RILEM State-of-the-Art Reports

Kamal H. Khayat
Geert De Schutter *Editors*

Mechanical Properties of Self-Compacting Concrete

State-of-the-Art Report of the RILEM Technical Committee 228-MPS on Mechanical Properties of Self-Compacting Concrete

Springer

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State-of-the-Art Report

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All committee members have contributed to this STAR-report, by providing relevant information to lead chapter authors of the chapters, by providing some sections summarizing and contributing to the discussions of the Committee.

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Preface

Dear Colleagues,

We are pleased to provide you with this state-of-the-art report on the mechanical properties of Self-Compacting Concrete (SCC). Given to the fast growth of research output in the field of SCC and the growing acceptance of this high-performance material around the world in both precast and cast-in-place applications, the members of the RILEM Technical Committee TC 228-MPS "Mechanical Properties of SCC" have worked diligently to provide a concise summary of key topics pertaining to the mechanical properties of SCC. This report comprises of eight chapters covering various topics pertaining to mechanical properties of SCC. This includes compressive, tensile, flexural, and shear strengths and elastic modulus, stress–strain behaviour, and mechanical properties at elevated temperatures. The report also discusses creep, drying and autogenous shrinkage behaviours of SCC and the applicability of various models to SCC. Bond strength to reinforcement, existing concrete, and freshly cast SCC are discussed. A review of the main structural behaviour characteristics of SCC used in various structural elements is provided. A comprehensive review of the behaviour of fibre-reinforced SCC (FR-SCC) is provided. Finally, the report discusses the properties of specialty SCC including lightweight and heavyweight SCC, preplaced aggregate SCC, underwater concrete, self-levelling concrete, and self-compacting repair mortar and concrete.

I would like to acknowledge the contributions of all 26 members of this TC 228-MPS who have worked diligently since 2008 to gather a large body of technical knowledge literature that is synthesized in report. Particular thanks go to the lead authors of the various chapters listed below for championing the efforts in analysing large body of technical literature and synthesizing the findings and the Committee's option in their respective chapters. Special thanks are extended to the Secretary of the Committee, Prof. Geert De Schutter, for his help in coordinating the work of the Committee and the preparation of this state-of-the-art report on the mechanical properties of SCC.

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Chapter 1
Introduction and Glossary

Geert De Schutter and Kamal H. Khayat

1.1 Introduction

Self-compacting concrete (SCC) [1], also known as self-consolidating concrete [2], was developed in the late 1980's, although earlier 'look-alikes' surely exist, though not defined as such. In comparison with conventional concrete, referred to in this report as vibrated concrete (VC), SCC can be considered on the one hand as a new type of high-performance material of a different approach to mix design and rheological characteristics. On the other hand, SCC can be seen as a new approach to casting concrete enabled by adjusted fresh concrete properties. In reality, SCC is a combination of both approaches that has enabled to push the boundaries of concrete technology to a new area.

Several methods exist for the mix design of SCC, as explained in [3]. In various parts of the world, different concepts might be followed for the proportioning of SCC and are referred to as 'powder-type SCC', 'VMA-type SCC', or 'mixed-type SCC'. This makes it complicated to present general conclusions and recommendations concerning the mix design and specific characteristics of SCC. Since the introduction of 'modern' SCC, RILEM has been very active in producing state-of-the-art reports related to this innovative class of high-performance cementitious material. At first, focus was aimed at describing the mix design and workability of SCC [3] then on mixing and casting of SCC [4]. Later on, other aspects of SCC were targeted, including durability [5]. Also, the American Concrete Institute (ACI) Committee 237 "SCC" is working on producing a comprehensive state-of-the-art report dealing with all aspects of SCC [6].

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Although SCC has been used in actual structures for the last 20 years around the world, until recently it was not fully clear whether existing design codes for structural design can be fully applied when using SCC. Some initial problems have been reported in the past, e.g. bond and shear behaviour of SCC. Due to the lower aggregate content, aggregate interlock was expected to play a limited role in comparison with VC, which might result in a reduced bond and shear strengths. Another point of discussion was the strain-softening behaviour of SCC under compression, and linked to that, it was not clear to which extent the traditional parabola-rectangular constitutive law used for VC would be applicable to SCC. Creep and shrinkage of SCC have also been extensively discussed in the literature, leading to contradictory conclusions (see Chap. 3).

In recent years, many research groups have been investigating the mechanical properties and structural behaviour of SCC. Recent publications have answered a lot of questions, showing that the mechanical behaviour of SCC is similar to that of VC. Although the contribution of aggregate interlock to the shear resistance might be lower in case of SCC, the greater intrinsic quality of the matrix and of the interfacial transition zone (ITZ) with the aggregate seem to compensate this negative effect.

The compressive stress-strain relation for SCC seems to be fundamentally of the same nature as for VC; however, with slightly lower Young's elastic modulus, and with slightly higher peak strain. This latter issue seems to depend on the powder type, and still needs further fundamental evaluation. The toughness of SCC seems to be slightly higher than VC of similar compressive strength, which is mainly due to the effect of the higher peak strain value, as the strain softening curve is quite comparable to the case of VC.

In spite of some early problems related to relatively low bond strength to reinforcement when using SCC, which are probably related to segregating of the SCC mixtures, bond between SCC and reinforcing steel and prestressing strands was found to be as good as in the case of VC. For small bar diameters, bond of SCC can be significantly higher than that of VC of similar compressive strength. When the SCC mixture is designed to exhibit proper static stability, the top-bar effect of SCC can be similar or even lower than VC.

One aspect which will certainly be further developed in the future is the incorporation of fibers in SCC. It has already been shown that excellent properties can be obtained when adding steel fibers to SCC, while maintaining appropriate rheological properties needed to remain self-compaction properties. The alignment of the rigid steel fibers, following the flow patterns of the SCC, when cast into relatively thin formwork section, could be better exploited by applying advanced Computational Fluid Dynamics (CFD) techniques. Casting operations could be optimized to obtain the desired fiber orientation, depending on the mechanical actions in the finalized structure.

The previous paragraphs have pointed to some existing discussions related to the mechanical properties of SCC, and to some challenges and remaining research areas. In order to give a detailed answer to these and other questions and discussions, based on thorough understanding of various mechanical properties of this

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