

## A Report from the ITA Working Group on Shotcrete Use

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**W**orking Group 12, Shotcrete Use of the International Tunneling and Underground Space Association (ITA), was established in 1989. The group has primarily concentrated its work on making new information available to all national groups, advancing knowledge about the material by collecting available information, or obtaining new information by means of specific testing programs.

The first task Working Group 12 had was to prepare two state-of-the-art reports: “Shotcrete in Tunneling—Status Report 1991,” and “Shotcrete for Ground Support: Guidelines and Recommendations—A Compilation, 1992.” The first report was the basis for a publication in *Tunneling and Underground Space Technology* (Franzén 1992).

The working group also investigated the durability and use of shotcrete for the permanent lining of tunnels. Two reports were prepared: “Guideline to the Processing of Durability Data,” by K. Garshol, and “Shotcrete as Permanent Lining,” by N. Tomisawa, compiling information from nearly 150 cases in 11 countries. These reports were also published in *Tunneling and Underground Space Technology* (Franzén et al. 2001)

After collecting case histories about the use of shotcrete in many countries, the Working Group compiled the contents of national codes, standards, and guidelines. This report was prepared by B. Malmberg (Malmberg 1993a) and also published in *Tunneling and Underground Space Technology* (Malmberg 1993b).

A report on health and safety in shotcreting, which was based on a survey by K. Ono, was released in 1995. The results were also published in *Tunneling and Underground Space Technology* (Ono 1996).

In 2005, two reports were produced about state-of-the-art shotcrete for rock support and the design of shotcrete support. The findings reported are briefly presented herein. Some ongoing activities will also be described, such as a testing program for the comparison of performances of synthetic and steel fibers for shotcrete reinforcement, and a survey about products for shotcrete fire protection will be presented.

Whereas cultural differences related to tunnel design and construction will always exist, improved

knowledge about materials and their capabilities has contributed to a more rational use of shotcrete for the improvement of tunnel construction.

### State-of-the-Art Report on Shotcrete for Rock Support

The report was based on a compilation of information from the ITA National Groups under the coordination of K. Garshol, then Animateur of the working group. The report contains replies from the national groups on guidelines, specifications, and standards; design; concrete technology; equipment and application methods; method of reinforcement; shotcrete for permanent linings; health and safety; and other items. Contributions were received from 21 countries.

Excerpts from comments by the Animateur are presented as follows about each one of the subjects covered in the report.

- A variety of local and international codes, standards, and guidelines are adopted in different countries. The EFNARC specifications, the Austrian, Norwegian, and Japanese guidelines have good international recognition, as well as part of the ASTM International guidelines. The Australian Round Determinate Panel test for failure energy testing has gained international acceptance;
- With respect to design, the report reflects a very wide variety of concepts adopted in different countries. Whereas there is a clear trend to move from the concept of rock support to rock reinforcement, different ways of approaching the problems are illustrated by examples of thickness reduction from approximately 3.3 ft (1 m) cast-in-place concrete down to 3.9 to 5.9 in. (10 to 15 cm) of shotcrete. This is an area in which the role of information exchange between different member nations may still lead to significant rationalization;
- There is clear progress in the use of alkali-free accelerators due to improvements related to health and safety requirements and performance. The use of high-range water-reducing admixtures has also increased aiming at reducing water-cement ratios and increasing fluidity. A trend is also observed with respect to the improvement

of the bond between fibers and the concrete matrix. Also significant is the trend toward using a wet-mix instead of a dry-mix process;

- Contributions show a tendency toward the use of wet-mix dense-stream application methods, as well as robotic shotcrete equipment with computer-assisted capability to monitor the dose rate of the accelerator. An increase in output is reported to values of 26.2 yd<sup>3</sup>/hour (20 m<sup>3</sup>/hour) with dust reduction;
- The progress in the use of fibers for reinforcement instead of wire mesh is very clear from almost all contributions received. Several examples presented labor-saving advantages and a reduction in construction time. A contribution is presented to overcome the problem of the lack of reinforcement continuity through construction joints when using fibers;
- The use of shotcrete for permanent lining has increased in many countries, but has not been adopted at all in others. As mentioned previously, the advantages of this procedure are very clear when observing the reduction in lining thickness. Improvements in durability have increased the reliability of shotcrete for this purpose. As shown in the introduction of this paper, the working group presented important contributions on this subject;
- The contributions concerning health and safety are related to reducing dust and avoiding falling rock during construction; and
- Other contributions covered subjects such as terminology, ambient temperature conditions, and the effects of dynamic loads from blasting close to the applied shotcrete.

## Report on Design and Guidelines for Shotcrete Support

This report was first prepared in 2003 as a reference of the former report, "Shotcrete for Rock Support." After the working group meeting in Istanbul, Turkey, in 2005, a decision was made to publish the report independently.

The report is based on a compilation of information from the ITA national groups, under the coordination of N. Tomisawa, then Vice-Animateur of the working group. The report contains replies from the national groups on the subjects such as design of shotcrete for rock support, guidelines and standards, and references on mechanisms and roles of shotcrete for rock support.

Contributions were received from seven countries including the Czech Republic, Germany, Iceland, Italy, Japan, South Africa, and the United Kingdom (Hong Kong). In addition, the author

quoted the content concerning the design of shotcrete from the state-of-the-art reports submitted by Belgium, Brazil, Sweden, Turkey, and Denmark.

## Ongoing Activities Fiber-Reinforced Shotcrete Testing Program

A testing program on the comparative structural behavior of different types of synthetic and steel fibers for shotcrete reinforcement is underway. The idea of the program is to obtain information about the performance of as many fibers as possible, with a neutral and independent testing program. Today, this type of information is only available from suppliers, and it is based on different types of tests—each carried out on shotcrete with different properties. This program intends to obtain data from the same tests to be carried out on the same type of shotcrete.

The spraying and testing activities have been carried out at the Hagerbach Testing Gallery in Switzerland. Spraying of shotcrete with the first set of fibers has already occurred, and tests are under way. A second stage of spraying and testing with new fibers is being planned.

The program consists of:

### Investigation Program A—Early Strength

- Applying shotcrete with a fiber content that is defined by the supplier;
- Investigation of the unset concrete;
- Plate tests on round samples after 12 hours, 3 days, and 28 days; and
- Determination of the fiber content in the tested samples.

### Investigation Program B—Long-Term Behavior

- Applying shotcrete with a fiber content that is defined by the supplier;
- Investigation of the unset concrete;
- Aimed Energy absorption E 1'000J;
- Plate tests on round samples after 28, 90, 180, 270, and 365 days; and
- Determination of the fiber content in the tested samples.

Both programs could be combined to save efforts in the application and testing of some samples.

All results will be treated confidentially. Results will be published in an anonymous way. Only final and global results will be released in the reports and publications. Partial and individual test results may be accessed only by the corresponding supplier. ITA will provide each supplier with an identification code to be used in the reports.

## Shotcrete Fire Production

A survey of sprayable mortars for fire protection has been studied for several years. Based on a report and list prepared by the French Group, a decision was made to compile data from other member nations and to summarize the information in form of a table.

## Concluding Remarks

A summary of the activities of the ITA Working Group on Shotcrete Use has been presented. Emphasis has been given to the independent testing program on the performance of different types of fibers for shotcrete reinforcement. The working group is actively pursuing its goal of improving and disseminating knowledge of the important advantages of using shotcrete for underground applications.

## References

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