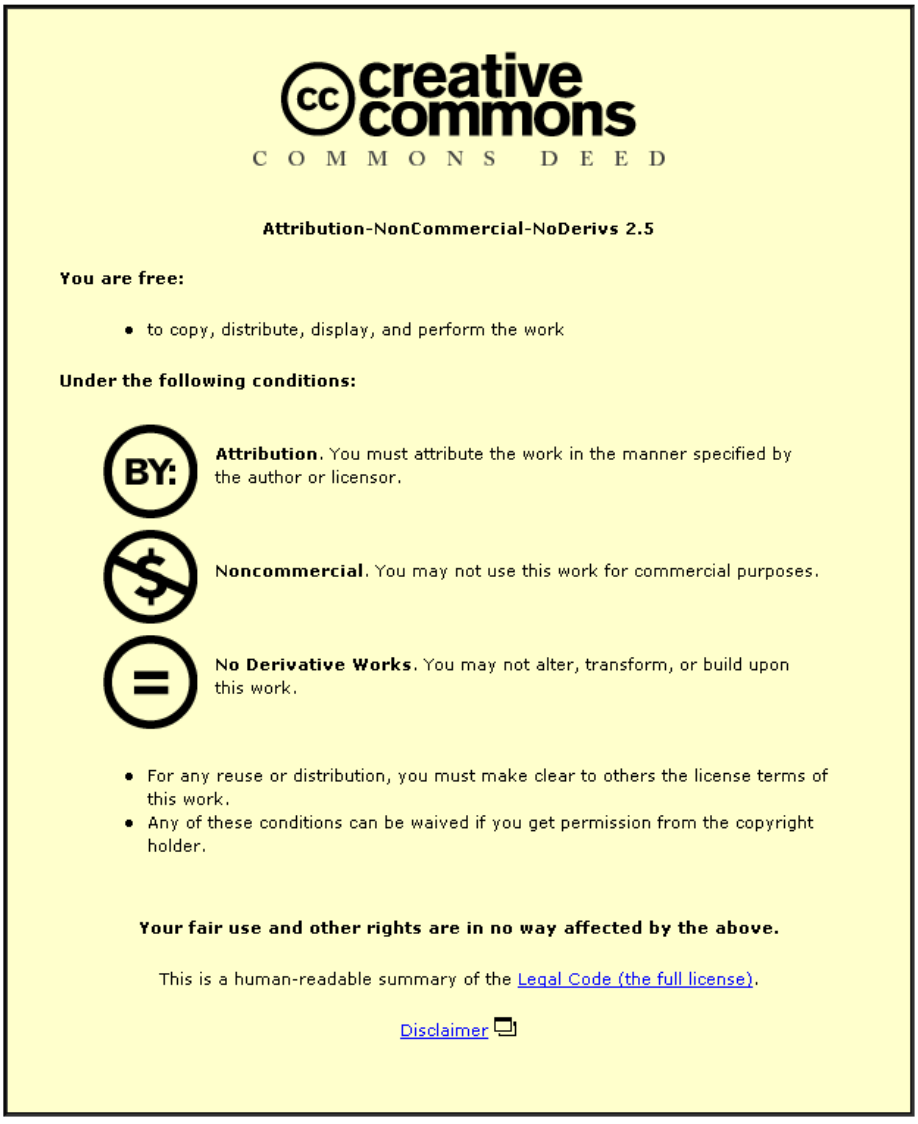

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Doing it the Wet Way – Sprayed Concrete for Repair

Scottish Builder & Engineer

Prof. S A Austin, Dr P J Robins and C I Goodier, Loughborough University

Sprayed concrete is a unique construction material that is ideally suited to the repair of concrete, brick and masonry structures. Repairing with sprayed concrete is attractive because of the flexibility of the application process and the elimination of formwork, but nearly all sprayed concrete repair projects in the UK are currently carried out by the dry process. The wet process has become dominant for large-scale tunnelling applications involving robot-controlled spraying (e.g. in Scandinavia and more recently in the UK with NATM), but is currently not a common solution for repair work.

The dry process is capable of producing high-quality concrete but has several drawbacks including 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 in a healthier working environment, but the technology developed to date is inappropriate for repair work, because it is based on rock support, large-aggregate mixes and high volume production (not controlled overlays). A three-year research programme at Loughborough University has therefore recently been completed which examined and further developed the wet process for use in concrete repair.

The main purpose of the research was to advance the understanding and technology of the wet process, with an emphasis on mortars and small-aggregate concretes, to enable it to be specified and used with confidence for repair in the United Kingdom.

The specific objectives were to improve understanding of the influence of the process and mix constituents on fresh and hardened properties; improve the wet-mix spraying process; specify, measure and optimise in-situ properties; and to disseminate information in appropriate form to practising engineers to accelerate the use of wet-process sprayed concrete for repair.

Industrial collaboration was provided by Balvac Whitley Moran, Fibre Technology, Fosroc International, Gunform International Ltd and Putzmeister UK Ltd. All the collaborators assisted in the field trials and participated actively in the project giving insights into the industrial developments and thinking, thus the project focused on issues of greatest relevance. The main funding for the project was provided by the Engineering and Physical Science Research Council (EPSRC).

The research focused on three types of repair mortars/concretes which we recognised as ripe for development: proprietary pre-blended mortars (<3mm aggregate); designed laboratory/site-batched mortars and fine (<6mm aggregate) concretes.

The principal findings of the work were as follows:

(i) Rheological behaviour

A rheological audit can be used to characterise pumpability and sprayability. Rotational viscometers produced useful results with low workabilities, although care needs to be taken in conducting these tests and their interpretation. Both the grading of the constituents and the presence of polymers had a significant effect on the pumpability. A pressure bleed test proved to be capable of measuring the rate of flow of the liquid component from a concrete or mortar under pressure (Figure 1). A shear vane test was also developed which can give an instantaneous measurement of shear strength wherever this property needs to be assessed. High-speed video (Figure 2) determined the spray-stream velocity to be 9 - 11 and 20 - 25 m/s with the small worm and piston pumps and it was found that waste may be minimised (and the stream made more uniform) by changing the design of the nozzle orifice.

(ii) Performance of hardened material

The relatively simple laboratory-designed mortars possessed compressive and flexural strengths comparable with the best of the commercially available pre-blended mortars. The 6 types of wet-process pumps used for the project had little effect on the in-situ compressive and flexural strengths.

Bond strengths to concrete were in a narrow range relative to their compressive strengths and easily exceeded the Concrete Society recommended minimum. The pump type affected the bond strength, mainly due to the stream velocity and w/c ratio, not the pumping process.

The mixes exhibited a wide range of drying shrinkage, but data from restrained specimens suggest a repair is influenced more by the ambient conditions than by the mix design itself.

A test was devised to measure the effectiveness of reinforcement encasement. The pump type had an effect with higher stream velocities producing better encasement.

(iii) Material and mixes

29 pre-blended and designed laboratory mortars and concretes were investigated for this project with the majority pumping and spraying successfully. Three mixes were successfully designed to be un-pumpable, to test our ability to predict pumpability. Significantly, the best laboratory designed mortars performed as well as, or better than, the pre-blended proprietary materials. For worm pumping the grading is critical: the voids content of the combined constituents must be kept to a minimum to minimise bleeding of the wet mix. A grading zone for worm pumping has been established.

(iv) Equipment

A range of existing pumping equipment has been evaluated and all proved suitable, from small worm to 100mm piston pumps. The latest designs of worm pump were tried, including a pump with a dual-mixing system which ensures adequate mixing and a constant flow of material (Figure 3). Undoubtedly the process is less dependent on operator skill than the dry process and can encase reinforcement satisfactorily. However, improvements can still be made to nozzle design and automation of metering, mixing and controlling pumps, which will enhance the spraying process and in-situ performance. Modified working procedures should be adopted to suit the process, in terms of appropriate cycles and methods of advance preparation, batching, application and finishing.

(v) Quality control and testing

Appropriate quality control should be regarded as a critical part of all contracts (but is not always so at present). The project has produced a large array of data against which mixes and products can be benchmarked. It has also developed a number of tests, covering pump/spray-ability and hardened performance that demonstrate the soundness of the wet process, that can also be adopted for site use.

Dissemination of the information into and beyond the academic community has played a significant part in the project. This has been, and continues to be, undertaken by publication in conferences [1-3], academic and professional journals (the latter raising industrial awareness) [4-7] plus a related edited work [8]. A major output of the research is the Guideline Document which is to be published by the Concrete Society [9]; this will give excellent accessibility for the industry and disseminate information in appropriate form to practising engineers to advance the use of wet-process sprayed concrete for repair in the UK.

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For further information please contact:

Prof. S A Austin
Department of Civil and Building Engineering
Loughborough University
Leicestershire LE11 3TU

Email s.a.austin@lboro.ac.uk Tel 01509 222608

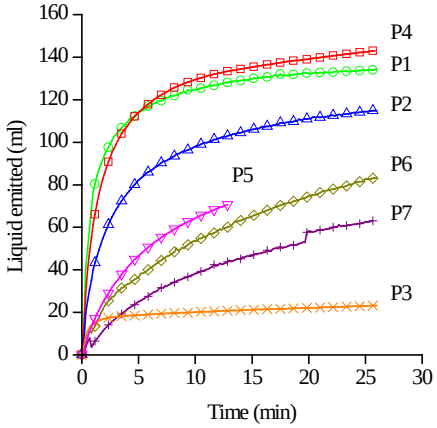

Figure 1. Pressure bleed test on propriatery pre-blended mortars

Figure 2. Still from a Ektapro High-speed camera

Figure 3. Dual-mixing wet-process pump in operation