DEVELOPMENT OF GROUTING TECHNIQUES

ABSTRACT
The development of grouting techniques at RAG is presented here. The focus lies on the process technology of the two-component synthetic resins and their development. Using the example of the stabilising grouting at the T-junction of longwall and roadway, one variant of the operational applications of synthetic resins is shown. Following the chronological review the current state of grouting technology at RAG and future development steps are shown.

INTRODUCTION
During the last two decades the application range at RAG for rock grouting injection has continuously increased. This development can be explained by the higher rock-mechanical loading of the mine workings, caused by the continuous increase in depths and the expanding mine structures of the German deposit (Figure 1). Furthermore, the concentration on just a few high performance extraction operations at RAG - with the requirement for a trouble-free retreat readiness or a lower support time at the longwall/roadway transitions - has redefined the requirements for grouting technology [1]. The objective of the stabilising work at the longwall/roadway T-junction is to sustainably reduce or prevent any sloughing at the open roadway support by grouting just ahead of the longwall passage. The following descriptions will present this application case, the so-called stabilising grouting in the extraction phase.
The operating point concentration of the extraction operations at RAG led to an increase in the necessary drive power of the longwall conveyors. The increase in the geometric dimensions that this involves also requires larger openings at the longwall / roadway transition. This development and the high rock-mechanical loading frequently lead to an overloading of the direct roadway shell. This again increases the hazard potential for possible rock and coal sloughing. The present roadway support system of RAG, the so-called combination support, also ensures in such cases the stability of the mine excavation, that is, a failure of the roadway support will be prevented in each operational phase. Nevertheless it is not always possible to avoid loosening at the direct roadway shell. A preventative rock stabilisation with chemical grouting media has been proven to stabilise this rock loosening in the direct proximity of the longwall.

**Review of grouting technology with synthetic resins**

Since the 1970s foaming polyurethane resins are used for the stabilisation of coal and rock in German deep coal mining.

The initial standard resin system on a polyurethane basis for the stabilising grouting at the longwall / roadway transition was rapidly further developed, and a wide range of applications for the most different operational uses was produced. In the late 1980s and early 1990s the first organic resins or silicate resins were used. These resin types had the advantage not to foam, featured a high bonding strength, and their hydration temperature was far below that of
the polyurethanes. Their disadvantage, the so-called brittle behaviour, placed a question mark over their use for rock bonding at the longwall/roadway transition, because here the plastic and also elastic polyurethane clearly had its advantages.

In spite of the high requirements of the mine inspectorate with regard to the resin products a large innovation potential developed, which led to a large number of products.

This development climaxed in the late 1980s and/or early 1990s. According to the motto, "for each application a new product", a large variety of products was generated. Among these are for example:

- Resins with a high bonding capacity (rock)
- Resins with a high bonding capacity and water resistance
- Resins with high stabilisation capacity for coal
- Resins as cavity fillers etc.

The technical applications within these main groups were also very varied. Here, examples are: high foaming factor – low setting temperatures – high viscosity – strong penetration capacity - etc. In those days, RAG had 4 – 5 suppliers and the product range in their purchasing basket temporarily comprised up to 23 different variants (see in Figure 6 in the year 2000).

**Figure 6: Wide range of synthetic resin types**

A decision in favour of a particular product within the wide ranging offerings available became increasingly more difficult, as an objective technical comparison was missing. There
was a wide range of operational experience but they were based on different framework parameters.

For this reason, in co-operation with DMT, a data sheet was developed, which provides for a comparability of the products. With regard to the individual usability characteristics tests for grouting agents, the reader is referred here to Chapter 12 in the specialist book – Gebirgsbeherrschung von Flözstrecken (“Strata control of in-seam roadways”) – [1]. This data sheet defines some of the necessary technical characteristics such as e.g. the

- uniaxial compressive strength,
- foam factor,
- penetration rate,
- specific grouting capacity and
- bonding strength

**State of grouting technology in 2008 at RAG**

Today, the grouting systems are standardised; decentralised systems are used which, for instance, are installed in the energy train of a longwall or for special projects within the mine working. As a rule, however, the stabilising grouting of a longwall is effected with the standardised, modular, central injection system (Figure 13).

These plants consist of a radial piston pump with a receiver of up to 200 litres. Plants are supplied via pipelines or hose pipes. The delivery widths are greater than 4,000 metres with a delivery flow of 25 litres per minute and step. As a rule, the installation is effected at a central site so that an entire panel can be supplied from here.

Control and monitoring is effected by means of industrial PCs and a direct transfer of the data to a location above ground. Furthermore, it is possible to call up the running data from all computers of RAG via our own works’ Intranet.
Figure 13: Example of a standard system

The advantages of this system at a central panel location are:

- Logistically favourable delivery
- Supply of several working panels via a pump system
- Remote-controlled grouting
- The running time of the pump is logged and visualised
- Display of faults on the system
- Long stay in a working panel, no relocation of the plants.

The above-ground displays or flow diagrams of the grouting systems are shown in Figure 14.

This illustration permits a visual monitoring of the grouting process and the display of faults on the system. Furthermore a grouting protocol is prepared. The grouting protocols provide the basis for the various different coal seam horizons. The grouting quantities determined are correlated with a parallel endoscope examination and stored. This offers the option to make very exact grouting specifications in further headroom dimensions of the panel area. In addition, using a database currently being worked on, an agreement with other headroom dimensions is prepared.

Figure 14: Monitoring screen in the section stand above ground
In the case of grouting resins, the development is characterised by a stringent standardisation. While the number of products used in 2000 was still 23, this number has now been reduced to 5 products in 2008. Within the framework of the continuous improvement process, designated in brief as CIP, the employees of RAG work continuously on improvements in the operating sequences and technical applications; the success of this method is demonstrated by the following example. During inspections of grouting points in the longwalls it was found again and again that the necessary static mixers, installed downstream of the Y piece of a resin fitting (see Figure 5), were missing. This and other quality defects led to training measures for the employees responsible for resin work. Many faults were removed but forgetting to provide the static mixers occurred time and again. In 2007, in co-operation with Minova, RAG has devised a simple but most effective solution within the framework of a CIP.

Figure 15. Packer with integrated mixer

Within the scope of our quality assurance the necessity for a resin injection is examined by means of the above-mentioned borehole endoscope, and the success of the injection checked on completion of the same. Furthermore, the flow pressure of the running grouting injection as taken from the monitoring protocols of our grouting systems is entered in a check list. The requirement to work with a maximum injection flow pressure of approximately 30 bar – measured at the borehole mouth – must be continuously monitored as the employees persist to associate a higher flow pressure with a deeper grouting effect. The sustained checking and repeated training and sensitisation regarding the extreme forces generated by flow pressures > 30 bar in an already loosened rock, is an important task of quality assurance.

Summary – Outlook

Ladies and Gentlemen, we took only a short excursion into the development of grouting work at RAG. There are certainly still a large number of topics that would merit a report; the examinations regarding the grouting data sheet can be stated as just one example.

The development of the process technique, that is the use of networked pipeline operations for conveying the chemical grouting injection components shows clearly how important standardisation is. In our view, constantly changing the resin types in existing pipeline networks does not appear to be meaningful. Therefore, RAG has significantly reduced the
range of products in recent years and, in co-operation with suppliers, RAG developed products permitting universal use.

Processing today, with central pipeline supply in combination with the IPA control system, provides for an economical and technically reasonable control of the grouting work. Today, many years of investigation into the flow behaviour of chemical grouting media for optimising the pipeline operations over lengths of < 3,000 m are stored in IT-supported calculation programs. These tools allow an optimised design adapted to the individual operational case.

With the pressure-controlled and volume-controlled grouting available today, grouting injections carried out under the premise "mass instead of class" are a thing of the past. The geotechnical analyses in advance with the resulting knowledge about the actual size of the surface fracture structures and the cavities provide the basis for a volume-controlled and economical injection. Furthermore, the modern supply plants of RAG prevent that excessive flow pressures during grouting will crack the surrounding rock. Proceeding according to the motto "create fracture zones first, in order to stabilise them afterwards" is also a thing of the past.

The technical measurement control of the grouting injection success by endoscopies is a further component within the framework of an economical grouting measure.

In respect of all grouting work the proven principle still applies: "As much as necessary, but as little as possible".

**BIBLIOGRAPHY**