

ÖKAT FOKUS PÅ BETONGSPRUTNING - OLIKA OPERATÖRSCERTIFIERINGAR I VÄRLDEN

INCREASED FOCUS ON CONCRETE SPRAYING - DIFFERENT OPERATOR CERTIFICATION SCHEMES AROUND THE WORLD

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Summary

During the last 10 years the tunneling and mining industries have had greater focus on the quality, costs and above all the safety around concrete spraying works. In 2009 the international industry group EFNARC established the Nozzlemen Certification Scheme – a certification that was intended to fill the qualification and accreditation gap existing for sprayed concrete operators, so called Nozzlemen. The organization has since then certified approx. 400 operators and the majority of them in Great Britain. Establishing the EFNARC has also led to a raised awareness of the importance of having skilled and qualified Nozzlemen among other countries, projects and organization that have started requiring or setting up other qualifications. The Swedish Transport Administration is one of those who established a certification in 2016 that now have become a national standard in the country Sweden.

This article provides information on four different projects and organizations around the world and the qualification schemes for Nozzlemen that they have required:

- The road tunnel project, E4 Stockholm Bypass in Sweden,
- the road tunnel project WestConnex M4 East & New M5 in Australia,
- the metro tunnel project Crossrail in Great Britain and,
- Boliden Mineral's mines in the Boliden Area in Sweden.

The qualifications all differ in structure and content, but share the purpose of being required to enhance quality, cut concrete costs and improve safety, during and after concrete spraying

It is likely that more will follow now when the above written prestigious tunnel projects and organization have required qualifications for Nozzlemen. The conclusions from this article therefore lean towards and elaborates around the need for a European or global standard for Nozzlemen qualification requirements. That standard could be based on the requirements and certification schemes revealed in this article such as the one developed by the Swedish Transport Administration.

1. E4 Stockholm Bypass, Sweden

About the project

The project will connect the southern and northern parts of the Stockholm county in Sweden, relieve the arterial roads and the inner city of traffic and reduce the vulnerability of the city's traffic system.

A new link west of Stockholm has been under investigation for several decades and a large number of different alternatives have been studied. When the link opens for traffic it will be one of the longest road tunnels in the world. By 2035, the project's client, the Swedish Transport Administration (Trafikverket) estimates that the E4 Stockholm Bypass will be used by approximately 140 000 vehicles per day. (Trafikverket, 2018)

The construction work for the first main contract started in January 2016 and now all tunnel production sites are under construction. The E4 Stockholm Bypass will take approximately 10 years to finish.

To reduce the impact on the surrounding nature and cultural environments, just over 18 km of the total of 21 km of the link are in tunnels. The 18 km of tunnels are divided upon six main rock tunnel contracts; Akalla, Lunda, Johannelund, North and South Lovön, and Skärholmen. Accounting all works in the project then there will be approximately 55 km of tunneling done.

Required Nozzleman qualifications

The contracted theoretical volume for sprayed concrete is approximately 82 000 m³. (Roslin, 2019) The outcome is however likely going to be much higher. The North Link project ran by Trafikverket a few years earlier showed in average an over spraying of 89 % - the project had required 75 mm of sprayed concrete, but when measuring the thickness afterwards it was in average 141 mm. (Dalmalm, 2019) The figures did also not include other sprayed concrete consumption like truck waste and rebound.

The different subprojects have some minor difference in the stated competence requirements for Nozzlemen. The general one written is, however that "All sprayed concrete works requires a project certified concrete sprayer/operator which is responsible for all sprayed concrete works performed and documented according to technical descriptions. The project certified concrete sprayer/operator should be present at all times at the worksite." The text also includes all information and prices on how to attain the certification. (Trafikverket, 2015)

The specification above was written before the name, exact structure and execution of the certification was decided. The "project certified" now refers to a certification created for the E4 Stockholm Bypass project; "Sprutning med sprutbetong inom Trafikverket" (Translation: Spraying concrete within Trafikverket's tunnels), which now has been adopted by various projects in the country where Trafikverket is the tunnel client. There are also other tunnel clients, such as the Public Transport Stockholm, that have required the certification in their projects and hence one could

consider that it has become a national standard in Sweden. Later projects have however simplified the text in the requirements to just state that “all sprayed concrete works requires a Nozzleman having the certification “Sprutning med sprutbetong inom Trafikverket” which now entails enough information to bidding and executing contractors. (Edeblom, 2019)

Training and certification performed

The certification required in the project “Sprutning med sprutbetong inom Trafikverket” is issued by Trafikverket and is valid for five years. It can be attained by individuals going through four steps:

- Attend a theory course
- Pass a theory test
- Perform training and evaluation on a concrete spraying simulator
- Provide a document showing eligible concrete spraying experience

The training and certification plan was developed together with key stakeholders in the industry. Trafikverket’s role in the certification process is mainly to evaluate if individuals have passed all required steps, issue the certificate and uphold a database of all certified individuals. Arranging the actual courses are handled by course providers that have gone through a thorough accreditation process.

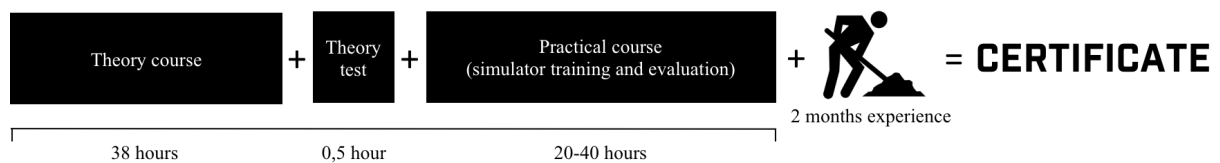


Image 1: The image visualizes the steps required to attain the certificate.

Individuals can renew the certificate by attending a short refresher theory course, pass the theory test again and also pass a few simulator tests.

Over 85 persons have began the certification process, meaning passing at least on of the required steps, since the project started and Trafikverket introduced the certification “Sprutning med sprutbetong inom Trafikverket” in October 2016. So far have 44 of those persons finished the whole process and have received their certificate. (Nylen, 2019).

Theory course and test

The theory course follows a theory course plan written by Trafikverket together with the industry. It comprehends of classroom lectures and practical concrete lab sessions covering the following four areas; basic knowledge, sprayed concrete, technical descriptions and concrete test methods. The course is 38 hours long divided upon five days.

The Trafikverket have accredited training course providers, such as EDVIRT, which offer the courses on a regular basis and contractors or individuals should contact the course provider directly to book and attend the course.

After attending the theory course individuals need to prove their competence by doing a multiple-choice test with 30 questions, where 20 correct answers are required to pass the test. The test is offered in several languages and is held by Trafikverket in their facilities and under their staffs' supervision.

Training and evaluation on a concrete spraying simulator

The practical part of the certification includes training and tests on a concrete spraying simulator. The part is included to see that the individuals really have the required skills to conduct safe, efficient and cost-effective concrete spraying. The training and evaluation are conducted by individuals doing 17 evaluation tests on a simulator, where the tests evaluate the individual on e.g. sprayed thickness, rebound and safety violations. The individual can choose a preferred robot model to perform the training and evaluation on and multiple brands are offered, such as Epiroc, Normet, Putzmeister and AMV. The training and evaluation are normally performed during 20-40 hours where two individuals share one simulator. The needed time varies dependent on skill-level of the individuals going through the simulator training and evaluation.

The Trafikverket have accredited the course provider, EDVIRT to offer the training and evaluation as offered courses. The accreditation requires that the provider have a simulator that can conduct the training and evaluation according to Trafikverket's specification, that the simulator is scientifically validated by an independent body, and that the provider have staff and resources to run and supervise the training and evaluation adequately.

Work experience

Individuals need to send in a document to Trafikverket which shows that they have a minimum of two months of on site robotic sprayed concrete experience during the last three years.



Photo 1: Training and evaluation in VR at site Lovön using EDVIRT's VR Shotcrete Simulator™. (Source: EDVIRT AB)
Photo 2: A group receiving certificates after finishing a training certification course. (Source: EDVIRT AB)

2. WestConnex M4 East & New M5, Australia

About the project

The M4 East twin underground motorway tunnel's construction started in 2016. With a length of 5,5 km, the M4 motorway connects Homebush to Haberfield. It is being built by a joint venture consisting of the companies John Holland, Leighton Contractors and Samsung C&T. The New M5 twin underground motorway tunnel's construction also started in 2016. Its length is 9 km and it connects the new M5 motorway from Kingsgrove to St Peters. It is being built by a joint venture consisting of the companies CPB Contractors, Dragados and Samsung C&T. Both Tunnels are part of Sydney's WestConnex project - Australia's largest transport infrastructure project. The WestConnex project aims to improve connections to western Sydney, provide links to Sydney Airport and Port Botany and to remove bottlenecks and relieve congestions across Sydney's streets. At its completion WestConnex will comprise of 33 km of motorway, where the majority will go underground.

Required Nozzleman qualifications

There were no direct qualification requirements set on Nozzlemen by the client WestConnex, aside from the current national and state regulations in which governs that all heavy machinery operators should receive adequate training and have necessary qualifications.

The training and certification scheme that applied for the project was established by the joint ventures – the main contractors of the two tunnels. The training was developed and implemented by the company EDVIRT and the M4 East & New M5 Training Academy. The scheme is also aligned with the Australian Unit of Competency 'RIIUND310D', which makes it a nationally recognized vocational training. Completion of EDVIRT's training program ESCOT™ was made mandatory for all shotcrete operators working at the M4 East and New M5 tunnel sites. Since the certification was implemented at the WestConnex M4 East and New M5 projects more than 100 operators have successfully completed the certificate required for it.

Training and certification performed

To allow for an efficient training process, operators were categorized as "experienced" or "inexperienced" Nozzlemen. The experienced Nozzlemen had to show at least one year of concrete spraying experience within the last 5 years.

Nozzleman certification for inexperienced operators consisting of five parts:

- 1) Theory course (via self-study online) including a written test
- 2) Training and evaluation on a concrete spraying simulator – 18 tests in total
- 3) 1st on site assessment
- 4) Completion of a log book showing at least 50 m³ of sprayed concrete applied
- 5) 2nd on site assessment

Nozzleman certification for experienced operators consisting of three parts:

- 1) Theory course (via self-study online portal) including a written test
- 2) Training and evaluation on a concrete spraying simulator – 18 tests in total

3) On site assessment

The theory course covers the basics of concrete technology, spraying equipment, spraying technique, health & safety in sprayed concrete application. It was customized to cover project specific topics such as the respective ground support design, work methods, etc. Operators usually completed the theory module within half a day and pass it by answering a multiple-choice test containing approx. 100 questions.

The simulator training consisted of 18 tests with increasing difficulty. The simulator training focuses on the safe and efficient application of shotcrete and defines minimum requirements for several parameters such as target thickness, rebound, over-spraying, shotcrete wastage, fall-outs etc. To pass this module all 18 tests must be successfully completed. Shotcrete Application Trainers are present during the simulator training to provide guidance and support the participating operators in the process. For this module EDVIRT's VR Shotcrete Simulator™ are equipped with the same sprayed concrete machines used in the WestConnex M4 East and New M5 tunnels.

Following the theory and simulator training and evaluation, operators complete an on site assessment performed by a Shotcrete Application Trainers. Its purpose is to ensure a smooth transition from the simulator-based training. After completion of the on site assessment experienced Nozzlemen are signed off and receive a certificate.

Inexperienced Nozzlemen continued to work under supervision until at least 50 m³ of sprayed concrete have been applied and documented in a logbook. At this point a second on site assessment is conducted to complete the certification process for the inexperienced Nozzleman.

3. Crossrail, Great Britain

About the project

Crossrail is a new addition to the London underground, stopping at 40 stations, 10 of which are new builds and 30 will have been upgraded. Eight TBM's were used to construct 21 km of new running tunnels and all at a cost of £15 billion. Tunnel construction started in 2012 and when complete, December 2019, the line will be called The Elizabeth Line. The support network for Crossrail included the building and facilitating of a brand new academy based in East London, which was known as the Tunneling and Underground Construction Academy (TUCA). The role of the TUCA was to provide the project with training and training support in a number of disciplines.

Required Nozzleman qualifications

Although the running tunnels were constructed using TBMs a considerable amount of sprayed concrete was required for the 12 km of station platform tunnels, passages, access and grout tunnels, 7.5km of which would be permanent. This would require approximately 250,000m³ of sprayed concrete. The specification for the sprayed concrete, known as KT20 stated that: "Nozzlemen shall have five years robotic application in SCL tunneling experience and hold relevant certificates of competence and training issued by the Contractor or written evidence of previous satisfactory work indicating compliance with EFNARC Nozzleman Certification Scheme, ACI 506R-03 or similar national standards to the acceptance of the Project Manager."

Problems with the requirements

The EFNARC certificate was interpreted as the suitable solution since the ACI standard referred to hand-spraying and there were no other national standards available. The problem was however that, with so much sprayed concrete, and therefore so many Nozzlemen required, there were nowhere near enough Nozzlemen with the relevant qualifications or experience to undertake the work. Training and certifying new ones was also not an option; in order to fulfill the requirement for an EFNARC certification the Nozzleman had to be able to demonstrate three years of experience. The only people with that amount of experience in the United Kingdom at that time had now moved on in their career, become e.g. “Pit Bosses” or “Foremen”. The option of training new Nozzlemen or changing the specification was the only way to go.

Training and certification performed

Together with the organization EFNARC, TUCA came up with a solution which was to launch a “Provisional EFNARC Nozzleman Course” (EFNARC P1). The purpose with the course was that individuals would be able to undergo a five-day course, as well as gather 240 hours of on site spraying experience, which then would replace the requirement of having three years experience before undergoing an EFNARC assessment. The designated training would go on four-five days, but it would take the individuals attending the course in average six months to attain the final EFNARC certificate. Over fifty Nozzlemen was awarded the EFNARC Nozzleman certificate in the end, as a result of establishing the EFNARC P1 for the Crossrail project.

EFNARC P1

The EFNARC P1 consisted of three parts: theory and test, practical training and on site spraying experience. The theory was conducted during a day and followed EFNARC’s regular theory content including the subjects:

- Healthy, safety and environment
- Concrete technology
- Application and equipment
- Standards and testing

The practical training was conducted at TUCA’s own facilities, which included two spraying machines and four big mandrels which one could spray into. The practical training followed a course plan where the course participants would practically learn about the equipment itself, driving it, operating the booms and nozzle as well as cleaning and maintenance. One of the major issues, aside from the enormous investments before running the course, was the costs involved in using so much concrete during the practical training and then having to dispose it. The project had to look for alternative viable methods, utilizing modern developments, of reducing the costs whilst maintaining the standards, credibility and objectives of the course. The solution for TUCA was to use simulators to teach, practice and assess the candidates in conjunction with live spraying. Various options were investigated and the only one that

met the needs of the course, providing high quality software and equipment along with support and backup from the company EDVIRT.



Photo 3: Training spraying in mandrels at TUCA. (Source: Ck-tech Ltd)

Photo 4: Simulator training using EDVIRT's 3D Shotcrete Simulator™ at TUCA. (Source: www.gov.uk)

After having gone through the parts in the EFNARC P1 course the attendees had to get on site experience and document it. This was done by apprenticeships where the attendees held a “Spraying Log Book”. When reaching 240 hours of spraying, the attendees could, if they had passed the EFNARC P1 course, do a traditional EFNARC assessment. If they passed that assessment they received the full EFN ARC Nozzlemen Certificate.

4. Boliden Mineral’s mine sites in the Boliden Area, Sweden

About the organization

Boliden Mineral AB (Boliden) is a mining and smelting company that was founded in Sweden in 1924. It currently operates in six geographical areas;

- Aitik in Sweden,
- Garpenberg in Sweden,
- Kevitsa in Finland,
- Kylylahti in Finland,
- Tara in Ireland and
- the Boliden Area outside Skellefteå in Sweden.

Boliden has three underground mines in the Boliden Area; Kankberg, Renström and Kristineberg. These three mines are run as individual operations and companies with a local head office in the town of Boliden. The mines mainly produce complex sulphide ores, which contain zinc, copper, lead, gold and silver.

The mine Kankberg consumes approximately 5 000 m³, Renström 11 000 m³ and Kristineberg 23 000 m³ of sprayed concrete per year. Boliden has previously not had any standardized way for training shotcrete operators. However, in 2017, Boliden created an internal certification for shotcrete operators together with the training company EDVIRT. The objective was for the three underground mines in the Boliden Area to:

- Coordinate training efforts among the mines.
- Enable standardized shotcrete training procedures and knowledge requirements among shotcrete operators.
- Enhance the shotcrete quality.
- Decrease costs for over-spraying.
- Improve the safety during and after shotcrete works.
- Ramp up training of new operators in order to cope with an increased competition over labour in Sweden.

Requirements for Nozzlemen

Boliden, together with EDVIRT, has set up the certification “Bergförstärkning med sprutbetong inom Boliden” (Translation: Rock support with shotcrete at Boliden). Boliden’s intention is to have all shotcrete operators go through the training required to attain the certification, but to do it gradually and to prioritize operators with the greatest need or that have expressed interest in receiving training. There is currently no requirement in place that operators need to pass the certification before commencing in production, but Boliden is evaluating to implement it as more operators have attained the certification.

Training and certification performed

The certification “Bergförstärkning med sprutbetong inom Boliden” is issued by Boliden Mineral. The certification is divided into four modules that need to be passed by each individual to attain the certification:

- Attend a theory course
- Pass a theory test
- Attend a concrete test method session
- Perform training and evaluation on a concrete spraying simulator

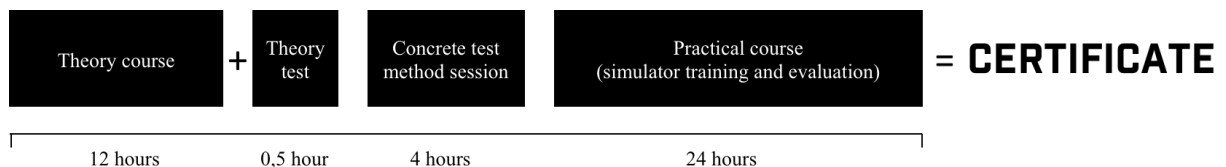


Image 2: The image visualizes the steps required to attain the Boliden specific certificate.

The modules above are bundled into a training course which Boliden and EDVIRT arrange three times per year in the Boliden Area. Since 2017, 18 operators have so far gone through the training course and have received the certificate and Boliden has already seen positive results - “the production managers...has experienced that this training has given results. The participants have developed their skills in handling the JAMA machines and have improved the concrete spraying, which is great!” states Lena Drugge - Skills development at Boliden in the Boliden Area. (Drugge, 2019)

Theory course and test

The theory course follows a theory course plan written by Boliden and EDVIRT. It comprehends of classroom lectures during one and a half day covering the following subjects: the material concrete, understanding the rock, sprayed concrete, spray methods and equipment, spraying technique, health, safety and environment as well as the general standard operating procedures for concrete spraying works in the Boliden Area. Each participant gets to do a written multiple-choice test after the theory course. It comprehends of 30 questions, where 20 correct answers are needed to pass the exam.

Concrete test method session

This session is performed during half a day in a lab located at one of Boliden's mine sites. A teacher goes through different sprayed concrete test methods which the group attending need to show they can later perform by themselves. The evaluation include e.g. slump, air content, fiber content and early strength.

Training and evaluations on a concrete spraying simulator

The training and evaluation on the concrete spraying simulator has been developed in line with the specification established by the Swedish Transport Administration for the certification "Sprutning med sprutbetong inom Trafikverket". The training and evaluation is conducted by a VR-simulator, which requires individuals to pass 17 different tests, during a three-day period. The tests evaluate the individual on e.g. sprayed thickness, rebound and safety violations. The difference between this part and the Swedish Transport Administration's is however that Boliden only uses a simulator with the machine JAMA CSU8000, which is the model currently used by the mines in the Boliden Area.



Photo 5: Training and evaluation in VR at Boliden using EDVIRT's VR Shotcrete Simulator™. (Source: EDVIRT AB)
Photo 6: A group receiving certificates after finishing a training certification course. (Source: EDVIRT AB)

5. Conclusions and the need of a European or global standard

There is an increased focus on qualifications for concrete spraying operators, so called Nozzlemen, in the mining and tunneling industries around the world. The certifications and initiatives set up by the prominent projects and organizations in this article shows that there most likely also is a need for a European or even global standard. The different projects and organization however have different motives and purposes for establishing their certification or requirements, which could be seen as evidence that there is a need and trend pointing towards more national, project or organization-specific certifications. It can also be seen as distrust in the current qualifications that

circle around in the industry, and hence projects and organizations take the matter into own hands and set up certifications where they know and can guarantee the value of the qualification.

Tommy Ellison, Technical manager at the tunneling contractor BESAB is involved in SIS's national group TK190 Betong, as well as CEN European Working Group 10 Sprayed concrete. Tommy is promoting a standard where Nozzlemen are trained and assessed on both the theoretical and practical elements of being a Nozzleman. He also promotes the use of simulators that now are common for training and evaluating Nozzlemen. He states "the current standard, especially SS-EN 14487-2:2006 Sprayed concrete – Del 2 Execution, only describes the most fundamental parts of performing concrete spraying. It does not set up qualification requirements, nor help the Nozzlemen in giving guidance on how the spraying should be done. One of the different training and certification plans developed around the world by organizations such as the Swedish Transport Administration should become a standard in Europe or even globally, now when the ISO standard is up for revision." (Ellison, 2019)

The future will tell if the industry will move in the direction of more country, project or organization-specific qualifications or a European and global standard. One thing however seems sure, and that is that the industry more widely will demand that concrete spraying Nozzlemen have proper and valid qualifications.

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