Editorial

Exploitation of research into self-compacting concrete

W. Price* and P. Domone†

Lafarge Cement UK and University College London†*

The development and practical application of self-compacting concrete (SCC) is an excellent example of the benefits that can be achieved by the close integration of research and production technologies.¹

SCC was a logical development from flowing concrete, which was made feasible by the introduction of superplasticisers in the 1970s,² and other high-consistency concretes such as those for underwater placing and bored piles. SCC was initially developed after pioneering studies by Okamura, Ozawa and their co-workers at the University of Tokyo in the late 1980s, which were undertaken as a response to poor durability arising from a lack of skilled workers in the Japanese construction industry.^{3,4} A number of large companies with in-house research facilities then took the technology forward to some spectacular large-scale uses in the early and mid 1990s. Since then both research on, and applications of, SCC have spread westwards and they are both now common worldwide.

The benefits of SCC that have been recognised and exploited include

- (a) full compaction in regions of congested reinforcement with restricted access
- (b) enhanced concrete durability
- (c) improvements to the surface finish of formed concrete
- (d) elimination of health and safety issues (such as 'white finger') associated with the prolonged use of vibrating equipment

- (e) reduced noise levels during placing
- (f) improvements in productivity as a result of reductions in the time and labour force associated with concrete placing.

As well as individual and national programmes, SCC technology has benefited from multinational projects such as the 1997–2000 Brite–Euram project,⁵ which demonstrated the feasibility of commercial SCC production for both housing and civil engineering purposes, and the 2001–2004 Testing-SCC project,⁶ which arose from the need to have standardised tests for the specification and conformity testing of SCC. Many countries have also had their own programmes.

In both Europe and North America, standards for testing will be shortly forthcoming. It is interesting to note these international standards will be produced some ten years after the material itself has been successfully used in many countries. In the interim period recommendations from consortia of trade organisations, such as European Federation for Specialist Construction Chemicals and Concrete Systems (EFNARC),⁷ have been invaluable.

The most successful developments of SCC have resulted from the integration of fundamental research on the rheological properties of fresh concrete, exploiting the understanding of rheology and test procedures developed during the preceding two decades, and increased understanding of the interaction between the constituent materials, particularly between the admix-

tures and the fine powders such as Portland cement, fly ash, ground granulated blast furnace slag, limestone powder and microsilica. Indeed, admixture technology has advanced to the stage where many products tailor-made for SCC are commercially available.

Not only should SCC have the ability to flow under its own weight but it must also be able to completely fill formwork, even in the presence of congested reinforcement, and remain stable and homogenous under dynamic conditions during handling and placing and when subsequently static. Mixes should also be able to tolerate variations in constituent materials, particularly in the moisture content of aggregates, that are inherent in any concrete production of significant scale.

It is important to recognise that, as with other types of high-performance concrete, there is no 'unique' SCC formulation or specification. Although the basic principles of SCC are now established and various methods of mix design have been published, the commercial production of practical SCC has generally been restricted to a limited number of technically sophisticated concrete producers.

Proprietary 'branded' forms of SCC have proved popular (certainly within Europe), with at least one major European ready-mixed concrete producer marketing a range of mixes specifically tailored towards different end uses, such as horizontal elements (slabs and screeds), vertical elements or trenchfill, together with specially developed production and quality control methods. Commercial interests have led to a situation where concrete producers, while underwriting performance, are often unwilling to discuss the mix constituents with the user or the purchaser; although understandable, this is not necessarily in the best interests of all sectors of the concrete industry. There is the possibility of misuse through lack of knowledge.

Although SCC still represents only a small proportion of the total ready-mixed concrete market it is steadily growing. Projects successfully completed using SCC will act as encouragement to building owners and specifiers alike to investigate the possibilities of using this technology in their own structures, and its use is expected to rise sharply.

One sector where SCC technology has really 'taken off' is the production of wet-cast precast concrete elements. In particular, initial developments in the Netherlands⁸ have stimulated developments elsewhere. The improvements in speed and ease of filling moulds with complex shapes and reinforcing cages are combined with a significant reduction in noise. This is not only beneficial to the workforce in terms of their working environment, but in locations where a precast plant is close to a residential area it may also enable working hours to be extended without adversely affecting the residents. Producers of architectural precast elements are also exploiting the improvements in surface finish, made possible when SCC is combined with proper mould preparation.

The widespread international interest in SCC has resulted in a series of major international conferences in Asia, Europe and North America over the last ten years (in particular the RILEM sponsored series⁹⁻¹²). Many important and groundbreaking papers were presented at these conferences, with a general trend to move from a concentration on fresh concrete testing, mix design development and exploitation, to a greater emphasis in the more recent conferences on investigations into all aspects of hardened properties. Much of the latter has involved comparing SCC with the properties of equivalent, normally vibrated concrete with many programmes proving that hardened SCC is not inferior to normally vibrated concrete. While this is clearly important, it is not exciting or groundbreaking research. In contrast, some detailed studies of micro-structure are producing some valuable basic understanding. The volume of research that has been carried out and the understanding that has been achieved is, however, such that the forthcoming fifth RILEM conference to be held in Ghent, Belgium in September 2007 will probably be the last in the series.

In summary, the increasing exploitation of SCC technology worldwide over the past decade has shown what can be achieved in short timescales by the willingness of all concerned to integrate sound fundamental concrete research with production and construction practice.

Further fundamental research will of course continue. One exciting challenge is to find ways of incorporating significant quantities of waste materials, which may not be either ideal or uniform, into SCC while maintaining its required properties.

References

1. SKARENDAHL A. The present: the future. In *Proceedings of 3rd RILEM International Symposium on Self Compacting Concrete*. RILEM Publications PRO 33, Bagnex, France, 2003, pp. 6–14.
2. CEMENT AND CONCRETE ASSOCIATION. *Superplasticizing Admixtures in Concrete*. Report of Cement Admixtures Association and Cement and Concrete Association Working Party, C&CA, Wexham, January 1976.
3. OZAWA K., MAEKAWA K., KUNISHAMA M. and OKAMURA H. Development of high-performance concrete based on the durability design of concrete structures. In *Proceedings of the Second East-Asia and Pacific Conference on Structural Engineering and Construction (EASEC)*, Chiang Mai, Thailand, January 1989. Asian Institute of Technology, Klong Luang, Thailand, 1989, vol. 1, pp. 445–450.
4. OKUMARA H. and OUCHI M. Self compacting concrete—development, present use and future. In *Proceedings of 1st International RILEM Symposium on Self-Compacting Concrete*. RILEM Publications PRO 7, Bagnex, France, 1999, pp. 3–14.
5. GRAUERS M. (project coordinator). *Brite EuRam project No. BE96-3801 Rational Production and Improved Working Environment through using Self Compacting Concrete*. Final Technical Report June 2000. Available online at: <http://www.civeng.ucl.ac.uk/research/concrete/sccBE.asp> (last accessed May 2007).
6. BARTOS P. (project coordinator). *European Union Growth Contract No. G6RD-CT-2001-00580. Measurement of Properties of Fresh Self-Compacting Concrete*. Final Report September 2005.

- Available online at: <http://www.civeng.ucl.ac.uk/research/concrete/Testing-SCC/> (last accessed May 2007).
7. EUROPEAN FEDERATION FOR SPECIALIST CONSTRUCTION CHEMICALS AND CONCRETE SYSTEMS. *The European Guidelines for Self-Compacting Concrete Specification, Production and Use*. EFNARC, Knowle, West Midlands, 2005. Available online at: <http://www.efnarc.org/pdf/SCCGuidelinesMay2005.pdf> (last accessed May 2007).
 8. WALRAVEN J. Structural applications of self compacting concrete. In *Proceedings of 3rd RILEM International Symposium on Self Compacting Concrete* (WALLEVIK O. and NIELSSON I. (eds)). RILEM Publications PRO 33, Bagneux, France, 2003, pp. 15–22.
 9. REUNION INTERNATIONALE DES LABORATOIRES ET EXPERTS DES MATERIAUX, SYSTEMES DE CONSTRUCTION ET OUVRAGES. *RILEM International Symposium on Self Compacting Concrete 1*, Stockholm, 1999, RILEM Publication PRO 07.
 10. REUNION INTERNATIONALE DES LABORATOIRES ET EXPERTS DES MATERIAUX, SYSTEMES DE CONSTRUCTION ET OUVRAGES. *RILEM International Symposium on Self Compacting Concrete 2*, Tokyo, 2001, COMS Engineering Co.
 11. REUNION INTERNATIONALE DES LABORATOIRES ET EXPERTS DES MATERIAUX, SYSTEMES DE CONSTRUCTION ET OUVRAGES. *RILEM International Symposium on Self Compacting Concrete 3*, Reykjavik, 2003, RILEM Publication PRO 33.
 12. REUNION INTERNATIONALE DES LABORATOIRES ET EXPERTS DES MATERIAUX, SYSTEMES DE CONSTRUCTION ET OUVRAGES. *RILEM International Symposium on Self Compacting Concrete 4*, Chicago, Oct/Nov 2005, Northwestern University.

Discussion contributions on this paper should reach the editor by 1 April 2008