Certification of sprayed concrete nozzle operators is an important issue in the ITA-AITES working Group 12 ‘Sprayed Concrete Use’. An updated state-of-the-art was asked by the South African member of the group in view of a the Conference “Shotcrete for Africa” during which the interest of certification was to be debated. This is the topic of this paper, presented in Johannesburg in March 2009, under the title “Why and How to Certify sprayed concrete nozzle operators?”

Abstract
The quality of sprayed concrete is highly dependent on the skill of the nozzle operators. No universal standards are available to certify their ability to spray concrete. So it is necessary to identify all the available certification programmes in order to check and, if necessary, to improve the expertise of nozzle operators.

This paper describes a number of independent certification programmes run by different organisations. Four main programmes are now available. Three others are being developed.

Certification, added to intensive training, is the best way to raise the quality of sprayed concrete operations.

Résumé
ETAT DES CONNAISSANCES RELATIVES À LA CERTIFICATION DES OPERATEURS DE BÉTON PROJETÉ
La qualité d’un béton projeté dépend beaucoup de la compétence des opérateurs. Aucun standard universel n’est disponible pour certifier leur aptitude à projeter du béton. Aussi est-il nécessaire de bien identifier tous les programmes de certification disponibles afin de vérifier et – si nécessaire d’améliorer – la qualification des opérateurs.

Cet article décrit un certain nombre de programmes de certification indépendants utilisés par différentes organisations. Quatre programmes principaux sont aujourd’hui disponibles ; trois autres sont en cours d’élaboration.

La certification, ajoutée à l’indispensable formation des opérateurs, est le meilleur moyen d’améliorer la qualité du béton projeté.

1 - WHY CERTIFY SPRAYED CONCRETE NOZZLE OPERATORS*?
Sprayed concrete is both very similar and very different from “ordinary” poured concrete:
• similar, as it is made of the same materials and provides about the same mechanical properties and durability
• but very different as it is much more flexible to use but also much more dependent on the skill of workers (which does not mean that qualifications are not also an issue for poured concrete).

Having said that, as it is in their best interests, we could expect companies to have “the right person in the right place”. But, how can we be sure of that? How do we minimise the risk of misuse? And how to distinguish between companies with or without real knowledge and expertise of this technique?

Standards, while necessary, are not enough to provide high quality projects. It is not enough to have good materials and mix design, efficient equipment, correct calculations and so on. However, there are currently no national or international standards to qualify operators.

Certification provided by independent institutions is a very convenient way to solve this problem. This paper aims to present the existing certification systems and their particular features.

2 - DIFFERENT TYPES OF SHOTCRETE, DIFFERENT CERTIFICATIONS
Sprayed concrete is widely used in civil engineering work nowadays. For example it can be found in:
• underground constructions, either for temporary or permanent support
• mining
• soil nailing and slope stabilization
• houses, swimming pools and various sports facilities
• repair and reinforcement of concrete structures, for instance bridges, buildings, etc.

It is used for applications needing immediate safety and/or long-term durability. In both cases, one needs to be able to rely on the quality of the in-situ materials, not only on their constituents.

Some countries have or are about to establish certification programs for sprayed concrete nozzle operators, such as Canada, the United States, France, Norway, Germany, Brazil and Sweden.

The issue is to check that certified nozzle operators have the ability to perform a good job. Therefore examiners need to verify their theoretical and practical knowledge.

Several types of jobs must be distinguished as they require different expertise:
• the dry-mix process is different from the wet-mix process (the nozzle operator has to precisely regulate the water flow as well as the air flow)
• projection onto vertical surfaces is easier than projection onto overhead surfaces
• repairs by spraying sand concrete in small galleries requires specific skills
• robot-aided spraying is different from manual spraying.

Some certification schemes distinguish all these fields, others only some of them. Some offer several qualification levels to make a distinction between more or less skilled operators, others don’t. This paper will present all these points in further detail.

* Previously known as nozzlemen
What is important is not to get ‘A’ certificate but to get ‘THE’ certificate that corresponds to the requirements.

3 - THE AVAILABLE CERTIFICATION PROGRAMMES

Information available in this paper has been gathered mainly from members of the International Tunnelling Association’s Working Group 12 “Shotcrete Use”. It may still not be exhaustive. Any comments or additions are welcome.

First, it is important to distinguish different types of certification organisations. Some civil engineering companies offer really good training courses to their staff and may award certificates to their qualified personnel. These certificates can be very valuable, and it is highly desirable that as many companies as possible put the greatest emphasis on the training and qualification of their staff. Nevertheless, this paper is not dedicated to in-house training and/or certification but to independent certification bodies.

3.1 - ACI

The certification scheme for shotcrete operators provided by the American Concrete Institute (ACI) is the most widely used. It is intended to certify experienced nozzle operators (prerequisite: 500 hours of verified work experience as a nozzle operator or operator-in-training). It certifies both their theoretical knowledge and their practical ability. It distinguishes four categories of work:

• wet mix process, vertical position only
• wet mix process, vertical & overhead positions
• dry mix process, vertical position only
• dry mix process, vertical & overhead positions

The first ACI “Guide to Certification of Shotcrete Nozzlemen” was published in 1991 and since then the “Shotcrete for the Craftsman” guide has been regularly updated. It allows nozzle operators to work by themselves in order to prepare their examination. ACI does not provide training courses but the ASA (American Shotcrete Association) offers training sessions to prepare for ACI certification. This distinction between certification and training is a way to ensure the neutrality of the examiner.

3.2 - ASQUAPRO

Initially based on the Canadian certification programme, a certification scheme has been available since 2001 in France from ASQUAPRO, a French non-profit technical Association for the Quality of Sprayed Concrete and Mortars.

In 1995-96, Canada first developed its own certification programme, required by the Ministry of Transport from Quebec (MTQ). Then the Canadian and American groups worked together and ACI certification is now required by the MTQ.

As with ACI certification, in France too, both theoretical and practical knowledge are required to be tested.

The major differences are:

• the ACI prerequisite of 500 hours work is not necessary. Instead there are four levels of qualification; the first is aimed at operators with less than 100 hours experience. They cannot be certified as nozzle operators but, if they pass both the theoretical and practical examinations, they can get an “approval to spray” under the supervision of a certified nozzle operator and they will be certified once they have done 100 hours of real practice. The three certification levels correspond to increasing degrees of operating experience: “certified”, “confirmed”, “highly qualified” operators

• dry and wet mix processes are distinguished but not vertical and overhead projection: the nozzle operator must spray both vertical & overhead panels

• as it is significantly different from the usual manual spraying, specific certifications have been established for spraying sand concrete in small galleries, and more recently for robotic application

• the certification can be taken either at the end of a training session conducted by independent institutes, or on the premises of the companies wanting to certify their nozzle operators or on the building site.

3.3 - The Norwegian Concrete Educational Council

The “Concrete Educational Council” is an association established by a group of large Norwegian organisations within the construction sector: ready mix suppliers, general contractors, manufacturers of prefabricated concrete elements, etc. It is in charge of both:

• training (offering courses with adequate content, competent teachers, good written materials)
• certification (offering examinations, delivering certificates and registering of certified nozzle operators).

The secretariat of this council is held by the Norwegian Concrete Association.

Requirements for the competence of key personnel are specified in the Norwegian Standards currently in use and the national versions of the relevant EN-standards.

Theoretically, in Norway, not every nozzle operator has to be certified but only leaders (foremen; production, control & testing working crew leaders) have to show that they are familiar with sprayed concrete. In fact, for the wet-mix process for underground support, only robot projection is used and the operator is considered as a crew leader, so must be certified.

For dry process operators engaged in concrete repair, the situation is different: they are considered as members of a concrete repair crew. So they do not need to possess a certification, but their leaders must (working crew; foremen; production and control & testing leaders).

There are three types of certification:

• one for foremen and crew leaders
• one for normal class production leaders and control & testing leaders
• one for extended class production leaders and control & testing leaders.

The Norwegian certification covers both manual and robotic spraying.

There is no distinction between vertical and overhead position.

There is no practical examination but practical experience is the first prerequisite for certification:

• one year for foremen, crew leaders and normal class production or control & testing leaders
• three years for extended class production and control & testing leaders.

The second prerequisite is education:

• engineering education for production leaders and leaders of control & testing
• professional education for foremen and crew leaders

The last requirement to pass the Norwegian
certification is a 5-day course (or 2 x 2.5 days) at the end of which everybody takes the same exam.

3.4 - The practice in Germany
In Germany, a certificate is especially required for the repair/strengthening of reinforced concrete structures by specific sprayed concrete or mortars containing resin. This certificate is issued after a training session by academies authorized by the "German Concrete and Civil Engineering Association". It consists of two parts, theoretical and practical (spraying concrete on a vertical surface with a high content of reinforcement). Spraying is only manual. It can be either done by wet or dry process. There is one single certification level, dedicated to experienced nozzle operators.

For all applications, the DIN 18551: 2005-01 (shotcrete - specification, production, design and conformity) postulates in chapter 4.2: "sufficient experience and knowledge of the nozzlemen", without mentioning a specific certificate.

4 - HOW MANY CERTIFIED OPERATORS AROUND THE WORLD?

4.1 - ACI
ACI certification is issued worldwide. It has been granted to:
• 3 operators are also certified for “robotic application on underground support”.

It is possible to take the certification after a training course organized by a separate body, or during the preparation phase, on site, in France or abroad, as a prerequisite step before the work can start.

4.3 - The Norwegian Concrete Educational Council
In Norway, since 2003, around 120 operators have been certified. Half of them are production or control & testing leaders (Class Extended Control). As many as 205 people are still “in the process”. Some still have insufficient experience, most have finished the special 2.5 day-sprayed concrete course and passed the exam but still lack the general concrete technology course.

5 - CERTIFICATION SCHEMES BEING DEVELOPED

5.1 - IBRACON
A certification programme was first established in Brazil in 1996 (Vieira, 1999). Some certificates have been issued but as there was no specific institution in charge of the certification system, it is impossible to know how many people are certified today.

Now, IBRACON, the Brazilian Concrete Association, is working to achieve a certification for shotcrete operators for the Brazilian federal programme of workmanship qualifications. So, the IBRACON qualification will be valid in the 26 Brazilian states. The certification will focus on the dry mix process but the programme could be extended to wet-mix in the future. Certainly there will be a distinction between manual and robot projection but vertical and overhead spraying will probably not be differentiated. Examinations will cover both the theoretical and practical aspects. There will be only one certification level.

5.2 - EFNARC
EFNARC, the European Federation of Specialist Construction Chemicals and Concrete Systems, was founded in 1989 by five national trade associations representing producers and applicators of specialist concrete products. Its membership has since widened and no longer includes trade associations but consists of companies, manufacturers, contractors and consultants. EFNARC’s aims and objectives include continually raising the technical and professional standards of the industry by producing technical specifications, guidelines, checklists and training certifications. A working group is preparing a nozzle operator certification scheme. They plan to deliver a document of about 200 slides for self-study in 2009.

The certification will cover the field of robotic projection for rock support, including vertical and overhead projection, as well as spraying into lattice girders and, in fact, on the whole tunnel profile.

The EFNARC certification scheme begins with examiners’ certification during sessions organized by VSH in the test gallery of Hagerbach, Switzerland. The duration of the examiners’ course will be 2 or 3 days. The second step will be the local certification of nozzle operators (on site) validated by approved examiners after providing a nozzle operator course in the local language.

The theoretical exam will be a 50-questions multiple choice paper. The practical one will consist of spraying concrete with a robot and testing its consistency. There will also be oral and visual examinations.

5.3 - The Swedish Shotcrete Center and Vattenfall Utveckling
In 2006, the Swedish Shotcrete Center and Vattenfall Utveckling, two consulting and Research & Development organisations, had already started to implement certification of nozzle operators in Sweden. The certification examination was only theoretical and written.

Since then, a new working group has developed a programme for certification of supervisors and nozzle operators. The working group is drawn from mine workers, contractors, the Swedish National Road Department, the Swedish National Rail Department, suppliers, Vattenfall Research and Development, and others.

Examinations will now be theoretical and practical and they will be taken after a 40-hour course, providing theoretical and practical training, called “rock support and
repairing with shotcrete”. The education before certification will be the same for supervisors and nozzle operators and therefore there will be only one certification level but different requirements for prior knowledge.

Certification will not distinguish between vertical and overhead position, manual and robotic spraying.

6. MAIN CHARACTERISTICS OF THE CERTIFICATION PROGRAMMES

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<th>Table 1</th>
<th>Process</th>
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<th>Table 2</th>
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<td>Several levels</td>
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More information is given by Larive & Gremillon (2007) on:
- the content of the theoretical examinations,
- the minimum marks required to pass the exams,
- how the panels are assessed after the practical tests,
- the duration of validity and re-examination conditions.

7 - WHAT ABOUT TRAINING?

Today as well as in the past, a lot of theoretical and practical sprayed concrete training is actually carried out by sprayed concrete equipment suppliers and admixture manufacturers (Normet, Mapei, TAM, BASF, Sika etc.). This is the case, at least when talking about wet-mix process, for all the tunnelling contractors and mining companies when they buy a new sprayed concrete robot. Such courses are usually tailor-made for the customers’ and operators’ specified needs. Usually all training is carried out in real workforce conditions on the same project where equipment is delivered. Training sessions can last between 1 day to 1 week depending on the general technical skill-levels of the operators. Separate courses can also be arranged for supervisors leading the sprayed concrete works at the site.

In terms of training prior to taking the certification examination, in Canada and the USA, the American Shotcrete Association (ASA) provides training courses. The two aspects - training and certification - are clearly separated and performed by independent organisations. In parallel, the ACI sells publications to help nozzle operators assess or check their knowledge.

The principle is exactly the same in France. There are some training sessions proposed by independent institutions, some of which are members of ASQUAPRO, such as the CPO and ABCCR. In parallel, ASQUAPRO produced publications about sprayed Concrete that can be freely downloaded from its website.

In Brazil, there are also plans to separate the two aspects, certification and training. IBRACON will only be in charge of certification and other institutions will give training sessions.

The situation is completely different for the other certification schemes, which require the attendance to training sessions or the study of training materials (Norwegian, Swedish, German, EFNARC certification).

Finally, we should not forget the training provided by civil engineering companies in order to raise standards in their workforce. In 1983, the importance of training and certification of nozzle operators was already highlighted by the Crom Corporation, referring to the ACI committee 506 (Hen-drix, 1983). Companies sometimes complete the training process by delivering an in-house certification, such as Stratecrete in Australia or Morgan Est in the UK. Sometimes, they prefer an independent body to certify the ability of their operators, for example Freyssinet in France.

8 - CONCLUSION

The ACI certification for nozzle operators is the most widespread and well-known. Ideally suited to experienced operators, it ensures their ability to do a good job.

The ASQUAPRO certification is quite similar but more open to beginners, distinguishing four levels, from the ”operator-in-training” with a minimum guaranteed level of theoretical and practical knowledge, to the plain ”certified” nozzle operator, then the ”confirmed” or ”highly qualified” nozzle operator.

The Norwegian and Swedish approaches both emphasise the important idea of certifying all staff involved in shotcreting, not only the nozzle operators.

The German practice illustrates that the field of repair/reinforcement of reinforced concrete structures is the most critical one.

The Brazilian and the EFNARC certification schemes will, at least in the beginning, be dedicated to specific fields of application: the dry-mix process for the first scheme and the wet-mix process with robotic spraying for the last.

It is quite surprising to reflect on the gap that exists between the well-known critical impact of the nozzle operator’s skill on the quality of the in situ sprayed concrete and the fairly scarce resources in independent organisations providing certification schemes for nozzle operators.

It would never cross a designer’s mind to
build a steel bridge with non-certified welders. So why don’t designers needing sprayed concrete make a point of always calling for certified nozzle operators? Is it because concrete is not prestigious enough? Is it for fear that prices would rise? Do people think that low-cost work will produce high quality results?

Certification opportunities are multiplying. Nevertheless the driving force should come from clients raising their requirements.

9 - ACKNOWLEDGMENTS

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DIN 18551: 2005-01 (Shotcrete - specification, production, design and conformity)


ASQUAPRO, “Sprayed Concrete Use”; “Sprayed Concrete Implementation”; “Sprayed Concrete Mix Design Optimisation”; “Sprayed Concrete Control”; “Sprayed Concrete Design” (see web site)

WEB SITES

ACI: www.concrete.org
American Shotcrete Association (ASA): www.shotcrete.org
ASQUAPRO: www.asquapro.asso.fr
EFNARC: www.efnarc.org
IBRACON: www.ibracon.com.br
GERMANY: www.verkehrsblatt.de/docs/ars-bau.php

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