Water Control using polyurethane resins

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Keywords: injection, polyurethane resin, sealing, waterproofing

ABSTRACT
Actually it is possible to use a wide range of techniques and products to control water ingress into underground and mining works. There are many products for waterproofing, consolidation, sealing, bolting, crack and joint repairing, bonding and cavity filling.
Unexpected water ingress during tunnelling usually escalates project costs and important delays. In this case the injection systems based on dual and single component polyurethane resins, are cost-effective. Appropriately engineered resin injection can transform running sands to the consistency of a sandstone and water-bearing gravel to a solid conglomerate.
There is no single resin that will suit all conditions. If the incorrect resin is chosen it may result in a performance that does not meet the requirements. The polyurethane injection systems assure high performances in the solution of problems in geotechnical field and waterproofing, in tunnelling, underground works and civil engineering in general.

INTRODUCTION

The purpose of this paper is to give an overview of the many aspects related to the injection resins and also to offer some guidelines for an understanding of these materials and their uses. It is a fact that resins are fundamentally used in order to solve leaks in waterproofing systems but they can also provide special solutions for other construction problems.
Once water finds its way into our workplace (shaft, gallery, tunnel, etc.) it seems to be complicated to stop it. As soon as we plugged one leak, the water will find another gap and a new leak will appear in a formerly dry point. We must to have always presented that water seeps through cracks induced by jacking forces, through grout holes and through any such fissure in the ground.
This is an attempt to present different types of injection systems based in resins and some of their possible application fields.

RESINS
Resins are very interesting compounds both in the field of structural renovation as well as in new constructions. Some of their most important uses apply to anchoring, sealing, cavity filling, rock stabilisation and crack injection.
There are many different resins for injection, each suitable to specific circumstances and conditions. The selection of the right one, for an especially problem, has proved to be a decisive question. Therefore we can find a wide range of products in the market.
The main advantages of the resins are:
- ✓ Set can be very quick, but can also be retarded
- ✓ Approved for contact with potable water
- ✓ Very good resistance to corrosive and aggressive environments

Following we will give a short ranging presentation of some resins.

Polyurethane resins

- ***Water reactive resins***

These kinds of resins are prepolymers of polyurethane single-component, and composed of a polyfunctional poliol with terminal isocyanate groups. The prepolymer reacts with water in-situ to form an expanded elastic solid. The reaction time is regulated by addition of a catalyst.

Typical physical properties of the resin can be:

Viscosity at 20 ºC	between	300 and 350 cps
Density	around	1,10 g/cm^3
Flash Point	near to	180 ºC

Their most appropriate applications are shown below in table 1.

Impermeabilization	water leaks cut-off waterproofing of joints and cracks treatment of joints between panels
Ground Consolidation	consolidation of docks, ponds & tanks water seepage elimination embankment stabilization

Table 1 Some applications of water reactive resins

The one component polyurethane resins have several advantageous properties:

1. - Fully pre-polymerised
2. - Ultra-low viscosities
3. - Solvent-free
4. - Un-dilutable
5. - Total control on set
6. - Water-resistant foam
7. - Resistant to aggressive ground conditions
8. - Very durable

- ***Two-component resins***

These are resins with a very fast reaction and free of CFC. With a low viscosity and a good fluency are the most suitable resins for consolidation works and cavities and voids filling.
Typical physical properties can be:

	Compound A	*Compound B*
Viscosity at 20 ºC	130 cps	300 cps
Density	1,12 g/cm^3	1,05 g/cm^3
Flash Point	214 ºC	185 ºC

Epoxy resins
Are two component resins with very low viscosity. Free of solvents. The flexibility of the cured resin allows movement at the existing crack, preventing thereby the transmission of stress to other areas of the structure.
Before the use, if possible, is necessary a surface preparation removing all lose and deteriorated concrete, mortar and old repair materials from the area to be repaired. Normally it is carried out with compressed air.

OPERATIVE PROCEDURE
Once the zone to be treated is determined the process is carried out as follows:
Perforation:
Execution of drill holes with an appropriate length, diameter and space between them. These parameters will be vary according to the problem. Remember that the wiser the crack, the greater distance of resin travel and the farther apart the holes may be spaced.
Shutter positioning:
Once the drill hole is clean, a mechanical shutter with an appropriate diameter, length and pressure is placed within.
Sealing:
In order to prevent uncontrollable loss of injection resin it is desirable to seal the proximity of the drill holes with a hydraulic mortar.
Injection:
Using the most adequate pump for each problem and type of resin (manual or pneumatic, mono or bi-component) begins the injection.
***Secondary injection*:**
In water reactive resin injections it is convenient to inject at the end of the process air/water to facilitate a right reaction.
Removal:
The shutter is removed and the drill hole sealed with an hydraulic mortar.
The consumption of resin has to be estimated by an engineer or operator and is depending on width and depth of the cracks and voids to be injected.
These materials are both temperature and moisture sensitive. Therefore they should be stored in an area with temperatures not exceeding 30 ºC or not lower than 10 ºC

Ordinary hygienic principles, such as washing the compounds from the hands before eating or smoking should be observed. Hands should be washed with a waterless cleaner followed by soap and water. Avoid breathing of vapours, prolonged contact with the skin, contact with open breaks in the skin, and ingestion. These materials should be used with adequate ventilation

CASE HISTORIES

Fill Shaft: Walls impermeabilization.

The shaft has a diameter ∅ = 1.50 m and in his 10 m to 13 m across an entail zone that was necessary to be treated with concrete for the proximity to the river.

Below, the ground is composed of slate and compact sandstone.

The problematic area has an extension around 40 lineal meters bellow entail zone, where come into water leakages being necessary to be eliminated.

After the problem evaluation the proposal solution is impermeabilization zone treatment by water reactive polyurethane resin injection.

An adequate treatment of the ground with this injection system leads to next benefits:

1. Eliminate present water leakages (Curative treatment)
2. Reduce the ground permeability avoiding future leakages (Preventive treatment)
3. As an add aftereffect, the resistance characteristic of the treated ground grow up and so the maintenance costs, during the exploitation time, decrease.

The resin more adequate for this type of problems is a mono-component water reactive polyurethane resin. It reacts with water present in ground to create a waterproof flexible solid.

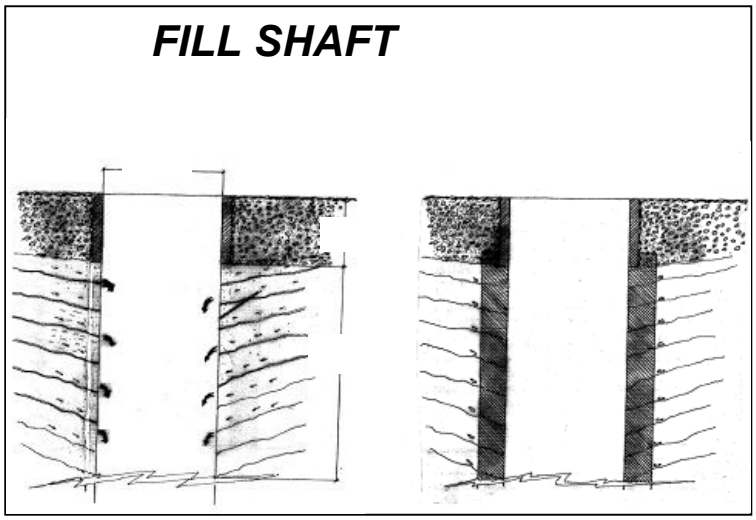

Figure 1 Fill shaft treatment

Shaft impermeabilization

The shaft has a diameter ∅ = 4.50 m and 200 m depth and is used to personal transportation.

The shaft is encased in force concrete (40 cm thick) and the ground awry is composed of slate and sandstone formations.

After checking inside the shaft can be see:

- water leakages through concrete joints
- perimeter fissures
- casing concrete porosity

These effects, growing up along the time, in conjunction with the frost-thaw origin a wash and subsequent breakage of the casing concrete.

Other way to appear water in the shaft is the anchorage bolts from the structure of the lift and mine ancillary services. Even though in theory these bolts doesn't cross the concrete (bolt length = 230 mm) can be produce an interior fissure that has a communication between the bolt drill and the casing contact.

The solution suggested is make a zone waterproofing treatment based in water reactive polyurethane resins injection and posterior concrete regeneration with cement mortar mixed with acrylic resin. This make good all the defects and avoid the casing structure continue deterioration process.

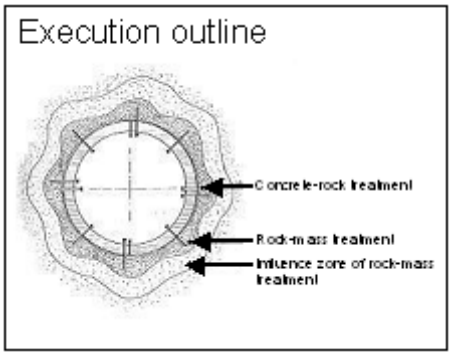

Figure 2 Treatment execution outline

Dam impermeabilization treatment

Presence of water due to filtrations into the basement of inspection galleries could produce in the long term stability problems decreasing the safety coefficient of the dam, in the short term, corrosive problems in metallic elements and electrical conductions.

To avoid these effects and improve the water tightness can be used two different treatments:

Waterproofing of the joint or fissure extreme in contact with water using waterproof membranes between basement and water (Treatment based on “in situ” elastoplastic membranes).

Filled the joint or fissure with waterproof and enough elastic products (Treatment based on water reactive polyurethane resins injections).

Both treatments can be used together and individually. For the purposes of this paper we will only explain the second treatment.

This treatment is based in waterproofing of the joints or fissures by filling the existing hollow by means of water reactive polyurethane resin injections. At the beginning of the foam reaction the detachment of micro bubbles of CO_2 suit the expansion in volume and the infiltration in all the gaps, even in the smaller micro fissures of the structure to be treated. Once the process has been finished the result is a solid, elastic and very stable in time mass.

Picture 1 Injection process at the inspection gallery

The reaction time (gel time) can be controlled by addition of the catalyst, and so is regulated the distance to be cover by the resin.

It is important to stress that this filling treatment avoid the possible negative water pressures (rainwater, etc) since avoid the water flow in any direction.

Dam Wall impermeabilization

The problem to be solved is the presence of water in the wall of mineral lixiviation pool. The wall dimensions are length 200 m, thick 15 m and depth 20 meters.

In a well defined zone of the wall appears some filtrations, approximated length 6 – 8 m and depth 8 – 9 m. It can be appreciated on the opposite wall side. Probably the origins of these filtrations are two parallel interfaces of one intercalate stratus on the wall.

The solution proposed is the execution of one impermeabilization barrier carried out by injection of water reactive polyurethane resins.

Operation method is the execution of ten drills parallel to the wall face with a length and depth enough to cut off the filtrations zone. The distance between drills will be one meter.

Picture 2 shows the flowing water.

Picture 2 General view of the pool

CONCLUSIONS

The usefulness of the resins is linked to their broad application fields. In terms of ground water control and running water cutt-off are the best solution.

The principal questions provide for to solve a problem are:

- Diagnosis of the problem
- The correct choice of resin and injection method
- Training and experience of installation personnel (skilled team is paramount)

The choice of resin is dependant of many factors, such as water quantity and pressure, the characteristics of the rock, soil or construction there are not a single resin that can solve all the range of problems.

As mentioned after, there are a lot of applications fields for the resins:

Consolidation of unstable rock formations

Sealing against water inflows

Anchoring to prevent rock bursts and collapsing mine faces

Ground stabilisation

Anchoring foundation structures

Sealing works

Treatment of fissured areas

Filling voids

Crack injection

Sealing of flowing water

To be successful in the future manufacturer and supplier of injection resins, will require knowledge and resources to keep developing products and concepts that fit the needs and demands of all interested parties.

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