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ACTIVITIES OF THE ITA WORKING  
GROUP ON SPRAYED CONCRETE  
USE

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## ACTIVITIES OF THE ITA WORKING GROUP ON SPRAYED CONCRETE USE

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### ABSTRACT

This paper describes the activities of the International Tunnelling and Underground Space Association (ITA) Working Group 12 on Sprayed Concrete Use. The Working Group has carried out tasks with the purpose of promoting information exchange between National Groups and planning, coordinating and releasing the results of testing programs in order to advance the state-of-the-art of sprayed concrete use for underground support. The intention of the Working Group is to explore and develop the idea that the rational use of sprayed concrete improves possibilities for design and construction of new underground works.

### INTRODUCTION

The ITA established the Working Group 12 on Shotcrete use in 1989. Since then the main activities of the Group have concentrated on:

- Making available new information about the material to all ITA National Groups;
- Promoting the advance of knowledge about the material by collecting information available, or obtaining new information by means of specific testing programs.

The first task of the Working Group was the preparation of two state-of-the-art reports: "Shotcrete in Tunnelling – Status Report 1991", and "Shotcrete for Ground Support: Guidelines and Recommendations – A Compilation, 1992". The first report was the basis for a publication in *Tunnelling and Underground Space Technology* by Franzén (1).

The Working Group also dedicated efforts to the subject of durability of sprayed concrete and its use for 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. The reports were also published in *Tunnelling and Underground Space Technology* by Franzén *et al.* (2).

After the collection of case histories about the use of sprayed concrete in many countries, the Working Group decided to compile the contents of national codes, standards and guidelines. This report was prepared by Malmberg (3) and also published in *Tunnelling and Underground Space Technology* by Malmberg (4).

A survey was conducted by K. Ono and resulted in a report on health and safety in shotcreting, being released in 1995. The results were also published in *Tunnelling and Underground Space Technology* by Ono (5).

In 2005, two reports were produced about the state-of-the-art of sprayed concrete for rock support and on the practice of design of sprayed concrete support. The results of these two reports are briefly presented here. Some of the ongoing activities of the Working Group are also described, including a testing program for comparison of the performances of synthetic and steel fibers for sprayed concrete reinforcement, and a survey about products for sprayed concrete fire protection.

Whereas specific aspects of local culture in different countries related to tunnel design and construction will always exist, knowledge provided by the ITA Working Group about the material and its capabilities has contributed to more rational use of sprayed concrete and improvement of tunnel construction.

## **REPORT ON SPRAYED CONCRETE FOR ROCK SUPPORT**

This ITA 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 with respect to the following subjects.

- Guidelines, specifications and standards;
- Design;
- Concrete technology;
- Equipment and Application Methods;
- Methods of Reinforcement;
- Sprayed concrete for permanent linings;
- Health and safety;
- Other items.

Contributions were received from 21 countries. The report also contains comments by the Animateur about all subjects of the survey.

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

- A variety of local and international codes, standards and guidelines have been adopted in different countries. The EFNARC specifications, the Austrian, Norwegian and Japanese Guidelines have good international recognition, as well as part of the ASTM Standard Test Methods and Specifications. The

Australian Round Determinate Panel test for failure energy testing has gained international acceptance and is now published as ASTM C1550.

- 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 about 1 meter for cast-in-place concrete down to 100 to 150mm for sprayed concrete. This is an area in which the role of information exchange between different Member Nations may still lead to significant rationalization in design.
- 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, reducing water-cement ratios and increasing fluidity of pumped sprayed concrete. A trend is also observed with respect to improvement of the bond between fibers and the sprayed concrete matrix. Also significant is the trend towards using wet-mix sprayed concrete in preference to the dry-mix sprayed concrete process.
- Contributions show a tendency towards the use of wet-mix dense stream sprayed concrete application methods, as well as robotic sprayed concrete equipment with computer assisted capability to monitor the dosage rate of accelerator. Increased sprayed concrete output is reported with values of 20m<sup>3</sup>/h, with dust reduction.
- Progress in the use of fibers for reinforcement in substitution for wire mesh is very clear from almost all contributions received. Several examples are presented with advantages of labor savings and construction time reduction. A contribution was received regarding how to overcome the problem of the lack of reinforcement continuity through construction joints when using fibers.
- The use of sprayed concrete for permanent linings has increased in many countries, but has not been adopted at all in others. As mentioned before, the advantages of this procedure are very clear when observing the reductions of lining thicknesses. Improvements in durability have increased the reliability of sprayed concrete for this purpose. As noted in the introduction of this paper, the Working Group has presented important contributions for this subject.
- The contributions received about health and safety are related to dust development and workers' health, and how to avoid falling rock during construction.
- Contributions about other items covered the subjects of terminology, ambient temperature conditions and the effects of dynamic loads from blasting close to the applied sprayed concrete.

## **ONGOING ACTIVITIES**

### **Fiber Reinforced Sprayed Concrete Testing Program**

A testing program on the comparative structural behavior of several synthetic and steel fibers for sprayed concrete was undertaken. The idea is to obtain independent information with the same testing procedures, not usually available, about the performance of different types of reinforcing fibers. The first stage of spraying and testing at Hagerbach Underground Laboratory took place in 2006. A second and

broader stage is planned for 2009. Besides the performance of different fibers, the tests will also investigate the influence of sprayed concrete age. The tests have been planned after an extensive survey of similar results in the literature.

### **Sprayed concrete Fire Protection**

The use of sprayable mortars for fire protection of new and existing tunnels has been studied for several years. The work is based on a survey conducted CETU – Centre d'Etudes des Tunnels, France. The main objectives of the survey were:

- To check the fire resistance of a structure protected by different products; and
- To facilitate the selection of the most suitable product for each specific application.

A paper about this work was presented by Larive *et al.* (6) at the Conference on Fire Protection Engineering for New and Existing Tunnels, held in London.

### **Nozzleman Certification**

Different procedures for nozzleman certification exist in different countries both for manual and robot operations. In most countries, no procedure exists at all. The intention of the Working Group is to disseminate ideas and improve exiting guidelines by promoting the exchange of experience in a field which is crucial for the final quality of sprayed concrete. Papers about this subject were published by Larive and Gremillon (7) and Larive (8).

### **Curing and Durability**

Curing is another aspect with strong influence on the final quality of sprayed concrete and its durability. While some specifications require curing procedures, water spray or the application of membranes in some countries, nothing is adopted in most of the spraying operations. Variable environmental conditions in tunnels contribute to variable concrete properties, a strong component for low quality. For equal reasons, the Working Group intends to collect and disseminate information.

### **Glossary**

A glossary of technical terms related to sprayed concrete is being prepared. So far, more than 120 terms have been compiled and organized in 10 languages: English, German, Spanish, Portuguese, French, Italian, Dutch, Japanese, Czech and Persian (Farsi).

### **CONCLUDING REMARKS**

A summary of the activities of the ITA Working Group on Sprayed concrete Use has been presented. Even taking into account local peculiarities related to the practice in different countries, the information created and released by the ITA Working Group has contributed to the rationalization and broadening of sprayed concrete applications, and to the improvement of construction of underground works.

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