Robotic spray application.

Dry-spray process.

History and uses of sprayed concrete in the construction industry

Reinforced concrete has for many years, been the most widely used of all building materials in construction. During this time, the industry has looked at many different application methods for use in new construction and the refurbishment of structures. The need to review methods of application, environmental elements and speed of application have all been essential in the industry over a number of years. ***Michael Threadgold*** *of* ***Fosroc International*** *reviews the history of sprayed concrete, as well as its different types and developments over the years that have benefitted construction.*

In 1895 at the Field Museum of Natural Science in Chicago, USA, Dr Carlton Akeley was searching for a way to create models of prehistoric animals. A skeleton frame had been manufactured, but shapes could not be formed using the application of conventional trowelled mortars.

Dr Akeley needed to develop a device to enable the mortar mixture to be sprayed. After experimentation, he developed a single-chambered pressure vessel, which contained a mixture of cement and sand. When pressurised with compressed air, the mixture was forced through an opening and along a delivery hose. At the end of the hose was a nozzle that was fitted with a water spray, which would hydrate the mixture of sand and cement.

The equipment when it was developed was known as the 'cement gun' and the spray material was named 'gunite'.

The method was patented in 1911 and was taken over by the Cement Gun Company. After moving from the USA to Germany in 1921, it eventually become a British-owned company in 1953.

The early machines placed the dry mix of sand and cement into the pressurised chamber from where it was projected to the nozzle, where water was added. This system was therefore termed the 'dry process'.

As the dry process was being developed, the 'true gun' method was also being developed. This required the sand and cement mixture to be fully mixed with water before being pumped through a fundamentally different machine. Due to its different mixing method, the system soon became known as the 'wet process'. The wet process was not fully developed commercially until well into the 1970s, with much of its experimentation being carried out in the USA.

The use of sprayed concrete is now accepted worldwide. The process allows complex shapes and structures to be formed without the high cost associated with formwork.

Some of the early projects undertaken in the UK included the construction of freestanding hangers for Spitfires during World War Two using the dry-spray process method. Examples of these hangers can still be been standing today. The River Mersey's Queensway Tunnel in Liverpool opened in 1934 and is another example of a major engineering structure lined with sprayed concrete.

As wet- and dry-sprayed methods were developed, manufacturers developed spray equipment and materials to improve the processes and product performance, and to this day these developments continue.

Today, it is common practice to use both wet- and dry-sprayed concrete in new and refurbishment projects. These include fireproofing, creating steel-framed concrete structures, linings for tunnels and refractory situations, swimming pools, river/sea defences, domes, structural concrete repair reinstatement and as an overlay for cathodic protection systems.

Some properties and advantages of sprayed concrete include:

- Low water:cement ratio – generally, sprayed concrete has a lower w/c ratio than poured concrete.
- High-strength and rapid-strength gain – sprayed concrete can be expected to attain high compressive strengths, and manufacturers have developed

formulations for both site batch and pre-bagged materials to achieve high early strength.
- High density/low permeability – the placement methods can provide good compaction and high density.
- Enhanced adhesion and bond strength – when surfaces are correctly prepared, the bond strength with sprayed concrete is generally excellent without the use of bonding agents.
- High speed and high output – sprayed concrete can deliver high volumes quickly and economically. Free-formed tunnel linings or retaining walls can be sprayed immediately after excavation. Walls up to 1m thick have been constructed using the wet process, even with very high levels of reinforcement.
- Reduction of formwork cost – in comparison with conventionally poured concrete, sprayed concrete requires far less formwork. This is especially so if curved or other intricate shapes need to be formed.
- Ease of access – the easy application of sprayed concrete means that materials can be applied in restricted areas, and the use of robotic spraying equipment further reduces the need to erect formwork and access equipment.

Environmental compatibility

The spray material must be able to withstand exposure to the environment that it is to be used in, irrespective of whether this is a new or refurbishment project.

The material, whether site batched or pre-bagged, must exhibit low permeability to the ingress of chloride irons, CO_2 and water due to the negative effect of these elements on steel reinforcement.

As water or moisture is also required for corrosion to proceed, materials should exhibit low water absorption and high-permeability performance equal to or better than a high-performance concrete.

Safety and ecology

Concrete is a material that can use a lot of energy in its manufacture, transportation and application. When using these spray application methods, there can, in addition, be a great deal of waste created if the applicator does not use quality, specially formulated products and purpose-built machinery.

During application, a proportion of the applied concrete falls off the structure (commonly called rebound) and is then effectively classed as waste. By reducing this waste, you are reducing associated clean-up risks for site workers and also the likelihood of contamination of sensitive areas such as watercourses.

A number of manufacturers have therefore formulated pre-bagged dry-spray products. These products reduce the amount of rebound to less than 5%. This saves time and money, and more importantly increases site safety while decreasing waste to landfill.

Recent spray projects undertaken in the UK include: Northern line extension, London; Thames Tideway Tunnel, London; M6/M38 Birmingham; A13/A130 Interchange Essex; Cheval Place, London; Crossrail, London; Bexley Waste Transfer Station; and Disserth Gauging Weir, Wales.

Steve Jones, director at Concrete Repairs Limited, says, "Sprayed concrete is an excellent process to repair concrete or to apply an overlay to a structure, to achieve a higher level of production than hand-placed repairs.

"There are a variety of sprayed materials on the market that have been tried and tested over the past few decades. This gives confidence to the installer and client that if correct spraying principles are followed from preparation to final curing, sound, durable repairs and applications can be achieved.

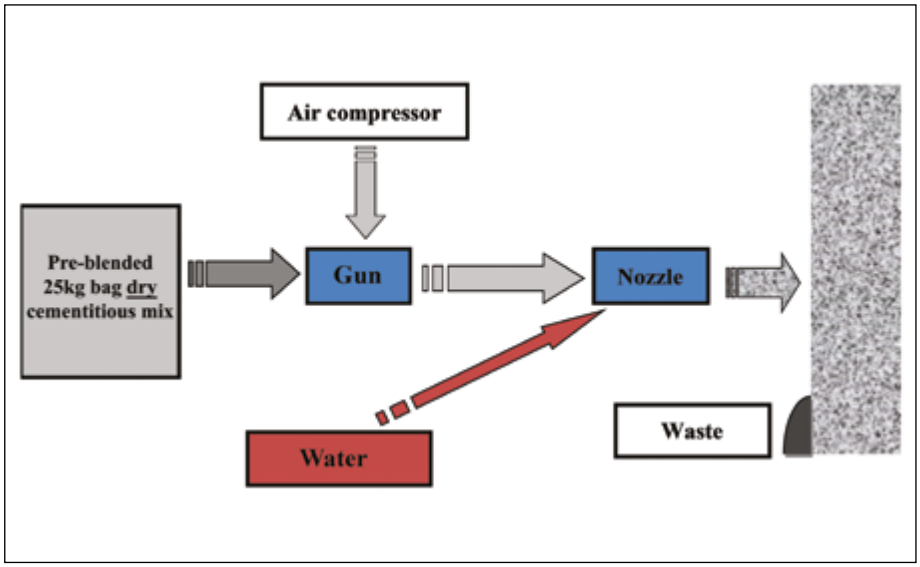
"Clearly the skill and competence of the spray team is crucial. Using sprayed operations allows repair sections to be installed far quicker, while achieving greater depths of build-up than conventional hand-placed repairs. Such sprayed work will require a small amount of formwork and profiles compared with flowable type repairs.

"Sprayed repairs and overlays are particularly useful where tidal conditions are encountered, using rapid-setting materials, and again where it is necessary to provide a build-up or overlay for the installation of an ICCP anode."

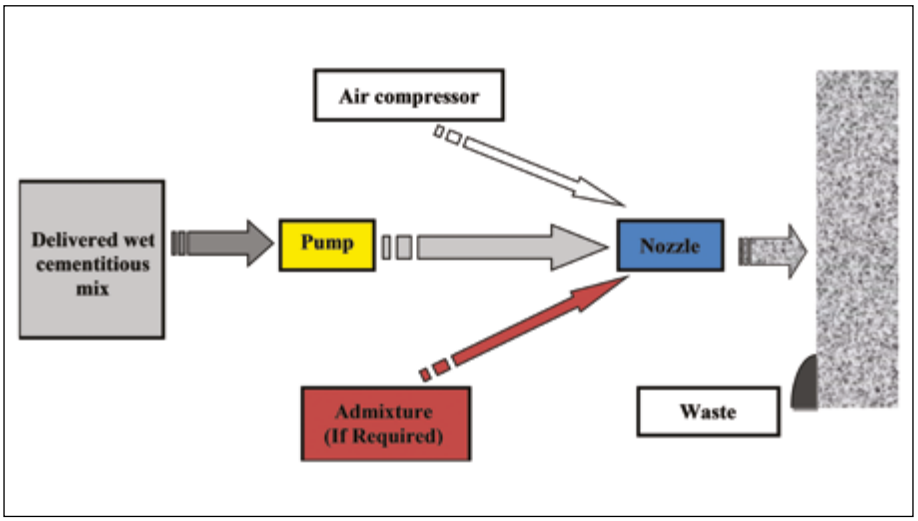
Enda McKenna of McFarland Consulting says, "Sprayed concrete is versatile and offers many advantages over poured concrete.

"Its application over hand-placed mortars in concrete repairs offers many considerable benefits, especially on large vertical and overhead areas. Adhesion to the full surface of the parent concrete and a bond around all of the exposed reinforcement cannot always be

First spray machine.



Dry-spray process.



Wet process.

guaranteed when placing by hand. At times, hand placing can create voids and air pockets, particularly behind reinforcement, and this can affect the repair's long-term performance. This risk is greatly reduced through spraying.

"Continued advancements in robotic equipment are further reducing programmes and associated costs on larger repair schemes. It will also help to reduce numerous occupational health and safety risks, such as operator fatigue, manual handling and exposure to silica dust."

Patrick Quarton, chair of the Sprayed Concrete Association, adds, "Sprayed concrete has an extensive record of accomplishment in both wet and dry processes, and has extensive advantages over other placement methods. The Sprayed Concrete Association, in conjunction with the Structural Concrete Alliance and The Concrete Society, actively work with the industry to promote and develop spray-applied options to improve environmental impact and reduce health and safety elements."

Concluding remarks

Specifications for sprayed concrete methods and materials are becoming increasingly comprehensive.

They should be based on the complete understanding of the design requirements and, in the refurbishment market, the causes of deterioration and scale of required repairs.

Any specification needs to look at all the adjoining elements, such as movement joints, finishes and other components of the structure.

In relation to refurbishment, a full condition survey and understanding of the client's requirements are fundamental; only then can the correct method and materials for application be defined.

It is always of paramount importance to not only review the application methods to be used for spraying, ie, dry or wet process, but also the materials being used and the equipment being used to apply them.

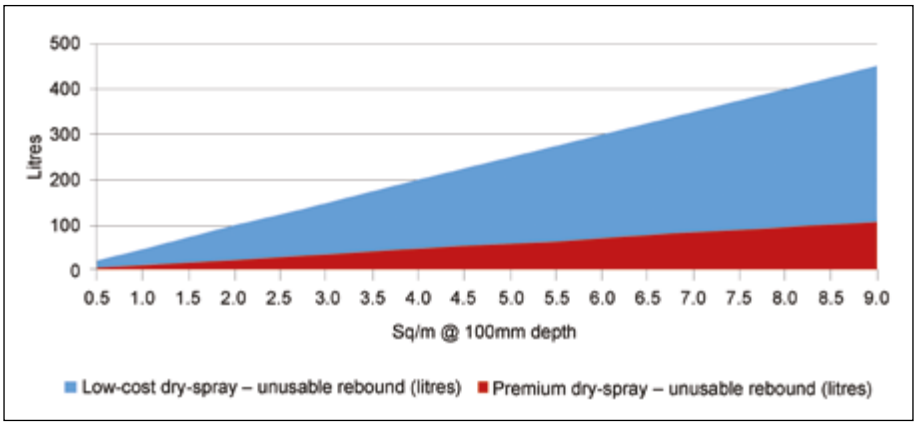
Always take into consideration the location of the project and access requirements, as well as scaffolding and reinforcement requirements.

Always use experienced contractors and suppliers that can support the project through the entire process, from specification through to completion. Engaging with specialist applicators and material manufacturers prior to the project commencing has been shown to improve project delivery and can reduce overall costs and project timescales.

The following is the outline specification requirements for high performance, based on materials and methods discussed in this article:

- All specialist materials used should come from one manufacturer from an audited manufacturing facility.
- All materials should confirm to relevant British Standards, such as BS EN 1504[(1)].
- The installing contractor shall be a member of a recognised industry body such as the Sprayed Concrete Association.
- The contractor must be able to demonstrate that a minimum of 50% of the applicators installing materials are certificated to QCF level 2. ■

> "The equipment when it was developed was known as the 'cement gun' and the spray material was named 'gunite'. The method was patented in 1911 and was taken over by the Cement Gun Company."



Unusable rebound at depth.

Reference:

1. BRITISH STANDARDS INSTITUTION, BS EN 1504. *Products and systems for the protection and repair of concrete structures. Definitions, requirements, quality control and evaluation of conformity. Part 3 – Structural and non-structural repair.* BSI, London, 2005.

Further reading:

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