11 GPa.

These parameters are verified against relevant procedures included into the mentioned British Standard and confirmed by the certificate issued by Rock Mechanics Technology Ltd.

Minova examines punch shear strength of capsules also by its internal standard. For resin capsules of the type LOKSET HS that parameter is above 25 MPa.

Resin capsules of the type LOKSET HS meet also requirements British Standard, which is also confirmed by appropriate certificate. Therefore it is the most comprehensive product of the Company's offer that simultaneously meets all, or at least most of, local requirements. The next advantage is very low viscosity that facilitates or event sometimes makes it possible to apply them for less robust bolting equipment, including pneumatically driven handheld bolters.

Resin capsules LOKSET in practical use

Resin capsules LOKSET represent a technologically advanced product, so there is a large number of rules that must be obeyed to enable the capsules to fulfil its functions in the rock-bolting practice and to guarantee anchoring parameters assumed by the project. The most important parameter is the loading capacity of anchors that is verified by means of the Rock Anchor Pullout Test. Minova Ekochem carries out pullout tests in its own laboratory, mostly for granite blocks or for concrete slabs. These are examinations of the type ***short encapsulation test*** where bolts are fixed along a relatively short length, from 20 to 100 cm. The frequent practice includes also field tests where experiments are carried out under real conditions in underground excavations of mines.

Based on long-term investigations it is possible to state that a standard anchor, if properly installed into base rock with the strength >15 MPa, exhibits typical pullout resistance between 0.5 and 1 ton for each 1 cm of bonding. For instance, if a bar with its diameter of 22 mm and loading capacity of about 20 tons is bolted into granite to the depth of 30 cm, the pullout test demonstrates that strength of the bolting connection is usually higher than the strength of the anchor itself. In practice, bearing capacity of anchors not only depends on these parameters of capsule that can be checked by laboratory tests but also on a great number of other factors, including but not limited to he ones described below.

<u>Type and strength of base rock</u>

Dependence of bolting strength on the strength of base rock is obvious and very strong, which is conformed by long-term experience of Minova company as well as a number of investigations performed by third-party organizations. Nevertheless appropriate homogeneity of rock within the bolted area is also a matter of key importance. It is why construction of a sole bolted roof support is only possible for the base rock that meets defined criteria. Pursuant to Polish regulations these criteria include: the weighted average for compression strength of a rock package with its thickness of 3 m must be not less than 15 MPa for rocks with plated

structure and 10 MPa for rocks with solid structure; the rock mass must be dry and must have sufficiently high coefficient of soaking (min. 0.8); the measured fissure rate (Rock Quality Designation – RQD) must be at least 20% for rocks with plated structure and min. 40% for rocks with solid structure.

According to our knowledge the loading capacity of rock bolting can be approximately defined as a function of the base rock type by means of the diagram (Fig. 2).

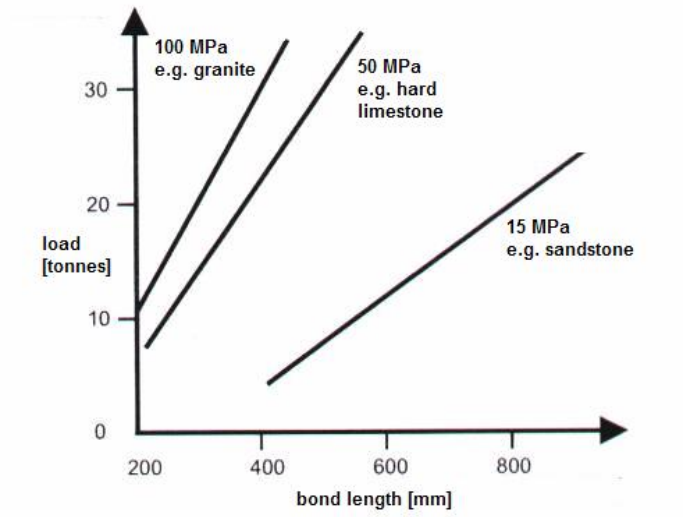

Fig. 2 *Strength of rock bolting as a function of bond length for various types of base rock.*

Other important features of the base rock that must be taken into account for rock bolting include water content as well as presence of contaminations (coal dust, drillings).

Presence of water in the borehole where the anchor is to be installed may pose a real problem under some specific circumstances. One of the hazards is soaking and expansion of rock that results in dramatic weakening of the base rock – it frequently happens for some types of schist. In such a case rock bolting should not be carried out by means of the standard method or, if the rock mass is sufficiently dry, boreholes should be drilled without flushing with water. Other problems occur during bolting floors with high content of water, which leads to elongation of the setting time and substantial deterioration of mechanical parameters of the bonding. Under other circumstances presence of small amounts of water should not lead to significant decrease of bolting performance. It means that application of water flushing for normal, non-soaking base rock has only insignificant effect onto loading capacity of anchors. Contamination of boreholes with drillings, coal dust or other debris may substantially deteriorate strength of anchoring, thus the rule should be observed that beside aforementioned circumstances presence of small amounts of water in boreholes is a less harm than presence of contaminations.

Effectiveness of component mixing

As assumed mechanical parameters of the resulting bond are determined by results of the chemical reaction between components of the capsule, thorough mixing of the capsule components (in terms of both quantity and quality) becomes an issue of key importance. Effectiveness of the chemical reaction process may be the implied by duration of mixing as well as

power and rotation speed of the bolting machine or the difference between the anchor and the borehole diameters, or type of the applied anchor. In practice, the most frequent reason for ineffective bolting lies in disobeying the following rules.

Duration of the mixing process depends on the length of the bolting borehole. The rule should be observed that the anchor should start rotating in the borehole immediately when the anchor bar comes into contact with the capsule and carry on rotating until it reaches the borehole bottom with additional 5 – 10 seconds afterwards. Rotation speed of the bolting machine should be not less than 200 rpm, preferably it should be 400 rpm or more. If the setting time of the capsule allows, lower rotation speed can be compensated by prolonged mixing process. According to Minova USA recommendations, sufficient mixing effect of the LOKSET capsule components is reached when at least 35 revolutions of the anchor is performed altogether.

The frequent error consists in bolting with too large difference between diameters of the anchor and the borehole. Polish mining regulations impose that the maximum difference between borehole and anchor diameters should never be higher than 12 mm. Based on own experiences Minova Ekochem recommends application of the 8 mm difference for boreholes with diameters below 32 mm and 12 mm for large boreholes. In British coal mines, where roof bolting is commonly used as a primary roof support method, standard boreholes are drilled with the diameter of 28 mm for anchors of 22 mm in diameter. Failure to observe these rules may lead, in extreme cases, to the lack of amalgamation between the base and the hardener. The practice shows that too large difference between borehole and anchor diameters may be the result of insufficient expertise or a compromise enforced by e.g. too low power of the bolting machine. Usually, to achieve the desired effect it is enough to use a smaller crown for drilling and /or a bar with a bigger diameter. However, in many cases amendments to the bolting technology or application of different equipment (e.g. hydraulically driven instead of pneumatic actuation) should be taken into account. Anyway, everyone who uses the rock bolting technology should be at least aware of possible problems and related hazards.

Other factors that can be essential for optimum amalgamation of capsule components include surface of the installed anchor (it should never be smooth or plain), its tip (must be sharp-pointed), possible presence of additional parts (e.g. a spring wrapped around the anchor). However, if all the foregoing basic rules related to anchor rotation and appropriate difference between anchor and borehole diameters, even application of standard anchors should lead to satisfying results.

Selection of the capsule type

When the rock-bolted roof support or auxiliary anchoring is being designed it is necessary to pay attention to selection of resin capsules that are to be applied, with regard to their dimensions, setting time or viscosity.

If the design requires achieving the full-length bonding between anchors and the base rock, theoretical dimensions of capsules should be adjusted in such a way that the capsule volume (or total volume of all the capsules to be used) is slightly higher than the difference between volumes of a borehole and an anchor. It should be kept in mind, that in case of real applications rock mass can be cracked and the fissures in various manner may lead to the need to use higher volumes of the capsule that is results from theoretical calculations.

Selection of the setting time should be guided by type of the bolting machine, contact length of the anchor and operation time, from starting of rotation until tightening the nut. It should be kept in mind that the sealant bonding must remain untouched until it is strong enough to tighten the nut. That time is estimated as 30 – 40 seconds (after expiring of the setting time) for 30-second capsules and 90 – 120 seconds for 3-minute ones. Therefore it is convenient to place fast-setting capsule to the bottoms of boreholes as that makes it possible to quickly tighten the nut and pre-stress the anchor with no risk of damages to the bonding.

One should remember that the gel time significantly depends on temperature of the capsule, base rock and the anchor itself. Such a dependence is exhibited in Fig. 3.

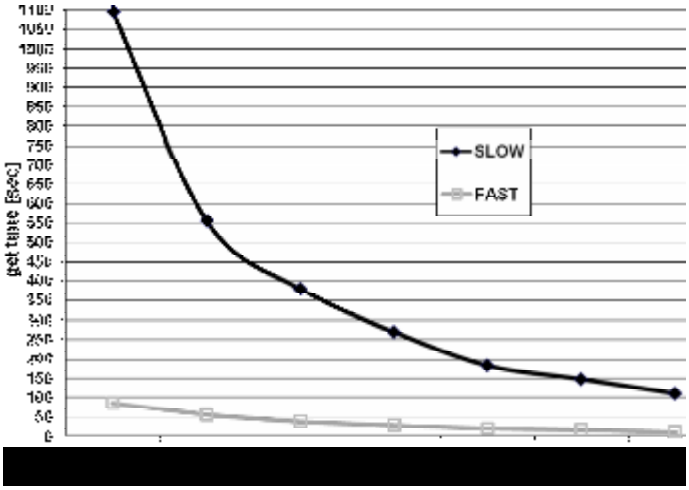

Fig. 3. *Gel time as a function of temperature – LOKSET HS*

Prior to commence a project consisting in installation of anchors it is necessary to carry out field (on site) tests in order to verify the previous calculations and to check actual length of anchoring under specific conditions as well as to evaluate actual time of curing before the nut can be tightened.

Such experiments are also helpful for adjustment of other details related to the rock bolting technology, e.g. type and power of a bolting machine. In case of any doubts employees from Minova are always ready to support with consultations with regard to optimum selection of capsule type, parameters of capsules and guidelines for application.