

Construction and Repair with Wet-Process Sprayed Concrete and Mortar

A Preview of the Forthcoming UK Concrete Society Technical Report

by Chris I. Goodier and Simon A. Austin

A technical report has just been published in the UK by the Concrete Society. This new report has been prepared by a team from the Department of Civil and Building Engineering at Loughborough University: Simon Austin, professor of structural engineering; Peter Robins, senior lecturer; and Chris Goodier, a former research associate at Loughborough University, now a senior consultant with BRE's Centre for Concrete Construction.

Purpose of the Report

The aim of the report is to provide practical guidance for designers, specifiers, contractors, and clients on all aspects of low-volume, wet-process sprayed mortars and concretes. It provides information on both new construction and small-scale repair, and covers choice of application method, materials and mixes, specification, pumping and spraying, finishing, curing, and testing and performance. The information is a combination of existing good practice and new knowledge acquired during a recently completed three-year research project conducted at Loughborough University titled "Wet Process Sprayed Concrete for Repair." This was funded by both the UK government (the EPSRC) and industry; namely, Balvac Whitley Moran, Fibre Technology, Fosroc International, Gunform International Ltd., and Putzmeister UK Ltd.

This document concentrates on wet-process

mortars and small aggregate concretes (< 8 mm [5/16 in.]) applied in thin layers (< 100 mm [4 in.]) at low/medium output rates (< 5 m³/hr [6.5 yd³/hr]), in some cases with mesh or fiber reinforcement.

The report uses terminology standardized by the European Federation of National Associations of Specialist Repair Contractors (EFNARC), namely sprayed concrete, with mixes containing aggregate with a maximum size of 3 to 4 mm (1/8 to 5/32 in.) being classed as mortars and anything larger as concretes.

The Wet Process

In the wet process, the constituents (cement, aggregate, admixtures, and water) are batched and mixed together before being fed into the delivery equipment or pump. The mixture is then conveyed under pressure to the nozzle, where compressed air is injected to project the mixture into place. This differs from the dry process in which the dry constituents are batched together before being conveyed under pressure through the delivery hose to the nozzle, where pressurized water is introduced and the mixture is projected into place.

The wet process has become dominant for large-scale tunnel construction, often involving robot-controlled spraying, but is not a common solution for low-volume work. Low-to-medium-volume wet-spray applications are increasing, especially for repair, because of the better consistency of the sprayed material and reduced dependence on operator skill, as well as the improvements in materials and production technology, particularly its stop/start flexibility. Low-volume wet spraying has traditionally been used in continental Europe for the application of sand/cement renders and plasters, which are typically 10 to 20 mm (3/8 to 3/4 in.) thick. It has become the standard method for applying plaster in many European countries, although little is done in the UK.

In some countries there has been a large swing toward the wet process, partly because of better control over mixture proportions, particularly the water-cement ratio. These include Norway and Sweden, where the majority of work is wet process,

Figure 1: Holme Pierrepont canoe slalom course, Nottingham, UK.



and the USA, where the two techniques are both used for repair. Although the proportion of wet-sprayed concrete is increasing in the UK (Figure 1), other countries, particularly Germany, are predominantly orientated toward the dry process. These differences partly reflect the functional emphasis of the two processes, that is, the wet mixture for high-output applications such as tunnelling, and dry mixture for low- to medium-output applications such as repair or situations requiring greater transport distances and flexibility, like mining.

There is relatively little quantitative data available on wet-process sprayed concrete for repair. However, expanding interest in the process is demonstrated by an increasing number of published articles and papers on the wet process that have an industrial perspective. Previous publications derived from this research at Loughborough University have discussed the rheology¹⁻³ and hardened performance⁴ of wet-process sprayed mortars, and the rheology⁵ and hardened performance⁶ of wet-process sprayed concretes. Other work has also discussed these topics, as well as comparing the results obtained with mortars with those for fine concretes.⁷

Pumps and Equipment

Various types of pumps are suitable for the wet-mix spraying of mortars and concretes. The main requirement is that the pumps should be capable of delivering a continuous, even flow of material to the nozzle. The two main types of pump are the piston pump for medium-to-high outputs (5 to 20 m³/hr [6.5 to 26 yd³/hr]) and the worm, or screw pump, for low outputs (< 5 m³/hr [6.5 yd³/hr]) (Figure 2).

Due to the relatively small size of the opening in the rotor-stator in worm pumps, they can only pump aggregate up to approximately 4 mm (5/32 in.) in size, and are unable to pump steel fibers. Their main disadvantage is high wear, especially with coarser aggregates. They produce a continuous and pulsation-free mortar supply; and as they require no valves (unlike piston pumps), they are generally reliable. Piston pumps, both single- and double-action, can deliver both mortar and concrete mixes at larger outputs than worm pumps, although the flow sometimes pulsates more due to the pumping action of the pistons.

Comparison with Dry-Process Sprayed Concrete

The dry process is capable of producing high-quality concrete but has several drawbacks, including the difficulty of achieving quality and consistency, high material losses, and a dusty and dirty working environment. The wet process has the potential to produce more consistent concrete with lower wastage, and promotes a healthier working environment.

Both methods have their advantages, and before a decision on process type can be taken, detailed consideration of design and application must be made. For example, dry spraying is well suited to

contracts that require an intermittent supply, while the wet process is more suited to contracts that require continuous spraying, little rebound and dust, and more control over the mixture quality. The choice of spraying method influences both the drawing up of the specification and the choice of associated quality control procedures.

Mix Design

The material constituents of sprayed concrete are similar to those in ordinary cast structural concrete. Until the 1980s, most of the sprayed concrete in Europe typically incorporated a portland cement-and-sand mixture in proportions of approximately 1:3. Since then, supplementary cementing materials (such as silica fume and fly ash), special admixtures (such as retarders and superplasticizers) and fiber reinforcement, have all been increasingly used. Most sprayed and hand-applied repairs in the UK are carried out with pre-blended proprietary materials and products. This is because they are perceived to be of higher quality than site-batched materials (in terms of the consistency of the ingredients) or ready-mixed concrete. Ready-mix is reserved for large-volume repairs and new construction.

Sprayed concrete can be specified using either the designed mixture or prescribed mixture approach. The designed mixture is designed by the contractor to achieve the specified compressive strength and/or other specified properties such as minimum cement content or toughness. This method is preferable for sprayed concrete, as the contractor is free to select constituents to produce the best pumping performance for a mixture. The prescribed mixture is a mixture for which the designer specifies the proportions of the constituents and is responsible for ensuring that these proportions will produce a concrete with the performance required. Previous, reliable experience

Figure 2:
Typical worm pump
(Putzmeister P11).



with the available materials is usually required, and it must be clear whether the proportions apply to the original mixture or to the in-place material.

The report goes into further detail on mixture design, including details on cements, aggregates, additions and admixtures, fibers, reinforcement, and batching and mixing. Suggested aggregate and total constituent grading curves are also included. Advice on design for sprayed concrete is included, including details of relevant codes and standards relating to sprayed mortars and concretes.

Test Methods

Many countries have national standards for the testing of fresh and hardened concrete, and some of these can be applied to sprayed concrete. The report provides the relevant European Standard method where available and the corresponding British Standard. Several countries have standards specifically for sprayed concrete and a list of relevant standards is provided. The EFNARC specification⁸ provides the most recent and relevant European information on test methods for sprayed concrete, together with the draft European Standard test methods proposed by the European Committee for Standardization Working Group on sprayed concrete, TC104/WG10. Details and some limited results of new testing methods are also included, both on site (Figure 3) and laboratory based.

Further Information

Copies of the "Concrete Society Technical Report No.56, Construction and Repair with Wet-Process Sprayed Concrete and Mortar," can be obtained for £50 (approx. \$72) from the Concrete Society (e-mail: concsoc@concrete.org.uk; website: www.concretebookshop.com).

Further information can also be obtained from the authors: C. I. Goodier (goodierc@bre.co.uk), S. A. Austin (s.a.austin@lboro.co.uk), and P. J. Robins (p.j.robins@lboro.ac.uk).

Figure 3: Hand-held shear vane test.



References

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Chris I. Goodier works as a senior consultant in the Centre for Concrete Construction at BRE in Watford, UK. His background includes work as a civil engineer for Laing Civil Engineering and as a research associate for Loughborough University. He is currently undertaking research work in various aspects of concrete technology such as self-compacting concrete and reinforcement corrosion, together with work in the inspection, testing, and repair of concrete structures.



Simon A. Austin is Professor of Structural Engineering in the Department of Civil and Building Engineering at Loughborough University. He previously worked for Tarmac Construction and Scott Wilson Kirkpatrick before joining the University in 1984. He has conducted research into concrete materials for 20 years, including the main themes of sprayed concrete, durability, fiber reinforcement and slab structures. He is a member of the Institution of Civil Engineers, Fellow of the Concrete Society, consultant member of the Sprayed Concrete Association, and member of EFNARC Technical Committee, Sprayed Concrete, CENTC104/WG10–Sprayed Concrete, and TC 104/WG11–Fibers in Concrete.