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A special technology to increase the bearing capacity of soil by deep injection

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Abstract. The paper refers to a new injection process using polyurethane materials called Geopur. The author presents their wide field of application, able to solve optimally many technical problems arising from the reinforcement and insulation of building parts. The new process, the materials used, the technological steps and the benefits are hereinafter described.
Keywords: reinforcement injection, insulation injection, polyurethane resin, material expansion, strengthening

1. INTRODUCTION

The improvement of physical- mechanical characteristics of foundation soils for civil and hydrotechnical engineering has always been a primary concern for builders.

The first attempts were made in the 19th century, the grouting technique evolving from the simplest forms, that of lining holes and cracks with mortar, to the modern methods of injecting under pressure different types of chemical suspensions and solutions. The discovery of cement by the end of the 18th century was the beginning of the development of grouting technique for reinforcement and insulation of permeable rocks [1].

In 1878, the first attempt to inject under pressure cement suspensions in boreholes was made. Subsequent good results led to this method being applied on an increasingly larger scale.

Today, injection technique already has a tradition; it is recognized by a wide circle of specialists based on works performed using this technology, as well as a rich literature.

Injection is a process by which some fluid substances, binders or chemical substances are being introduced under pressure into the pores or cracks of the soil, and which, after their hardening, increase the strength of the soil or prevent water circulation. This process is called reinforcement injection if used to restore or increase the bearing capacity of the soils. If used to decrease the permeability, we deal with insulation injection.

There might be situations when the process serves both purposes, in which case the injection is called reinforcement - insulation [1], [6]

The list of used injection fluids includes:

- cement suspension;
- clay- cement suspension;
- clay- bentonite gel;
- bitumen emulsion;
- silica gel;
- synthetic resins .

Synthetic resins are organic substances. Water-soluble synthetic resins are of particular importance for injections. Usually, two substances are mixed prior to their pressure injection.

The synthetic resins are classified in three groups [1]:

- condensation resins and formaldehydes, such as resorcine, urea, polimers;
- reaction synthetic resins, such as epoxy and polyurethane resins;
- polyester resins.

The reaction time, the time until the change of the resin status (hardening), may be widely adjusted by adding catalysts. In the hardening process, macromolecules appear that determine insulation and reinforcement of the soil. They form from water solutions, by polycondensation (formation of macromolecules by stratification without scindation) [6].

Injection fluids have some disadvantages such as: quick sedimentation, high fluidity, seeping in the underground water flow, high resilience towards surrounding rocks, long hardening process, need for high pressure equipments.

Synthetic resins also show some drawbacks, such as: high toxicity to some products, rather high costs, environment problems resulting from pollution of drinking water within underground collecting areas.

2. PRINCIPLE OF THE NEW INJECTION METHOD

The new injection method uses polyurethane materials called Geopur. This type of polyurethane resin has been implemented by the company CarboTech headquartered in Essen, Germany, at the beginning of the 1990s. In 1995, manufacturing of this material has been continued by a subsidiary of the Essen company, located in Ostrava, Czech Republic, and also in Hungary by the late '90s, by the company Gavex in Miskolc [2].

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The materials used, manufactured in these countries, meet ISO 9001 and ISO 14001 requirements; the implementation of technologies in Europe allowed spectacular solutions to reinforcement and insulation issues [2], [3].

The new injection method eliminates shortcomings presented in the previous chapter. Hereinafter, the process is being presented in detail.

3. FIELDS OF APPLICATION

The main fields of application of the Geopur polyurethane material include [2], [3]:

- reinforcement of dykes and dams, removal of water infiltration;
- injection of cracks in underground constructions, their insulation against groundwater;
- sealing of adduction tunnels against water dripping or seepage, sealing of underground train tunnels against water inflows;
- stopping of landslides and changing of the groundwater pattern;
- solving environmental problems, such as prevention of the seepage of toxic harmful substances from a waste deposit;
- stopping of liquid or gas leakage through the ground or construction elements;
- reinforcements and rehabilitations of concrete structures or elements, such as reservoirs.

We may conclude that the fields of application of the injection with polyurethane material is very large, being able to optimally solve many technical problems arising from reinforcement and insulation.

4. DESCRIPTION OF THE PROCEDURE

The procedure is based on polymerization reaction, accompanied by an increase in volume of the material resulted by mixing the two components, A and B.

The two components in liquid stage are pressure injected (1-2 atmospheres) in the mass of the reinforcement (insulated) element, penetrating all gaps.

By injecting soils with a grain size larger than dust, a quite homogenous mixture results, known in literature as geocomposite [2]. After 20 – 30 minutes, the mixture of the two components achieves mechanical strengths comparable to concrete. Due to volumetric expansion, the molecules of the two component mix fill the slightest pores and cracks of the injected environment.

The duration of polymerization reaction depends on the field of application, and is adjustable from 0.5 to 3 minutes.

The polymerization reaction is not influenced by the presence of water and it takes place in anaerobic environment. The material resulted has a very good adherence to soil particles, concrete, brick, wood, coal, etc., being water and gas proof.

The surveys performed by specialized institutions in the Czech Republic and Hungary, showed that both A and B components, as well as their mixture, are inert, chemically resistant and non-toxic [2], [3].

. TYPES OF MATERIALS

The materials used in the new procedure are classified into three main groups, with following fields of application [4]:

- Geopur 082 – used in construction elements where lasting mechanical strengths are required, reinforcement of soil and rocks, cavity fillings, prevention of water infiltrations in the ground or construction elements, rehabilitations and repairs of brick and stone works, foundation piles, consolidations and repairs under water level;
- Geopur 230 -1 – used in stabilization and sustainable strengthening of soil, sealing or changing of groundwater patterns, prevention of landslides;
- Geopur 240 – used for temporary consolidation of quicksand and for cavity fillings.

The properties of A and B components of Geopur are shown in Table 1, while the properties of the mixture of both A and B components, in Table 2.

Table 1. Properties of the components of Geopur materials

Type	**Component**	**Density at 20°C (g/cm³)**	**Viscosity at 20°C (m Pas)**	**Mixing ratio**	
				In weight	**in volume**
082/350	**A**	**1.075**	**± 100**	**1/1.26**	**1/1.10**
	B	**1.235**	**300**		
082/290	**A**	**1.075**	**± 100**	**1/1.26**	**1/1.10**
	B	**1.235**	**300**		
082/180	**A**		**± 100**	**1/1.26**	**1/1.10**
	B		**300**		
082/90	**A**		**± 100**	**1/1.26**	**1/1,10**
	B		**300**		
230-1	**A**	**1.173**	**± 100**	**1/1.70**	**1/1.51**
	B	**1.235**	**300**		
240	**A**	**1.07**	**± 100**	**1/1.75**	**1/1.51**
	B	**1.235**	**300**		

Table 2. Mixture properties

Type	**Volume growth (x initial volume)**	**Thermal stability (°C)**	**Reaction start at 20°C (sec.)**	**Duration of liquid state (sec.)**
082/350	**2-4**	**132**	**25**	**64**
082/290	**4-5**	**132**	**25**	**64**
082/180	**5-6**	**132**	**25**	**64**
082/90	**6-8**	**132**	**25**	**64**
230-1	**10-15**	**140**	**45**	**185**
240	**40**	**132**	**28**	**106**

6. STEPS OF THE TECHNOLOGICAL PROCESS

The main steps of the technological process are [5]:

The injection probes are pushed in the predetermined depth by various procedures

including striking, sticking, vibropressure, vibropercussion.

- After placing the probe in a preset depth, the actual injection operation starts. This is done by pumping the two components with a double pump, driving them in a mixing head where they are homogenized. The prepared material is then injected in the element to be reinforced or insulated.
- After the injection is finished, the probe is closed so as the chemical reaction of foam formation and volume growth with material hardening not to overfill the probe, but to take place in the element mass.

Before starting the injection process, geological, hydrogeological and geotechnical studies of the affected area need to be performed. Based on such studies, the reinforcement injection project is then developed, this determining the injection depth and location of the probes. Also before starting works, it is necessary to identify underground electric and communication cables, gas, water and sewer ducts, to avert damaging them or the occurrence of accidents.

7. CONCLUSIONS

The method described in this paper has often been implemented in Germany, the Czech Republic and Hungary, with remarkable results.

Compared to traditional cement injection methods, the new procedure has the advantage of speed; the material strengthens in about 30 minutes as compared to 28 days in the case of concrete. It does not require a too high injection pressure due to the mixture of two components that ensure its penetration into any crack or pores of the injected layer.

The material is non-toxic, inert, chemically resistant, and can also be used in wet environment.

The author estimates that taken its benefits, the procedure described in this paper will be largely spread in the near future in our country too.

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