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Review paper

INJECTION COMPOSITIONS

INJEKCIONE MASE

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Abstract: This paper provides a brief overview of the methods and materials for injection in underground construction, with a focus on the use of new injection compounds for this purpose. The aim is to draw attention to the possibility of applying new materials for injection that are present in the world, which would facilitate the work, significantly shorten time of work and downtime.

Keywords: injection, materials, tunnels, underground construction, geotechnics

Apstrakt: Ovaj rad pruža kratak pregled metoda i materijala za injektiranja prilikom podzemne gradnje, sa fokusom na primenu novih injekcionih masa za ove potrebe. Cilj rada je da se ukaže na mogućnost primene novih materijala za injektiranje koji su zastupljeni u svetu, čime bi se olakšao posao, znatno skratilo vreme rada i zastoji.

Ključne reči: injektiranje, materijali, tuneli, podzemna gradnja, geotehnika

1. INTRODUCTION

With constant development of technologies and new materials on all fields, market offers new products with some significant improvements compared to traditionally used ones. This development has an impact on all branches of engineering, and thus mining and geotechnical engineering.

This paper shows fields of application of injection, with focus on new materials used for it. It is almost impossible to mention all the previous researches performed about injection process and injection compositions, so we will put focus on domestic researchers, and show as well some projects realized with use of new injection compositions.

Gorica dam is one of the most significant examples to what extent and how the injection can assist in the rehabilitation and prevention. The main part of project constructing and rehabilitation of the dam was upbuilding the double-row grout curtain in the profile on the river Trebišnjica downstream of the Gorica dam. While the part of activity was aimed

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to the contact and consolidation grouting at the zone of hydrotechnical tunnel HE Dubrovnik. Main issue in this case was leaking water in an amount greater than 0.25 m^3 in the pillar of the dam and flooding the coast which was a problem for the functioning of the dam. Creating a grout curtain profile dam Gorica took place in phases, and will be done in phases, and will continue to give them even better results to reduce the amount of leachate. Significant results can be expected only after the completion of the last phase in the development of injection curtains (Zubac and Bošković, 2012).

One of field practices mentioned by Pasqueto et al. (2016) is related to highway Celje-Ljubljana.

Ten years after building highway Celje-Ljubljana has been ruining, concrete plates started to crack as a result of excessive load on the weakened pavement construction in an area of stone materials and cement stabilization. The task was to reinforce the damaged area of pavement structure and flatten the upper surface of the boards in the same level. There were two solutions, to ruin the complete construction and to build the new one with longer traffic disruption or to improve the geomechanical features of the basic structure by injecting polyurethane resin expansion in the shortest time and without interruption of traffic. It was decided to go with the second solution wich accelerate the time of rehabilitation and troubleshooting as soon as possible (Pasqueto et al. 2016).

Trifunović et al. (2013) done a research about application of polymer composites for stabilization of degraded rock mass in mining, and gave conclusion that modern materials based on polymer composites have growing application in mining and civil engineering.

In the mining industry has begun a new era of usage of polymer resins for injection, due to the fact of their faster and safer and most important much more efficient installation for rehabilitation facilities that require medium or long usage term. They are used for stabilization of degraded rock mass in underground construction, within the cracks or boreholes in or around the facilities. Some types of resins that are been used in mining are such as Polyurethane resins, two-component silicate resins, Epoxy resins, Elastic silicate insulating resins - ESR resins (Trifunović et al. 2013).

2. HISTORY OF INJECTION

The first records of injection originate from the early 19th century, precisely in 1802, which was applied for the protection of river sediment. It is noted that Collin was the first to use this material for injection it into cracks in the body of dam Grosbois in France. Since the mid-19th century in the United States injectioning methods started it expanding development, but mainly for the rehabilitation of the foundation. 1887. Jeziorsky patented process of injection water glass and reactive in low carrying capacity and low permeable granular environments (Cvetković-Mrkić, 1995). Sealing injection was first used to build a 130 meter-high dam Ponsonon river Durance in France at about 100

meters thick gravel sandy sediments. In Serbia, the first performance of injection occurred when Grošnica dam was built in the thirties of the twentieth century. Injection of the modern era has found its place of application in construction of dams and in generally speaking of all underground facilities (tunnels, shafts etc.).

Injection, as a one of geotechnical works was introduced, on a large scale, in Serbia with project of building the railway Belgrade-Bar, on many of its 254 tunnels (total length 114.437 m). No less significant in terms of size are geotechnical works which were carried out for projects and works performed while building the Belgrade railway junction (Ćulibrk, 1999).

3. BASICS OF INJECTION

Injection is a procedure that aims to improve the mechanical and hydrological characteristics of the rock mass as the working environment (Jovanović, 1994). The process itself involves injecting injection compositions into the rock mass, with the task of fulfilling the cracks, pores, voids and fissures in the rock in order to gain functional compact working environment, after induration of mentioned compositions (Jovanović, 1994).

Depending on the material in use during the injection process prefixed is added:

- Cementitious injection, if cement is used for injection,
- Clay injection, if clay is used for injection,
- Bitumen injection if bitumen is used for injection,
- Synthetic injection, if synthetic resins is used for injection.

In the underground construction, cement in combination with clay, sand or other additives is commonly used. In recent years, various solutions of synthetic resins finds its application.

Injectable compositions must fulfill requirements such as: in moment of injection they have to be in liquid state, and after fulfilling the cracks, pores and voids, they have to have the ability to move to solid state. Also, compositions must possess a certain adhesion power to the rock (Jovanović, 1994).

Injection methods, according to its purpose, can be:

- Contact injection,
- Binding injection,
- Sealing injection,
- Consolidation injection,
- Tension injection.

Based on the time of perfoming injection in underground construction, we distinguish preventive and final injection. Figure 1 shows an example of preventive injection for the case of constructing a tunnel in unstable, water-bearing rock.

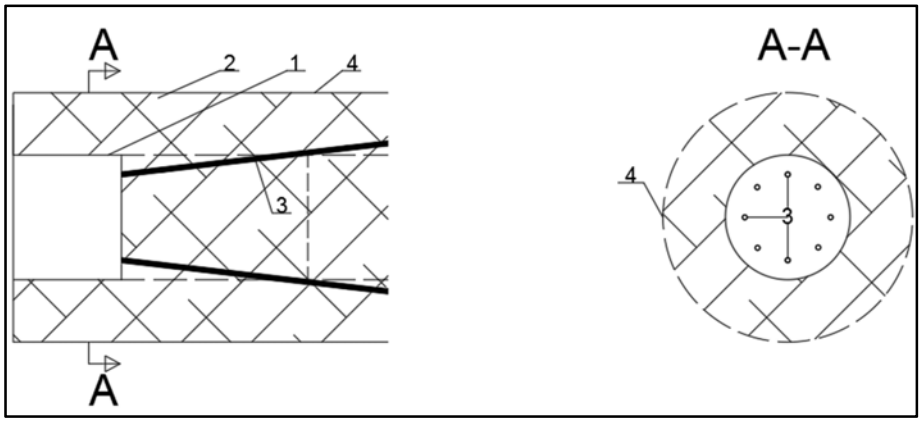

Figure 1 Example of preventive injection for the case of constructing a tunnel in unstable, water-bearing rock. 1 – Cracks filled with injection compositions, 2 – Unfilled cracks, 3 – Injection boreholes, 4 – Injection zone

4. INJECTION RESINS

Injection resins represent basic element of injection, and depending on their properties in liquid and solid form rely technological possibilities of injection (Cvetković-Mrkić, 1995).

The early injection resins consisted of cements, latter these were modified with supplementary materials such as bentonnite, fly ash and other puzzolans. In need for acceleration of the set time, silicate and similar materials were introduced, and are in use nowadays (these materials also reduce costs and they give practical solutions to many ground and water ingress problems) (Kay and Yang, 2007.).

In 70s started application of epoxy and polyurethane resin, but back in that time they were showing as non environmentally acceptable, but that problem was resolved during 80s and 90s.

If particle size of the primary substances are taken as a criteria of classification, we can divide them in three basic groups:

- Suspensions
- Colloidal solutions
- Real solutions

Suspensions, also known as classic resins or mineral suspensions, are dispersive systems of the cement particles in water. The size of particles goes from 10 μm to 100 μm. This suspensions, in their mixture, can include clay, bentonnite and different types of additives like sand and stone dust. These suspensions are in use for all types of injection in fractured rocks.

Colloidal solutions, with particle size of main substance is in area from 1 μm to 10 μm. With significantly smaller viscosity, compared to suspensions mentioned above, they have limited use mainly because of quality and durability of hardened composition.

Real solutions, also known as organic resins, are solutions of complex organic compunds in water with a series of additives with role to cause gelation and hardening of mass. Use of this group is limited because of high price.

Beside mentioned types of resins, in use are bitumen, bitumen emulsions and foams, which can be also put under classification according to the particle size of the primary subsistence, but can also represent a groups for themselves (Cvetković-Mrkić, 1995).

Injection resin have different viscosity, set time and strength, and they will be shown in Table 1.

Table 1 Injection resin properties (Kay and Young, 2007)

	Viscosity (Pa·s)	**Set time**	**Strenght (N/mm^2)**
Epoxy	0,25	10 – 60 min	40 – 90
Mineral suspension/Micro cement	0,025 -0,1	60 – 180 min	10 – 35
Polyurethane	0,095 – 0,25	5 – 200 sec	1 – 90
Acrylic Gel	0,01 – 0,04	5 – 300 sec	1 - 5

MC-Bauchemie Müller GmbH & Co. (MC-Bauchemie, n.d.) one of the leading international producers of building chemical products and technologies have 4 types of solutions which are in use for injection in underground construction of tunnels.

MC-Injekt 2700 stops pressurized water reliably during the construction of the start shaft and at the same time stabilizes the soil.

Sealing the contact area of a TBM between shaft and subsoil can be ensured by building a sealing ring with *MC-Injekt GL-95*. This tunnel sealing also saves time and money if the downtime of the TBM is minimized.

MC-Injekt 2300 top is used for concrete, when the ingress of water and pollutants must be prevented permanently.

The special hydro-structural resin *MC-Injekt GL-95 TX* is a proven technology in retro sealing of voids, cracks and joints in structures, concrete segments or in-situ elements. The flexibility and swelling properties meet the highest demands in terms of penetration and permanent sealing requirements.

In Table 2. properties of above mentioned resins will be shown.

Table 2 Properties of resins produced by MC-Bauchemie Müller GmbH & Co. (MC-Bauchemie, n.d.)

	MC-Injekt 2700	**MC-Injekt 2300 top**	**MC-Injekt GL-95**	**MC-Injekt GL-95 TX**
Density (kg/dm^3)	1,13	1,04	1,1	1,1
Viscosity (Pa·s)	0,2 ±0,05	0,055	0,005	0,03
Set time	30 s	35 min	5 – 73 s	19 – 140 s

5. THE APPLICATION OF THE POLYMER RESIN IN THE MINING INDUSTRY

The application of modified cement mixture, dispersion system cement and water in mining is increasingly confused by using polymeric resins.

Polymer resins must meet certain requirements in order to be used in mining, for sanation of degraded rock mass, those requirements are: sufficient adhesive ability, satisfactorily strong internal cohesion between molecules, resistance to lowered temperatures, non-toxicity, easy solubility.

Polymer materials that have large usage in today's mining, in terms of stabilization and insulation of degraded rock mass have features like: good consolidation speed, excellent adhesive strength, low viscosity, high resistivity to various chemical impacts and are also environmentally friendly (Trifunović et al. 2013).

In mining industry polymer resins find their field of application mostly in coal mines, in situations when they can be used for preventing penetration of water and gases into underground constructions, as well for consolidation of degraded rock mass (preventive injection of overburden in underground construction, preventive injection of coal layer on forehead of worksite, injection on forhead of longwall mining field, selective injection of excavation forhead, injection in tectonic zones...). Polymer resins in combined use with anchors represent very good reinforcement for underground construction, and their use is widespread. Figure 2 shows an example of combined reinforcement (anchor + polymer resin) for the case of insurance of overburden of corridor in one coal mine.

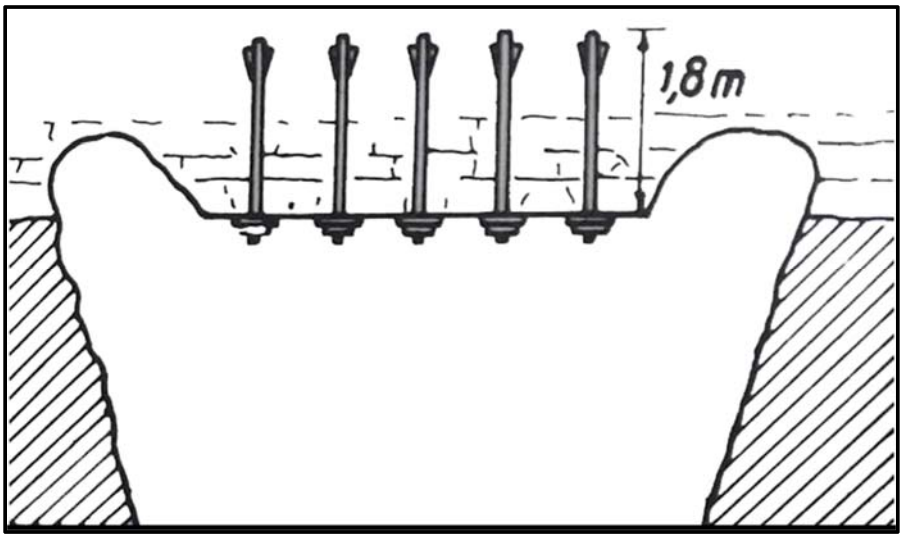

Figure 2 Example of combined reinforcement in one coal mine

6. CONCLUSION

As the technology develops every day, engineers in all branches should follow its development and find ways to applicate new knowledges. Awareness of mining and geotechnical engineers, that new materials for injection exist, need to rise to a higher level. Possibilities of development of these materials is expanded every day. Benefits of application are in first line is the reduced downtime, which has a direct reflection to the shortening of the total processing time. New resins showed very good technical characteristics (greater strengths with shorter set times than traditionally used ones), and in our opinion these resins should replace traditional ones for injection whenever the working conditions permit that. Also, before making a decision what material and type of resin should be used to get a job done, it is necessary to make a cost comparation, including down time, delay of project realization as well as all other parameters.

REFERENCES

CVETKOVIĆ-MRKIĆ, V. (1995) *Metode geotehničkih melioracija – prva knjiga.* Beograd: Rudarsko-geološki fakultet.

ĆULIBRK, R. (1999) *Geotehnički radovi u čvrstim stenama.* Subotica: Građevinski fakultet.

JOVANOVIĆ, P. (1994) *Projektovanje i proračun podgrade horizontalnih rudarskih prostorija – knjiga 1.* Beograd: Rudarsko-geološki fakultet.

KAY, W. and YANG, T. (2007) Advances in synthetic injection technology, do they improve tunnel construction productivity? In: *Underground Space – The 4th Dimension of Metropolises, Three Volume Set +CD-ROM: Proceedings of the World Tunnel Congress 2007 and 33rd ITA/AITES Annual General Assembly*. Prague: CRC Press, pp. 306-310.

MC-Bauchemie (n.d.) *Chemical products and technologies* [Online] MC-Bauchemie. Available from: http://www.mc-bauchemie.com/en/Products.aspx?key=injection%20products [Accessed 15/11/2016].

PASQUETO, A., CORBATTO, A. and SELETKOVIĆ, D. (2016) *Improvement of deteriorated foundation soil under abutments and pillars and depressions of pavement in the embankment area.* In: e-ZBORNIK, Mostar: Građevinski fakultet [Online] Available from: http://gf.sve-mo.ba/e-zbornik/e_zbornik_11_10.pdf/ Accessed [15/11/2016].

TRIFUNOVIĆ P., TOKALIĆ R. and GANIĆ A. (2013) Application of polymer composites for stabilization of degraded rock mass in mining. *Underground mining engineering*, pp. 23-31.

ZUBAC, Ž. and BOŠKOVIĆ, Ž. (2012) Issue of losing waters from Gorica's lake. *Vodoprivreda,* 44 (4-6), pp. 273-276.