STANDARDISATION AND PRACTICAL APPLICATION OF SELF-COMPACTING CONCRETE IN GERMANY

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Abstract

For seven years, self-compacting concrete (SCC) with a national technical approval can be applied in Germany. Self-compacting concretes do not comply with the German standards (DIN EN 206-1 and DIN 1045-2) due to their consistency and, depending on the composition, due to the limitation of the powder content. In December 2004, the guideline “Self-Compacting Concrete” of the Deutscher Ausschuss für Stahlbeton (DAfStb) (German commission for reinforced concrete) was introduced as a national technical regulation thus enabling the manufacturing and application of SCC without a national technical approval.

Within the framework of this paper, a survey is given regarding the state of the art of the regulations at the application of SCC in Germany. Here, a great importance is attached to the required fresh concrete tests and properties. The test methods for fresh concrete applied in Germany are discussed with regards to their possible suitability for the European test standard of SCC which is presently in preparation. In addition, there is a report on a practice-oriented test method to determine the optimum water content for SCC.

To give a survey of the application of SCC in Germany, finally definite examples are presented concerning the use of SCC in a precast element plant as well as the application as ready-mixed concrete.

1. INTRODUCTION

Self-compacting concrete (SCC) represents the present development in concrete technology. The application of this concrete is mainly a contribution towards an improvement of the concrete technologic, economic and ecologic/social aspects at the manufacturing of concrete. For about seven years the experience has been gathered in Germany by the producers of ready-mixed concrete as well as in precast element plants at the manufacturing, the examination and the application of SCC.

Based on the practical experiences the guideline “Self-Compacting Concrete” (SCC guideline) [1] of the Deutscher Ausschuss für Stahlbeton (DAfStb) (German commission for reinforced concrete) was developed for the manufacturing, the examination and the application of SCC. In December 2004 it was granted a national technical regulation. The SCC guideline is a supplement of the German concrete standard DIN EN 206-1:2001-07 in connection with DIN 1045-2:2001-07 [2]. A national technical approval and an approval in individual cases, respectively, were no longer necessary due to the introduction of this SCC.
guideline. As SCC differs from customary concrete mainly in the state of fresh concrete, the test methods for SCC are of utmost importance. Therefore, the present paper reports on the normative regulations of SCC, the test methods to determine the fresh concrete properties and the optimum water content of SCC as well as the practical experiences in Germany.

2. REGULATIONS FOR SCC IN GERMANY

SCC features fresh concrete properties deviating from DIN EN 206-1 and DIN 1045-2 because there is no compacting which is otherwise customary and stipulated by these standards. SCC compacts itself only under the influence of gravity. Furthermore, as a rule SCC differs from concretes according to DIN EN 206-1 and DIN 1045-2 by an increased powder content. SCC requires high shares of fines thus ensuring its stability towards segregation processes at a simultaneously high flowability. For these reasons it was necessary to develop regulations for SCC.

Concrete with a spread flow of more than 630 mm is termed “highly flowable” in DIN EN 206-1 and DIN 1045-2 and it is classified in the consistency class F6. Whereas such F6-concretes with a spread flow of up to 700 mm are manufactures according to DIN EN 206-1 and DIN 1045-2, concretes with a spread flow of more than 700 mm - self-compacting concrete – is produced and casted under consideration of the requirements of the SCC guideline [1].

The SCC guideline applies for reinforced or unreinforced as well as pre-stressed building parts which were produced with SCC up to a strength class of C70/85 according to DIN EN 206-1 and DIN 1045-2. For lightweight SCC only the design is regulated up to a strength class of LC60/66, not the production. Thus, the SCC guideline does only partially apply for lightweight SCC. It does not apply for concrete according to mix proportion, heavyweight concrete, concrete of the exposition class XM 3 and high-strength concrete as of compressive strength classes C80/95. For these concretes, a national technical approval or an approval in individual cases is still necessary.

The SCC guideline of the DAfStb rules the dimensioning and the construction of SCC as well as the concrete technology and the execution of the construction. It supplements and changes the DIN EN 206-1 and DIN 1045-2 for the application of SCC regarding the choice and the properties of the basic materials, the determination and examination of the consistency and the range of workability, regulations concerning an extended initial test, examinations of the mix stability and sedimentation stability and SCC specific test methods [1]. Thus the focus of the SCC guideline is clearly directed at the test methods of the fresh concrete properties of SCC.

In the technical bulletin “Self-Compacting Concrete (SCC)” of the Deutscher Beton und Bautechnik Verein (German association of concrete and building technology) [3] and the cement instructions “Self-Compacting Concrete – Properties and Examination” [4] the experiences with SCC gained so far were compiled. Thus, the application of SCC in Germany is supported by practical experiences.

3. TEST METHODS TO DETERMINE THE FRESH CONCRETE PROPERTIES

In the SCC guideline the test methods to examine the self-compacting properties are laid down. They comprise the examination of the slump flow and the V-funnel-time. With the knowledge of both these parameters the so-called “window of workability“ can be defined.
(Figure 1). When the respective SCC lie within the “window of workability”, the SCC features a sufficient flowability at a sufficient stability towards segregation. The blocking tendency is tested with the j-ring. To ensure a sufficient resistance against sedimentation of the coarse aggregate, a fresh concrete (Figure 2) as well as a hardened concrete procedure are specified [1, 5, 6]. These methods have proven themselves in the current production of SCC. The fresh concrete method has meanwhile been integrated into an ASTM standard [7].

While developing the EN 206-100 which shall regulate the application of SCC in Europe in the future, the fresh concrete test methods of SCC shall also be regulated. In detail, the test standards of the slump flow-, the V-funnel-, the L-Box-, the j-ring- and the sieve stability test are scheduled. In Germany there is sufficient positive experience concerning all above mentioned test methods with the exception of the sieve stability test to examine the segregation resistance. In German expert circles, the suitability of this method to determine the sedimentation behaviour of the coarse aggregate of a powder type SCC is controversially discussed.

4. **TEST METHOD TO DETERMINE THE OPTIMUM WATER CONTENT OF SCC**

Compared to customary vibrated concretes, the range of the mix proportions in which an SCC features an optimum workability is considerably smaller. In particular, this applies for the water content of the concrete. Here, minor changes may lead to an insufficient workability [8] or to a negative effect on the concrete stability (sedimentation of the concrete, figure 2). The determine the optimum water content and hence the optimum content of superplasticiser for SCC, there is no standardised method. The determination of the optimum water and admixture contents of the concrete mix is also not a component of the SCC guideline.
A quick, practice-oriented procedure to determine the optimum water and admixture contents of SCC was developed – the SCC-steag-method [9]. The development of this procedure was based on the assumption that the mix optimisation of a SCC can be conducted analogue to the mix optimisation of a no-slump concrete. Both concretes yield the maximum possible compaction only by the addition of the optimum water content. Whereas additional compaction energy must be applied to no-slump concretes from the outside, SCC need the addition of admixtures.

It is characteristic of the SCC-steag-method that it is possible to determine the optimum water content of a SCC directly on its no-slump concrete mix by means of the steag test device [10, 11]. This device is applied to determine the water content (Figure 2) at which the minimum air content and the maximum fresh concrete bulk density, i.e., the maximum compactibility of the planned mix proportion, is reached.

Figure 3: Determination of the optimum water content by the air content and by the fresh concrete bulk density, respectively at the example of a no-slump concrete

The SCC-steag-method can be applied to solve the following problems:
- Determination of the optimum water content and the optimum admixture content at the mix design of a SCC,
- Determination of the optimum water content of an existing SCC at the change of a concrete raw material,
- Conduction of the company-made production control at the manufacturing of SCC,
- Determination of the sensitivity as well as the robustness of SCC regarding the total water content.
5. EXPERIENCES IN THE PRACTICAL APPLICATION

For about seven years the experience has been gathered in Germany by the producers of ready-mixed concrete as well as in precast element plants at the manufacturing, the examination and the application of SCC [12]. Before the introduction of the SCC guideline in 2004, SCC were manufactured with an approval in individual cases or with a national technical approval which enabled the introduction of SCC into the practice. Despite a SCC share of the entire ready-mixed concrete in Germany of only 0.2 % in 2004 and 0.1 % in 2005 [13], SCC is applied in superior buildings of in-situ concrete. Thus, e. g. in the phaeno science centre in Wolfsburg and in the BMW plant in Leipzig more than 4000 m³ of SCC were used, each. In contrast to ready-mixed concrete, SCC is applied regularly in some precast element plants [14]. SCC is used i. e. for architecturally demanding building members as well as for special solutions in concrete construction. Figure 4 on the left shows columns with a geometrically complex design, figure 4 on the right shows basic elements of bubble decks which were produced with a powder type SCC with fly ash, each.

![Figure 4: Special building elements in precast construction with SCC: left, columns with a geometrically complex design (design: Schlaich, Bergermann und Partner, Structural Consulting Engineers, Stuttgart; production: Benno Drössler GmbH und Co. KG, Siegen); right, basic elements of bubble decks (BBS Bitter Beton Systeme, Goch)](image)

6. SUMMARY

Since December 2004, the guideline of the Deutscher Ausschuss für Stahlbeton (German commission for reinforced concrete) which regulates the manufacturing and casting of a self-compacting concrete (SCC) has been effective in Germany. Until the adoption of this guideline as a national technical regulation, the application of SCC in Germany was only possible by means of an approval in individual cases or a national technical approval.

A focus of the SCC guideline is directed at the test methods of the fresh concrete properties of SCC. They comprise the examination of the slump flow and the V-funnel-time. With the knowledge of both these parameters the so-called “window of workability“ can be defined (Figure 1). When the respective SCC lie within the “window of workability”, the SCC feature a sufficient flowability at a sufficient stability towards segregation. The blocking tendency is
tested with the j-ring. To ensure a sufficient resistance against sedimentation of the coarse aggregate, a fresh concrete as well as a hardened concrete procedure are specified. These methods have proven themselves in the current production of SCC.

The SCC-steag-method is used for a simple and practice-oriented determination of the optimum water content and the optimum admixture content of SCC. The fundamental idea of the SCC-steag-method is that a SCC can best be manufactured with an optimised no-slump concrete mix.

Although SCC has been applied in Germany only in special cases, extensive experiences were gathered mostly in the precast element plants but also at the application of SCC as a ready-mixed concrete. These experiences were predominantly positive and in the course of the increasing use of flowable concretes, also in Germany a medium-term increasing application of SCC can be anticipated.

REFERENCES