# Innovative materials and methods for ground support, consolidation and water sealing for the mining industry

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Journal Paper


## Synopsis

UGC International, now part of BASF the world's largest chemical company, has developed a new range of products to improve safety and reduce excavation time in tunnel and shaft development.

This paper will discuss the advantages of a cementitious TSL in temporary support as well as the full range of injection materials available for any ground or water problem. It will also address the flaws in present cementitious grouting procedures and provide new concepts for water control to owners and contractors.

As with fibre shotcrete, UGC now has the ability to provide a complete package of products, training and equipment for micro cements, colloidal silica, polyurethanes and acrylics. UGC also has a new range of fire resistant urea silicate resins for ground stabilization and void filling in mines. These products are specifically useful in coal mines due to their safety features. Superb technical performance combined with comprehensive theoretical and practical training can provide the mine with a quick, technically sound and cost-effective solution to ground consolidation problems.

This paper will be divided into two parts:

- TSL technology for ground support
- Injection techniques and products.


## Thin sprayed liners

As an emerging technology, the functions and properties of TSLs are still not well understood.

It is essential that the users of TSLs are provided with guidelines regarding mechanical properties, testing for TSLs as well as their limitations as a support method when used with bolts or on their own.

Users are cautioned on the use of TSLs as many suppliers create an expectation of their product's performance, which can be misleading.

UGC International in conjunction with Professor Pieter Kaiser of Mirarco have developed a document that can assist users of TSLs to make an advised choice on what support a TSL will provide.

### *Types and characteristics of TSL—Masterseal 845A*

There are many different types of TSLs on the market. They differ by mix type such as liquid/liquid or liquid/powder and by type of polymer-base.

TSLs are classified as reactive or non-reactive, depending on their film formation or curing mechanism.

Reactive TSLs cure rapidly by the immediate cross-linking of polymers after mixing.

Non-reactive TSLs that consist of cement/water/polymer systems cure by loss of water, which is therefore a relatively slow process.

The polymer-base grouping of TSLs is as follows:

- Acrylic
- Hybrid
- Liquid latex where latex is any known polymer (e.g. Masterseal 845A)
- Polyurethane
- Polyurea
- Methacrylate.

Reactive TSLs, even though the cure rapidly, are sensitive to water and therefore barely stick to wet surfaces. Because of the chemical compounds and reaction products, they also can often be applied with only stringent safety precautions.

On the other hand, non-reactive TSLs even though curing more slowly, adhere well to wet and dry surfaces and can be applied with normal safety precautions.

UGC International's Masterseal 845A is a non-reactive polymer developed to combine the advantages of reactive and non-reactive

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membranes in that it is relatively fast curing and can adhere to both wet and dry surfaces. Masterseal 845A cures by loss of water.

Three parameters that characterize the performance of a TSL are:

- Tensile strength
- Elongation
- Adhesion.

Typically tensile strengths of TSLs range between 2 and 20 MPa, elongation between 4 to over 200%, and adhesion between 0.4 and 2.0 MPa.

Masterseal 845A has a superior adhesion of 2 MPa after 7 days.

The mechanical properties of Masterseal 845A are time and thickness dependent as shown in the following table. Typical characteristics of Masterseal 845A as given in the UGC International Product Data Specification Sheet (2006) are:

| *Classification* | *Tensile strength* | *Adhesion* | *Elongation* |
|---|---|---|---|
| Latex (Polymer powder) | >1 MPa after 5 hours | 2 MPa after 7 days | >300% after 5 hours |
| | >1.5 MPa after 1 day | | >60% after 1 day |
| | >3.5 MPa after 6 weeks | | >20% after 6 weeks. |

The recommended thickness for Masterseal 845A is from 2 mm to 8 mm.

Good quality control and application procedures are essential to achieve these characteristics in a consistent manner in the field.

TSLs must be environmentally friendly to be accepted for underground applications and to ensure worker safety. Product inflammability and the impact of emitted fumes on ventilation requirements often dictate product acceptance.

Masterseal 845A is classified as a Class B interior wall and ceiling finish material. Thus, it can be applied underground with little risk to workers' health and safety.

### Mechanical properties of TSLs

TSLs technology is still emerging. Hence testing procedures for TSL products are still being developed and presently no recognized standard procedures exist for determining the mechanical properties of TSLs

The lack of agreed standard procedures for the testing of TSLs has resulted in the following difficulties:

- Various researchers and institutions are using different testing procedures to determine their mechanical properties, making it difficult to impossible to compare published properties.
- TSL products have different set times to achieve their optimal properties. The lack of standard testing procedures has led to testing at set cure time periods rather than at optimal product performance times. This approach favours properties of fast-curing products while underestimating the long-term properties of slower curing products.
- Some testing procedures do not reflect how TSLs will perform in service.
- Some properties (e.g. shear strength) of TSLs, even though important in assessing the surface strengthening abilities of TSLs when holding wedges, are still not available due to lack of proper testing procedures.

Because of these issues, the user is cautioned in the interpretation of models in which different product properties are used for comparison or for assessing applicability.

### Limitations of TSL models

The theory behind the functions of TSLs is still not well developed. In some countries failure modes for shotcrete as ground support have been adopted to explain the functions of TSLs. However, this is not completely relevant as TSLs are different materials with different functions and different ways of stabilizing rock.

TSLs provide area protection and excavation surface strengthening rather than structural support. They function best when acting in an integrated manner with the rock near the excavation wall, i.e., when they assist the rock to remain self-supporting.

Two models are currently being used to approximate the behavior of TSLs (Figure 1). These are the membrane model—(point loading for punch failure or distributed loading for retention of broken rock) and The beam model—in which the rock and TSL are considered as an integral part of the support system to enhance the rock's arching or interlocking capability.

- *Membrane model*—The membrane model presupposes that TSLs provide some structural support when in actual fact its primary function is to retain and strengthen the rock between bolts and to prevent fragments from detaching.
- *Beam model*—The beam model is more close to reality in explaining the interaction between the TSL and rock to provide a stabilizing effect (basis of the TSL technology). However, because the actual thickness of the rock beam may never be known the beam theory may be conservative whereas the actual rock beam thickness is underestimated and risky where it is overestimated.

An increasing rock beam thickness increases the load bearing capacity of the TSL-beam model. Thus the benefit of the beam model is limited to demonstrating the sensitivity of the beam capacity on the beam thickness.

As indicated above, another limitation of the models is that the input parameters are not determined from agreed standard test procedures. Thus, results of TSL models should be interpreted and used with caution.

### Primary functions of Masterseal 845A

Masterseal 845A was developed to replace mesh as an areal protection against the fall of relatively small rock fragments from both hanging-and side-walls.

TSLs cover this function in a different way from mesh by strengthening the rock surface and preventing the release of the rock fragments which, in the case of mesh protection, would only be caught by the mesh after the rock has moved

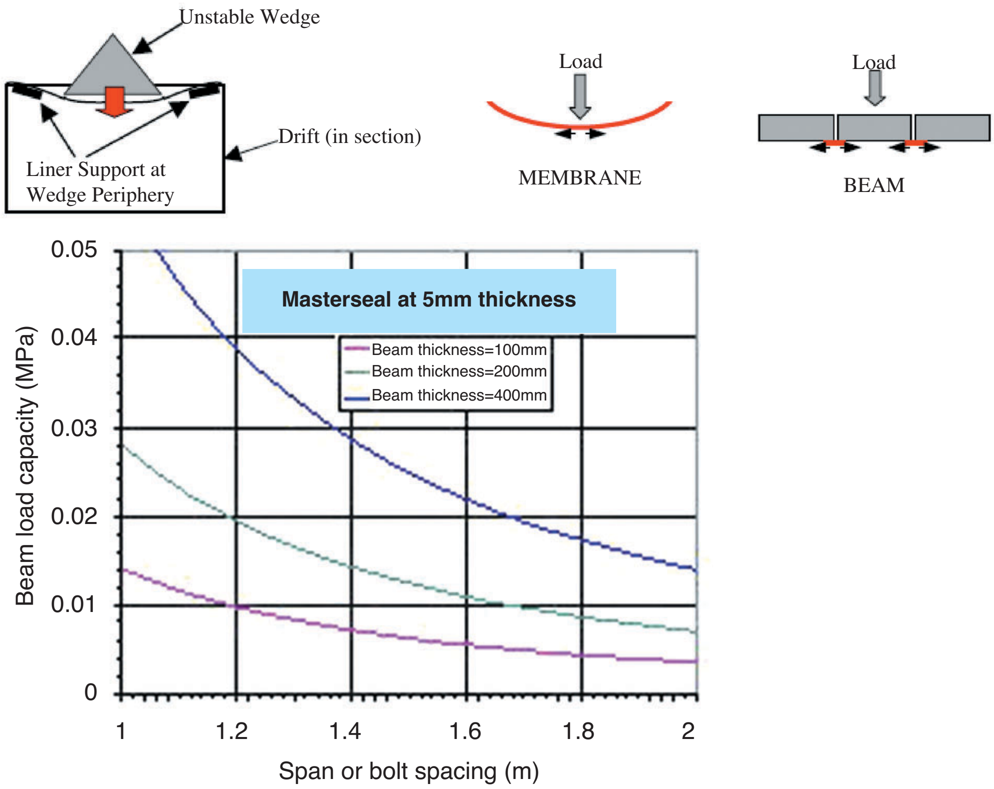


**Figure 1—Models illustrating functions of TSLs (Espley and Kaiser, 2002)**

Thus the advantage of Masterseal 845A is it is an 'active support' as opposed to mesh which is purely 'reactive'. In addition to holding rock in place, it also glues small blocks or wedges (between bolts) together and in this manner increases the effective block size. As a consequence of this rock quality-enhancing function, the rock wall behaves as if it were of better quality.

Masterseal 845A also enhances the stand-up time of fair to poor rock masses by improving the arching process through an increase of the effective block sizes.

The actual effect on stand-up time cannot be quantified accurately but field evidence shows that TSLs do slow down the fragmentation processes and improve 'hold-up' time.

### *Do's and don'ts when using TSLs*

As with most tools, TSLs function properly only when used in the right place, when properly installed, and when properly integrated into an overall support system.

#### *Do's*

Use TSLs alone:

- ➤ in rocks with good inter-grain bonding—rocks that are not friable
- ➤ in massive to moderately (non-persistent) jointed rock masses at low stress
- ➤ to retain (small) key blocks—hold small wedges or blocks in place when good adhesion can be ensured
- ➤ to retain spalled rock of hour-glassing pillars or walls when adhesion is ensured laterally or if a continuous closed membrane can be provided (ensure rounded corners and prevent punching effects)
- ➤ on highly stressed rock when small shards are being eject (spitting face, walls or backs)
- ➤ to slow environmental degradation processes (slaking, swelling in mudstones and clay shales)
- ➤ Always apply to clean rock surfaces to achieve optimal adhesion: carefully scale and if necessary wash before application. Hydro-scaling has the added advantage of removing loose rock and dirt that could cause membrane rebound. Controlled blasting practices will enhance the performance of TSLs.

Use TSLs together with pins or bolts as mesh replacement:

- ➤ in rocks with poor inter-grain bonding
- ➤ when large wedges are encountered that must be supported by bolts
- ➤ when relaxed ground is encountered where deep raveling is anticipated
- ➤ when surface parallel spalling occurs to shallow depth, particularly in backs
- ➤ in very mildly strain bursting conditions (with <<0.1m spalls) to enhance worker safety
- ➤ in mild to moderate strain bursting conditions (<0.3m deep spalling) together with mesh.

#### *Don'ts*

Besides obviously inappropriate applications where the load or deformation exceeds the liner capacity or where loads cannot be transferred by adhesion to rock or bolts, the following inappropriate uses can be identified.

Do not use TSLs:

- ➤ in areas where flowing water or other mechanisms prevents continuous application of the product
- ➤ without bolting to support large wedges in structurally controlled instability conditions, particularly when clamping stresses are low (<2 MPa)

- ➤ in high stress conditions where deep seated surface spalling is anticipated
- ➤ alone on friable rocks such as sulphide ores (there may be exceptions)
- ➤ alone on heavily blast damaged rock
- ➤ close to the face if blast gasses can penetrate behind the liner.

Also, do not use Masterseal 845A without test trials:

- ➤ on surfaces or in conditions where the curing/drying process is prevented or significantly slowed (e.g., on frozen surfaces).

### *Application of Masterseal 845A*

In general many of the same principles apply to Masterseal 845A as for Fibre reinforced shotcrete i.e.

- ➤ Surface roughness must be a smooth as possible, and as with shotcrete free from dust, oil and loose rocks
- ➤ The equipment is an upgraded Piccola Dry-Shotcrete machine which uses a 90 mm 12 hole rotor to deliver a low quantity of powder in a steady flow. A special dust collection system is also incorporated in the machine
- ➤ The spraying hose is 32 mm in diameter as is the nozzle which has an 18 hole water ring to ensure controlled and even water mixing with the powder.
- ➤ A dewatering device is supplied on the machine to remove excess moisture in the compressed air; this reduces material build up in the hoses and the nozzle. The minimum air pressure should be 7 bar at 7 $m^3$/minute.
- ➤ Water pressure should be a minimum of 6 bar or a water booster pump can/should be supplied.
- ➤ Application can be made up to 100 metres from the Piccola and it is possible to achieve in excess of 90 $m^2$/h application rates.

### *Advantages of Masterseal 845A*

- ➤ Simple and easy application.
- ➤ Polymer-based cementious sprayed powder
- ➤ High tensile strength
- ➤ Rapid strength gain providing early support
- ➤ 2.0 Mpa. @ 24 h. 4.0 Mpa. @ 6 weeks
- ➤ Good elasticity
- ➤ 300% @ 5 h; 20% @ 6 weeks
- ➤ Excellent bond to rock, coal and shotcrete
- ➤ 2.0 Mpa on concrete; coal fails first
- ➤ Does not deteriorate over time
- ➤ Non-flammable
- ➤ Fast application rate:- > 100 $m^2$/hr
- ➤ Non toxic and safe to use
- ➤ Very user friendly
- ➤ Simple equipment for application.

## Modern injection techniques and materials

Many of the materials and techniques discussed in this section are not relatively new or modern. However, it is the systematic and planned use of injection as a key part of the tunnel or shaft excavation process that is of paramount importance.

Injection in tunnels and caverns can be categorized as pre-injection and post-injection. Both are widely used around the world but the rational of the two approaches and their functions in tunneling are different.

### *Pre-injection*

Pre-injection is the systematic injection of grouting materials, usually cementitious, with pressure into the rock mass ahead of the tunnel excavation face. The rationale behind pre-injection is to treat zones of impermeability and instability ahead of the face from a zone of relative safety. The advantage of treating poor ground conditions ahead of the face is that rock mass conditions will be in a relative state of equilibrium, i.e. water pressures are balanced and poor rock is confined.

This will then allow the penetration of low-cost and simple cementitious materials and grouts to be injected into voids, flow paths and joints without washout. As a result, this will then prevent water inflows and modify the *in situ* rock mass conditions prior to excavation, hence lowering the risk of tunnel collapse and inundation.

In order for contractors to undertake pre-injection as a

Figure 2—Meyco Piccola for applying Masterseal 845

Figure 3—Hand application of Masterseal 845A

system, the designer must specify allowable water outflow from the excavation. This is usually specified in terms of litres/min/100 m. In sub-sea tunnels or tunnels with shaft access only, the typical limit can be from as little as 5 litres/min/100 m to 30 litres/min/100 m of tunnel.

Pre-injection relies on systematic probe hole drilling in front of the excavation face to check for water inflows and poor rock conditions that may indicate that a problematic zone with high water bearing capacity and/or associated instability will enter into the tunnel face.

The information obtained from the probe hole will then give the contractor the ability to assess the conditions ahead of the face, and hence make a decision as to whether pre-injection is necessary, and with what materials to be used.

Probe holes can be drilled with conventional drilling equipment such as a boomer. Drill hole sizes are usually 45 or 52 mm diameter and holes are drilled between 15 to 30 m ahead of the excavation face.

Water ingress criteria from probes holes are usually the main parameter that triggers an injection cycle and should be specified in the contract.

If the water coming from any one probe hole exceeds the specified limit, then pre-injection of the face should be started. The benefit of probe hole drilling is that the point of water ingress or the change in penetration rate and flush water colour can be identified.

By drilling three probes it is then possible to identify the location, dip and dip directions of the problematic rock mass and target injection as close as possible by placing packers close to the identified zone.

Injection pressure losses are then minimized and the effects of the injection can be optimized.

If from the probe hole information the decision is made to pre-inject, a full fan of injection holes are made around the circumference of the tunnel (Figure 14). Injection holes will be drilled with the same equipment and to the same depth of the probes holes, or drilled to just cross any identified problem zones. Pre-injection will then be commenced into every hole. The full circumference is drilled to ensure that a grout fan around the full periphery of the tunnel is achieved so the water is less likely to find an alternate path into the tunnel. Typical injection hole and grout fan configurations are shown in Figure 14.

The decision to stop grouting should normally be specified in the contract. This can be done using two parameters, pressure and volume. It should be noted that pre-injection usually means the injection of materials under high pressures.

Pressures of 60 bar and higher are common. Several factors can cause these pressures:

- Pressure losses in the system require high pressures to achieve a moderate pressure in the rock mass. Research from Barton highlighted that half the injection pressure is lost only 1 m from injection hole
- Rock masses may require high pressures before the mass accepts cementitious materials, even though significant quantities of water may still be coming from a hole
- Pre-injection ahead of the face by definition means that there are significant confining pressures, especially if overburdens are high, that can easily withstand grouting pressures
- Dilation of rock joints is of benefit to pre-injection as it ensures that a substantial grout mass will penetrate the rock joint improving the sealing effect of the pre-injection process.

If the injection pressure is not being achieved, then a volume stop criteria should be implemented say maximum 4000 kg per hole. This will then limit the wastage of grout by attempting to pump to pressures. This means that a very stable grout should be design so that bleed water channels are not formed in the grout when pumping is stopped.

Once injection is completed, control holes must be drilled between injection holes to verify the effects of grouting. If significant water ingress still occurs, then the injection cycle is continued into the control holes. If conditions are considered OK, then excavation can be restarted.

Figure 5 demonstrates a typical decision making process for pre-injection.

### *Factors influencing penetration*

Pre-injection materials are usually of the cementitious kind; however, it is important the correct type of cement is used in the correct situation and the pre-injection grout mix is designed to give a stable grout with maximum penetrability. Figure 6 shows the relationship between grout parameter to provide a grout with maximum penetrability.

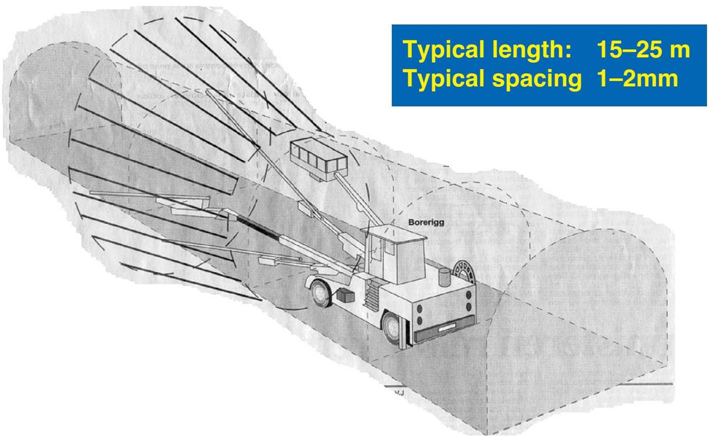


**Figure 4—Pre-Injection is 10–50 times less expensive than post-injection**

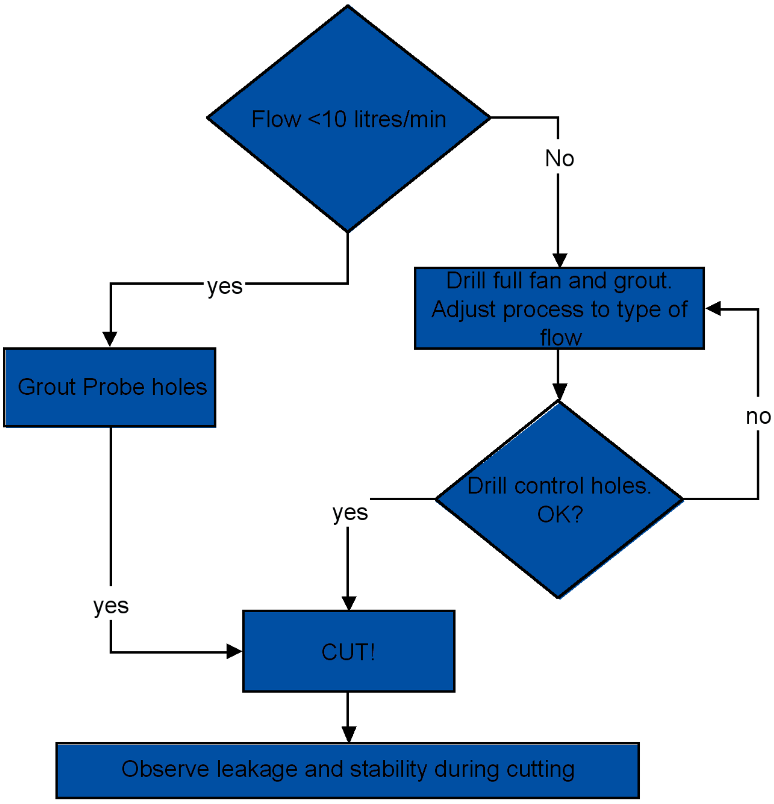


**Figure 5—Flow chart of injection decision criteria**

Stability, viscosity and grain size are the three parameters controlling penetrability. The stability of the grout means a grout with less than 5% bleeding after 2 hours. The viscosity is an apparent viscosity and is measured by Marsh Cone time. The grain size is the D95 of the particle size of the grout mix.

Typically, microfine cements are used for pre-injection works. The reason is because the D95 grain size is less than 20 microns vs. OPC at 60 microns. This means significantly smaller cracks can be injected with microfine cements than with OPC.

Also, microfine cements exhibit bleeding of less than 5% at a water:cement ratio of 1:1 as compared to OPC that segregates at water:cement ratios of greater than 0.4. Therefore, microfine cement satisfies the criteria of a highly stable grout (<5% bleeding), low viscosity (1:1 with March cone time 35 s) and small grain size (20 microns).

The performance of OPC can be significantly improved by using a special 'dispersion agent' or admixture called Rheobuild 2000PF.

By mixing normal OPC at a 1:1 water:cement ratio in a colloidal high speed mixer and dosing Rheobuild 2000PF at 1–2% bwc stability is significantly increased, viscosity and therefore penetration of the grout is significantly increased in the order of 200%.

Rheobuild 2000PF must be used at the same dosages when mixing Rheocem microfine cement at a 1:1 water/:cement ratio for pre-injection.

The other differentiating feature of the Rheocem microfine cements is early initial and final setting times of 60–120 and 120–150 respectively. (1:1 w/:c ratio @ 20 deg C)

- *Comments on high water/cement ratio*—Current local practices stipulate that grouting with OPC should begin at a high water/:cement ratio i.e. 5:1 and gradually decrease to 2:1 depending on the 'take and pressure'. This grout will still be unstable and have large particles so penetration into small fissures will not be achieved. By addressing the factors above a much faster and effective sealing can be achieved. Costs can be minimized by starting with an OPC grout at a 1:1 w/:c ratio, dosed with Rheobuild 2000PF and finishing with microfine cement.
- *Meyco MP 320 colloidal silica*—Other materials that are commonly used are known as mineral grouts, also termed colloidal silica. Colloidal silica has a viscosity almost like water (5 mPas), a much smaller particle size than cement (0.015 microns) and gelling can be adjusted between 5 and 150 minutes.

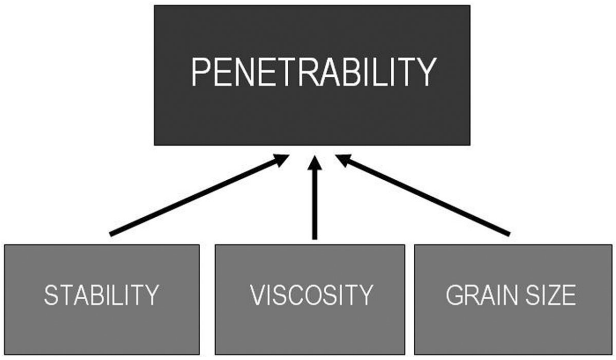


**Figure 6—Karl Gunnar Holter, BASF UGC international**

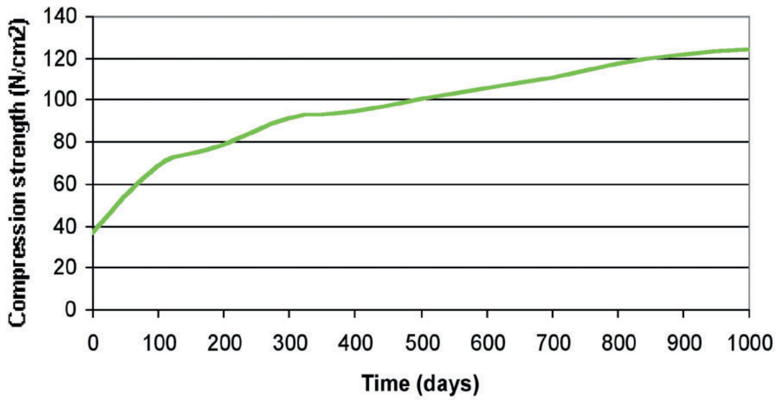


**Figure 7—Meyco MP 320 Compression strength over time**

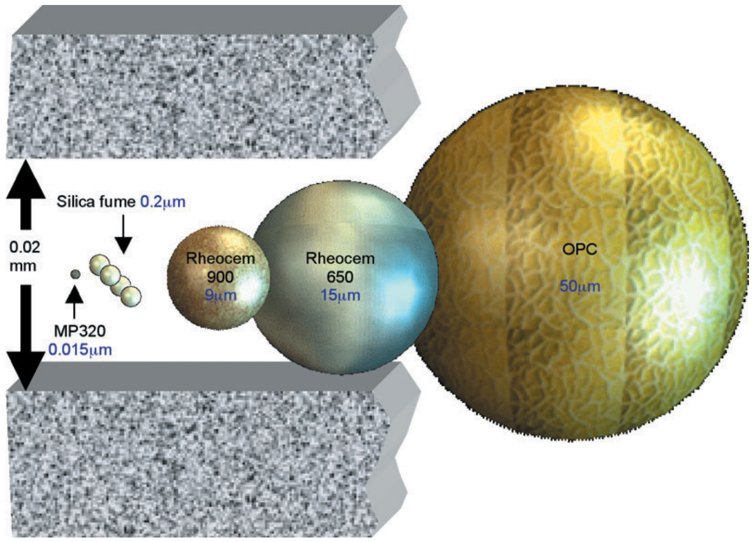


**Figure 8—Size comparison of various injection materials**

When it gels, the gel is very soft in the beginning, but it will be stronger and stronger over time. The reaction is not a chemical but a mechanical reaction. When salt water is added, (the accelerator), the particles collide to form an impervious gel.

Colloidal silica is a 100% nature product. It consists of silica and NaCl. Ready to use the salt concentration is lower than the seawater in the North Sea! There are no hazards or personnel risks when using it. Colloidal silica also has no detrimental effects on the environment. Colloidal silica can both be used in normal cement grout pumps, or in 2 component pumps. Colloidal silica has excellent penetration capability and it will penetrate fine silt and fine hair fissures, where microcement will not work.

Colloidal silica can also be used after the injection of Rheocem 650 to 'tighten-up' any small ingress of water that may still occur.

### *Bentonite*

Bentonite has traditionally been used on a routine basis in combination with cement for grouting of soil and rock. The reason for doing so was the strong tendency of standard cement to separate when suspended in water, enhanced by the normal use of water:cement ratio > 1.0.

Bentonite can be used to reduce the bleeding in such grouts and a standard dosage of 3 to 5% of the cement weight has a strong stabilizing effect.

Bentonite is natural clay from volcanic ashes and the main mineral ismontmorillonite.

There are two main types:

➤ Sodium-bentonite (Na-)
➤ Calcium-bentonite (Ca-).

Mostly the sodium-bentonite is used as an additive in cement grouts, because it swells to between 10 and 25 times the original dry volume when mixed in water. The particles resemble the shape of playing cards and will adsorb water on the particle surfaces, thus stabilizing the grout mix.

The particles also sink very slowly within the suspension because of their shape.

With the traditional cement grouting methods and materials, bentonite had its place. However, in combination with micro-cements it is normally not necessary and will mostly be of a disadvantage. One reason is that a typical d95 particle size of bentonite clay is around 60 µm. This is two to three times larger than that found in good micro-cements and will reduce the penetration achievable by ordinary cement.

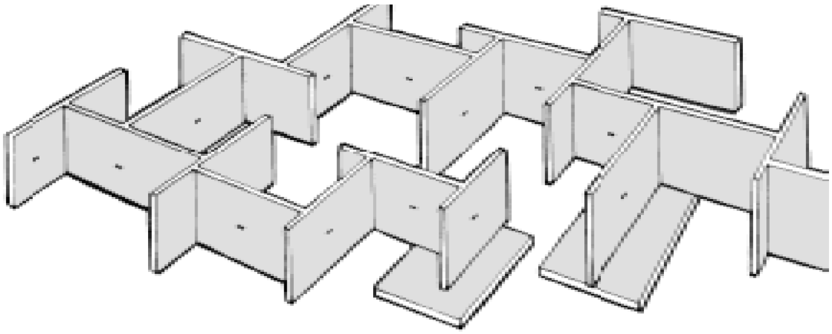

**Figure 9—Structure of bentonite clay after dispersion in water**

*Table I*

**Various injection materials, their application and indicative costs**

| Injection material | Typical situations/ problems | Properties of grout | Typical volumes per job | Typical cost of grout EUR /kg |
|---|---|---|---|---|
| Portland cement | Pre-injection, large voids, ground improvementor removal of water ingress | Viscous suspension, suitable for filling in ground with high permeability, long open time, (pot-life), which can be accelerated. High final strength | Large; > 5 tons | 0.06 |
| Micro-cement | Pre-injection, injections in soil or rock for ground improvement or removal of water ingress | Suspension with low viscosity and high stability, good penetrability. Suitable for injection in gravel/sand and rock with fine fissures. Open time, (pot-life), down to 2 hours. High final strength. | Large; > 5 tons | 0.5–0.7 |
| Colloidal silica | Pre-injection and post injection, injections in fine fissures in rock and fine grained soil ground, improvement and consolidation. | Extremely low viscosity for penetration in fine fissures, pores and fine grained soils. Highly adjustable gel time. Medium final strength. | Typical volumes; 200 kg–10 tons | 2.50–3 |
| Polyurethane | Post-injection for difficult situations with immediate need for ground improvement (instabilities) or water cut-off injections | Rapid reacting viscous resin which can be given foaming properties with high expansion factors | 300 kg–10 tons | 5–6 |
| Acrylates | Post-injection in rock or concrete structures, or in fine grained soil where penetration in very fine fissures or small pores is desired | Rapid reacting low viscous resin with extremely good penetrability and highly adjustable gelling time | 5 kg–100kg | 3–10 |

The shape of the particles is also a negative feature in this respect.

Modern micro-cement grouts can be made with very low viscosity and limited or no bleeding if combined with chemical admixtures. Thus the addition of bentonite is therefore unnecessary and negative effect on the end result.

The final strength of the grout is not important in most cases. However, with high water heads, or when a ground stabilization effect is important, the use of bentonite at normal dosage will reduce the grout strength by 50% and more.

This can be avoided when using modern admixtures such as Rheobuild 2000PF in micro-cement grouts, without sacrificing stability or penetration.

### Post injection

When pre-injection has failed or not been done, it is necessary to utilize various chemical products to handle uncontrolled water. Depending on the nature of the problem, UGC has a range of products to seal water or stabiles rock or coal as summarized in Table II.

### *Mining polyurethane and urea-silicate resin injection products*

UGC has recently developed 3 new 'mining' products due to demand from the coal mines in Germany and Australia. Coal mines are seeking high performance, safe chemical grouts and foams, which allow quick and effective ground control.

As can be seen from Table II above, the three new products are:

➤ *Meyco MP 357 GS*—Is a highly reactive two-component polyurethane injection resin specifically designed for rapid stabilization of rock and soils. This is a fast-acting flexible material, which can penetrate cracks of 0.15 mm. It will expand up to 3 times when not in contact with water and up to 8 times with water present. The reaction temperatures are below 140°C.

*Table II*

**Products used to seal and stabilize**

| Product | Reaction time | Expansion factor | Where to use | Pump | Application |
|---|---|---|---|---|---|
| MEYCO MP 355 1K Acc. Adjust speed 2–10% | 50–120 sec | 20–30 times | To stop water inrush in tunnels etc. Concrete cracks | 1 comp. pump | Small and low pressure water sealing as well as ground consolidation |
| MEYCO MP 355 A3 | adjustable | No water: 0 Water > 8 times can be adjusted with acc. | Consolidation and water stop in Tunnels etc. NB! Not in coal mines, due to too high temp. | 2 comp pump single mix spiral | For professional users Small and very big water sealing as well as ground consolidation |
| MEYCO MP 357 GS | 65 sec | No water: 0 Water > 8 times | Consolidation in Coal Mines Also water stopping (like MP 355 A3) | 2 comp. pump single mix spiral | Mining or tunnelling |
| MEYCO MP 364 Flex Fire resistant | 2 m 40 sec | No expansion with or without water | Consolidating of coal and ground. For tunnels and mines | 2 comp. double mix spiral | All mining applications |
| MEYCO MP 367 FOAM Fire resistant | 40 sec | No water: 20 Water: 20 | Cavity filling, water stopping, etc. | 2 comp. double mix spiral | Void filling in mines and tunnels |

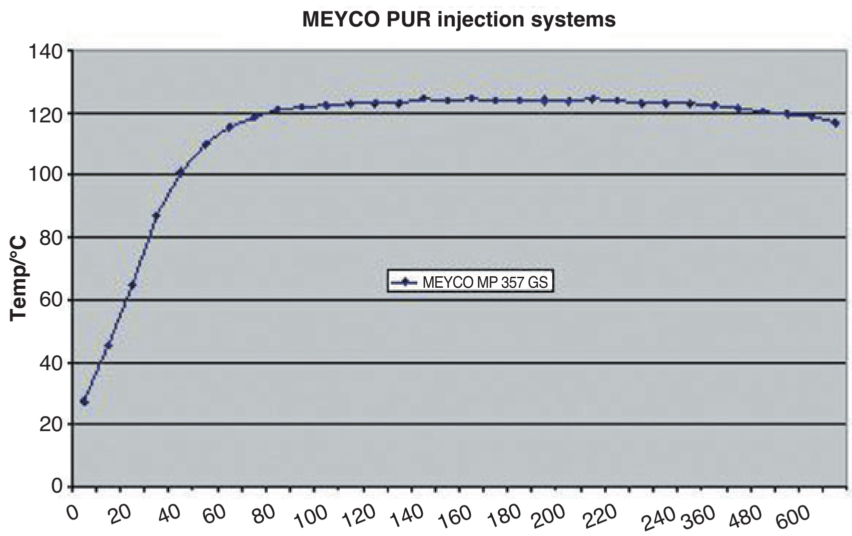


**Figure 10—Meyco MP 357 GS reaction temperature vs. time**

- *Meyco MP 364 Flex*—fire resistant. Is a two-component solvent free urea-silicate injection resin specially designed for rapid stabilization of coal measures, rock strata and soils as well as repair of underwater structures and concrete cracks. This product does not expand in or out; it also does not absorb water and shows good adhesion to wet surfaces. It is a very fast reacting material, exhibiting good structural strength and flexibility and importantly is 'fire resistant'. The reaction temperature is below 90°C.
- *Meyco MP 367 Foam*—Is a highly reactive two-component solvent free 'non-flammable' urea-silicate foam specifically designed for rapid cavity filling. The product foams without being in contact with water, nor does the water have any detrimental effect on the foaming factor. Foaming takes approximately 45–60 seconds and a foam factor of between 15–25 times can be achieved. The reaction temperature is below 100°C.

## Conclusion

UGC recognizes the needs of the customer for a 'one stop shop' for TSLs, injection and ground consolidation. We now have a full range of top quality products, excellent equipment and accessories. Above all, as with sprayed concrete, we now have expertise locally and internationally to train and assist customers on site. By also developing alliances with specialized, trained application contractors, we can provide the complete package.

We have also been holding practical injection and TSL seminars at an underground training facility in Switzerland where clients, consultants, and contractors, as well as our own engineers can take part in a two day courses run by our internal experts.

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