



SHOTCRETE AND ITS USAGE

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Abstract. Shotcrete is a technique where the concrete mixture is applied to the surface with the help of high pressure and special equipment. The installation can be done through dry and wet mix method. This technique is flexible and has a fast way of installation, but requires good mechanization as well as specialized and well-trained workers. It can be used alone, or in combination with anchors, steel mesh, fiber or other. Shotcreting is widely used in construction especially in: tunnel construction; construction of hydro-technical facilities; slope protection; protection of construction pits; mining; airfields; reconstruction of various buildings, and others. Evidence of the mass and increased application of this technique can be seen in the figures. Thus, in 2019, 4.88¹ billion dollars were spent, and it is predicted that in 2023 this figure will be around 11.5 billion dollars. The biggest consumers of the sprayed concrete technique are the Europeans, but also the built-in quantities in Asian and other countries are not negligible. While in our country this technique is almost new, and it is mostly used in the protection of: slopes in road infrastructure, tunnel construction, hydraulic structures, and similar. There are several examples, but with the announced infrastructure projects it is obvious that this technique will certainly be installed in much larger quantities.

Keywords: dry mix method; wet mix method, road infrastructure; shotcrete; tunnel.

1. INTRODUCTION

Sprayed concrete is a special kind of concrete intended for installation with pressure spraying equipment. There are two methods of installation: the dry mix method, in which a dry mixture of cement and aggregate is transported through a pressure hose, and water is added to the nozzle just before installation, and the wet method, in which the finished concrete mixture is applied directly through the equipment.

The basic components of sprayed concrete are: cement, aggregate, water and additives. The quantities of cement range from 300-600 kg/m³, depending on the size of the aggregate, and for the production of sprayed concrete fractions of aggregate from 0-4 mm or 0-8 mm are used, and less often 0-16 mm. The water should be clean and free of chemicals, which should meet the conditions according to PBAB 87(Rulebook on concrete and reinforced concrete). Accelerators are most often used as additives, but in the group of additives can also be included: plasticizers, super plasticizers, antifreeze, aerators, and others. The most used additives are Ingunit-T EKO and Superfluid EKO².

Special equipment and a professional team are needed to install the shotcrete. The equipment used in the dry procedure is simpler, only a mixer and a nozzle are used. The mixer transports the dry mixture and water is added directly to the nozzle. While the equipment for the wet method is more modern because the ready mixture reaches the nozzle.

From the team that is involved in the shotcrete technique both professionalism and dedication are required for successful execution of sprayed concrete projects. The number of participants varies depending on the size and complexity of the facility and the procedure used for installation, and that number ranges from 4 to 8 people.

¹ www.databridgemarketresearch.com/reports/global-shotcrete-sprayed-concrete-market

² <https://www.ading.com.mk/>

2. APPLICATION OF SHOTCRETE

The shotcrete technique is a specific type of protection for excavations in solid rock masses. This technique has huge potential and a great future. It is constantly evolving starting from the first application. In recent decades, its features are being improved daily and adapted to the needs. It can be used individually or in combination with anchors, steel mesh, fiber or other. There is a wide application in projects like: tunnel construction; construction of hydro-technical facilities; slope protection; protection of construction pits; mining, and others. The shotcrete is also very suitable for the construction of buildings with unusual geometries, such as swimming pools, buildings with a rounded shape and similar buildings. As proof that it is widely used stand the numbers in the reports. According to some research, in 2019 alone, \$ 4.88 billion was spent. The largest consumers are the European countries, such as: Germany, Great Britain, Russia, Turkey and others. But the other continents should not be forgotten, America, Australia and Asia are not so far behind European countries.

2.1 SAFETY STABILITY MEASURES

The stabilization of the slopes is necessary even after natural phenomena such as: climate change, humidity, precipitation, freeze-thaw cycles, etc. Such phenomena have become more frequent as climate conditions have changed dramatically globally, especially in recent years. For that purpose, the technique of shotcrete is used as a protective measure. Protection of slopes with shotcrete is mostly applied in the protection of slopes where landslides occur.

In recent years, the use of sprayed concrete to stabilize slopes has significantly increased, both in our country and around the world. The process is simple and efficient and shotcrete can be used alone, but more often in combination with anchors; reinforcement mesh; fibers, or similar. Also, the shotcrete can be combined with other protective measures: with a road net; with gabions; with supporting structures, etc.

Introduction to this technique has been done in the project for protection of slopes on the access road to the dam St. Petka. This example is one of the first usages of shotcrete in North Macedonia. After that facility, shotcreting was used in "Landslide rehabilitation and landslide protection on regional road R-1102, section Veles-Gradsko" in "Protection of slopes on the expressway Prilep-Gradsko" and couple of others.



Figure 1. a) embedded mesh and b) embedded anchors

2.2 REPAIR OF LANDSCAPE AND LANDSCAPE PROTECTION REGIONAL ROAD R1102, SECTION VELES-GRADSKO

At the beginning of 2018, on the regional road R1102, section Veles - Gradsko, a landslide occurred, and activities for reparation were undertaken in February, 2020. Landslide rehabilitation at a place called Cucka, was a combination of several methods for landslide remediation and landslide protection (Figure 2). As part of most methods was the protection of slopes with sprayed concrete in combination with several other protective measures: shotcrete with anchors and paving net; shotcrete with gabions, and others.

Shotcrete protection was used whenever there were possibilities for new landslides. Before starting the construction of the shotcrete, the surface was cleaned, the reinforcing mesh was placed and it was fastened with anchors. At the end of the surface prepared in this way the sprayed concrete was applied in two layers, with a total thickness $d = 10-15$ cm.



Figure 2. Construction of shotcrete on regional road R1102, section Veles - Gradsko

For successful performance of the shotcrete technique, the order of subsequent steps that should have been observed was:

1. cleaning the surface that was going to be treated;
2. drilling of holes for placing anchor rods;
3. purification of the hole and placement of the anchor body;
4. injection (watering) of the anchors;
5. placing a base plate and nut;
6. installation of reinforcement mesh;
7. application of sprayed concrete and
8. drilling of short holes for drainage;

All surfaces were properly cleaned using compressed air or water. The anchoring was performed by SN-anchors RA 400/500, with a length of $3\div 6$ m and a diameter of $\varnothing 25$ mm, and it was used to secure the unstable rock blocks. The reinforcement was done by placing wire mesh MA 500/560, with a wire diameter of 6 mm and a distance between the eyes of 10×10 to 15×15 cm. The reinforcement nets were set, ie. separated from the excavation surface, but

did not extend beyond the thickness of the shotcrete. For that purpose, wedges were placed which provided the required position of the net. After the shotcreting was completed, the net was 1 cm covered with the sprayed concrete.

The dry method was also used for embedding sprayed concrete, i.e. mix cement, aggregate and accelerator additives, and water was added after in the spraying nozzle. The aggregate grains were not smaller than 10 mm, nor larger than 20 mm, and the dosage of cement and aggregate was in weight ratio from 1:3 to 1:4. The humidity of the unit ranged from 3 to 6%. The application of sprayed concrete was done pneumatically in layers with a thickness of 5 cm on previously prepared surfaces. The applied shotcrete was maintained by wet spraying with water for at least 7 days after the application, i.e. until the application of the next layer. While the drainage of the shotcreted surfaces was done by drilling appropriate holes with a diameter $\varnothing 50$ mm and a length of $0.5 \div 1.0$ m. The forecast distance between the boreholes was 6.0×6.0 m. These holes should have been drilled further after the full completion of the shotcreting.

2.3 PROTECTION OF SLOPES ON THE EXPRESS ROAD PRILEP-GRADSKO

In 2013, a basic project for the construction of the expressway Prilep-Gradsko with a total length of 32.81 km was developed. This project was carried out in several phases, and the construction activities for the realization of the route that passes through Drenovska and Farishka canyons had been started three years ago. Due to the complexity of the terrain, the slope needed protection. As protection measures on slopes several types were envisaged, including protection of slopes with shotcrete technique in combination with anchors, reinforcement mesh, and similar. During the construction of this phase, a total of about 1,000 m³ of sprayed concrete was installed (Figure 2).

For the preparation of this mixture, finely ground Portland cement without additives was used, which was to reach MB30. The grains of the aggregate were with $d_{\max} = 16$ mm, while the water satisfied the prescribed requirements according to PBAB 87 (Rulebook on concrete and reinforced concrete). Amounts of accelerator additives ranged from 4-6% of the total amount of mixture. After clearing the surfaces where the shotcrete was to be applied, the reinforcement mesh Q188 (MA 500/560) was placed, with a wire diameter of 6 mm and an eye distance of 10×10 to 15×15 cm. The anchoring was done SN-anchors (RA 400/500), with length $L=3-5$ m and diameter $\varnothing 25$ mm, and the placement of the anchors is $a_p/a_n = 2.5 \times 2.5$ m.



Figure 3. Protection of slopes with shotcrete, anchors and reinforced network on the expressway Prilep-Gradsko

3. CONCLUSIONS

Shotcrete is a special concrete intended for installation with pressure spraying equipment. There are two methods of installation: the dry method, in which a dry mixture of cement and aggregate is transported through a pressurized hose, and water is added to the nozzle just before installation. And the second one, a wet method in which the finished concrete mixture is applied directly through the equipment.

The shotcrete technique requires professionalism and dedication for successful execution of sprayed concrete projects. The number of participants varies depending on the size and complexity of the facility and the procedure used for installation.

Shotcreting is a specific type of protection for excavations in solid rock masses that is constantly evolving and improving its properties and adapting to the needs. It is widely used in construction, especially in: tunnel construction; construction of hydro-technical facilities; slope protection; protection of construction pits; mining, and others. The shotcrete is also very suitable for the construction of buildings with unusual geometries, such as swimming pools, buildings with a rounded shape and similar types of projects. The numbers prove that, for example, in 2019 alone, \$ 4.88 billion was spent on the installation of shotcrete.

In our country the first step in wide shotcrete usage was made when protecting slopes of the access road to the dam St. Petka. As a continuation of the use of this protection measure are the facilities: "Landslide rehabilitation and landslide protection on regional road R-1102, section Veles-Gradsko"; "Protection of slopes on the expressway Prilep-Gradsko" and many more. Only with these two facilities are installed about 1,200 m³.

In both elaborated examples, shotcrete was used in combination with reinforcement mesh and anchors, with similar characteristics. The anchoring was done with SN-anchors RA 400/500 and diameter Ø25 mm, while the reinforcement was done by placing wire nets MA 500/560, with a wire diameter of 6 mm and an eye distance of 10 × 10 to 15 × 15 cm.

After the successful projects, the shotcrete received positive reviews from all experts, as well as opportunities for massive application in future. With the announced capital investments in road and railway infrastructure, such as the construction of Corridor 8 and the railway to R. Bulgaria, the future of shotcrete in North Macedonia will be bright. Large quantities of sprayed concrete and application of this technique are projected for installment in several planned facilities with a quantity of over 12000 m³.

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