Guideline

PCI Precast/Prestressed Concrete Institute

Guidelines For The Use Of Self-Consolidating Concrete In Precast/Prestressed Concrete

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Second Edition

Guidelines for the use of self-consolidating concrete in precast/prestressed concrete

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FOREWORD

Interim guidelines were prepared in 2003 in response to the increased use of and interest in self-consolidating concrete (SCC) in the precast/prestressed concrete industry throughout the United States. (Note: In current North American practice, the terms "self-compacting concrete" and "self-consolidating concrete" relate to the same material. However, "self-consolidating concrete" is the preferred term.) The guidelines have been updated to incorporate developments that have taken place since 2003. The term "interim" has been removed from the title in recognition that these guidelines represent current recommended practice of using SCC in the precast/prestressed concrete industry.

SCC is a highly workable concrete designed to flow through densely reinforced or geometrically complex structural elements under its own weight and fill voids without segregation or excessive bleeding and without the need for vibration to facilitate consolidation. The workability of SCC is, by design, intended to exceed the highest class of workability associated with conventional high-performance concrete typically used in precast, prestressed concrete fabrication plants. The workability of SCC is generally characterized by the following properties:

- Filling ability – The ability of SCC to flow under its own weight (without vibration) into and fill completely all spaces within intricate formwork, containing obstacles such as reinforcement
- Passing ability – The ability of SCC to flow through openings approaching the size of the coarse aggregate, such as the spaces between steel reinforcing bars, without segregation or aggregate blocking.
- Stability – The ability of SCC to resist segregation and remain homogeneous during transport, during placing, and after placement.

Concrete is classified as SCC if these characteristics are achieved. When passing ability is not a concern, this parameter need not be addressed.

The properties of fresh SCC differ significantly from those of conventional high-performance concrete. Thus, some auxiliary methods, such as characterization and quality control tests and procedures that are adapted to the special properties of the material, are warranted.

These guidelines address the use of SCC in precast, prestressed concrete manufacturing plants and reference PCI plant quality manuals MNL-116-99 and MNL-117-13. Construction site use of SCC is not addressed in these guidelines.

The goal of this publication is to present recommendations for best practices for use of SCC as applicable to current North American practice. It is recognized that practice is evolving because experience with the material is gained in differing circumstances and for different purposes.

The group that developed the original interim guidelines included material suppliers, precast concrete producers experienced in the development and use of SCC mixtures, representatives of governmental agencies, and engineering consulting firms. The PCI Concrete Materials Technology Committee members updated the guidelines; then, the PCI Technical Activities Council members as well as a special review group of selected experts on SCC, reviewed and commented on the guidelines.

Foreward

Definitions

The following terms are defined for use in this manual:

Admixture – A material, other than water, aggregates, hydraulic cement, and fiber reinforcement, used as an ingredient in concrete and added to the batch immediately before or during its mixing to modify the properties of the fresh or hardened concrete.

Aggregate blocking – The situation in which coarse aggregate particles jam between reinforcing steel bars or other obstacles within the form and prevent free flow of SCC.

Air migration – An undesirable condition in which the entrained air in the fresh concrete migrates to form areas of higher-than-designed entrained air content and corresponding areas of lower-than-designed entrained air content.

Architectural concrete – Concrete developed primarily for the visual appearance of the concrete surface.

Bingham fluid – A fluid characterized by a nonzero yield stress and a constant viscosity regardless of flow rate.

Bleed water – The water that rises to the surface subsequent to the placing of concrete. The autogeneous flow of mixing water within, or its emergence from, newly placed concrete; caused by the settlement of solid materials within the concrete mass.

Bleeding test (French) – A test **(Appendix A)** used to determine the tendency of a concrete to bleed. The test evaluates both the rate of bleeding and the total quantity of bleed water from a specimen of known volume.

Bleeding test (ASTM C232) – The standard test for determining the relative quantity of mixing water that will bleed from a sample of freshly mixed concrete. For SCC, ASTM C232 is used except that the sample is not rodded or vibrated for consolidation.

Blocking – The condition in which particles of coarse aggregate combine to form elements large enough to obstruct the flow of the fresh concrete between reinforcing steel or other obstructions in the concrete formwork. This property is significant in SCC because of the absence of vibration energy to dislodge these blockages.

Blocking resistance – The ability of the SCC mixture to avoid blocking.

Caisson test – See filling vessel test in Appendix A.

Cohesiveness – The tendency of the SCC constituent materials to stick together, resulting in resistance to segregation, settlement, and bleeding.

Confined flowability – The ability of a fresh concrete to flow in a form characterized by a low ratio of horizontal form surface to total form surface.

Consolidation – The process of reducing the volume of entrapped air in a fresh concrete, usually accomplished by imparting mechanical energy into non-SCC mixtures. For SCC, consolidation is normally accomplished solely by gravity flow.

Dynamic stability – That characteristic of a fresh SCC mixture that ensures uniform distribution of all solid particles and air voids as the SCC is being transported and placed. Also referred to as dynamic segregation resistance.

Filling ability – The ability of SCC to flow under its own weight (without vibration) into and completely fill all spaces within intricate formwork, containing obstacles, such as reinforcement.

Flowability – The ability of fresh concrete to flow in a confined or unconfined form of any shape, reinforced or not, under gravity and/or external forces, assuming the shape of its container. See also confined and unconfined flowability.

Fluidity – A property of fresh concrete indicating the ease of flow under gravity effects. When regarded as a Bingham fluid, fluidity is evaluated by the concrete yield stress and viscosity.

Fly ash – A finely divided residue with pozzolanic properties that results from the combustion of pulverized coal and is transported by flue gases. Due to its spherical shape and fineness, it can improve the rheology of SCC.

High-fluidity concrete – Concrete that flows with very little external energy input.

High-range water-reducing agent (HRWRA) – A water-reducing admixture capable of producing large water reduction (>12%) or greater flowability of a concrete without causing undue set retardation or excessive entrainment of air.

Initial set – The point at which the concrete reaches a penetration resistance of 500 psi (3.45 MPa) as determined in accordance with ASTM C403.

Jamming – See blocking.

J-Ring test – Test (ASTM C1621) used to determine the passing ability of SCC or the degree to which the passage of concrete through the bars of the J-ring apparatus is restricted.

L-Box test – A test **(Appendix A)** used to determine the horizontal and confined flowability of SCC and/or to verify that the placement of SCC will not be compromised by unacceptable segregation and blocking of aggregates.

Metakaolin – Calcined China clay. Mineral admixture sometimes used to increase powder content of concrete.

Mixture robustness – The characteristic of a mixture that encompasses its tolerance to variations in constituent characteristics and quantities, as well as its tolerance to the effects of transport and placement.

Mortar fraction – The volume percentage of all materials in concrete (cementitious materials, aggregate, water, and air) that pass the No. 8 (2.36 mm) sieve.

Mortar Halo – A concentration of mortar that can form at the perimeter of the slump flow patty during testing according to ASTM C1611. The width of this halo is one of the parameters evaluated in the visual stability index (VSI) test used to judge the stability of plastic SCC mixtures.

Orimet test – A test **(Appendix A)** for assessment of highly workable, flowing concrete.

Orimet with J-Ring test – A test **(Appendix A)** combining these two methods to assess flow and passing ability of a concrete.

Passing ability – The ability of SCC to flow through openings approaching the maximum size of the coarse aggregate, such as the spaces between steel reinforcing bars, without segregation or aggregate blocking.

Paste – The fraction of the SCC mixture comprised of powder(s), water, and air.

Plastic viscosity – Property of freshly mixed concrete that allows deformation to be sustained continuously in any direction without rupture, or the measurement of a material's resistance to increase in its rate of flow with increasing application of shear force.

Powder – Material of particle size passing the No. 100 sieve (0.15 mm).

Preset time – See initial set.

Rheological properties – Properties having to do with the deformation and flow of the fresh SCC mixture.

Rheometer – A device used to determine the yield stress and viscosity of fresh SCC.

Screen stability test – Test method **(Appendix A)** used to assess the segregation resistance (stability) of an SCC mixture.

Sedimentation – See settlement.

Segregation – The differential concentration of the constituents of mixed concrete, such as coarse aggregate, resulting in nonuniform proportion in the mass; or a separation of the components of fresh concrete resulting in a nonuniform mixture. In SCC, segregation may occur during transport, movement of the SCC within the forms, or after placement.

Segregation resistance – The ability of SCC to remain homogeneous in composition during transport, during placement, and after placement without constituents separating from the mass.

Self-consolidating concrete (SCC) (also known as self-compacting concrete) – A highly workable concrete designed to flow through densely reinforced or geometrically complex elements under its own weight and fill voids without segregation or excessive bleeding and without the need for vibration to facilitate consolidation.

Settlement – The process by which aggregates sink and moisture rises in SCC after placement, resulting in nonhomogeneous concrete.

Settlement resistance – The ability of a concrete to resist the tendency of aggregates to sink, resulting in nonhomogeneous concrete.

Silica fume – Very fine pozzolanic material, composed mostly of amorphous silica produced by electric arc furnaces as a byproduct of the production of elemental silicon or ferrosilicon alloys. This fine inorganic material can be used in SCC to modify its rheological properties.

Slag cement (previously known as ground-granulated blast-furnace slag or GGBFS) – A fine granular, mostly latent hydraulic binding material that can be added to modify its rheological properties.

Slump flow test – Test method (ASTM C1611) used (upright or inverted) to measure the unconfined flow and stability of SCC.

Slump flow – The numerical value in inches (mm) of flow determined as the average diameter of the circular deposit of SCC at the conclusion of the slump flow test as measured by ASTM C1611.

Slump flow T_{50} time –In ASTM C1611, the time concrete takes to reach the 50 cm (20.0 inches) diameter circle drawn on the slump plate, after starting to raise the slump cone. Also referred to as the T_{20} inch time in North America.

Stability – See segregation resistance.

Static segregation – Settlement of coarse aggregate particles in an undisturbed mass of fresh concrete as measured by ASTM C1610.

Static segregation resistance – The characteristic of a fresh SCC mixture that ensures uniform distribution of all solid particles and air voids once all placement operations are complete and until the onset of setting, without excessive settlement or bleeding.

Stickiness – The property of concrete that relates to its propensity to adhere to finishing tools and other surfaces that it contacts.

Structural concrete – Concrete of a quality specified primarily by its engineering properties for a structural use.

Superplasticizer – See high-range water-reducing admixture.

Thixotropy – The property of a material that will allow it to exhibit a low viscosity while being mechanically agitated but stiffen after a short period at rest.

Transportability – The ability of SCC to be transported from the mixer to the placement site while remaining homogeneous.

U-Box test – A test **(Appendix A)** involving a U-shaped filling apparatus composed of two separate compartments used to measure the filling and passing ability of an SCC by assessing the height of the mixture on one side of the U to the height on the opposite side of the U.

Unconfined flowability –The ability of a fresh concrete to flow in a form characterized by a high ratio of horizontal form surface to total form surface.

V-Funnel – A consistency testing device **(Appendix A)** used to measure SCC flowability by determining the V-funnel time, the time for a measured amount of concrete to flow through a funnel opening of a specific size.

V-Funnel at T = 5 min. – Same test as the V-funnel test except that the test is performed after allowing the SCC mixture to stand in the apparatus for five minutes before performing the test. The difference in flow characteristics is a measure of the tendency of the SCC mixture to settle. This test method is not applicable to thixotropic mixtures. See **Appendix A**.

Viscosity – One of the rheological constants of fresh concrete, fresh mortar, and fresh paste when they are regarded as Bingham fluids. The magnitude of the change in the applied stress required for changing the unit flow velocity.

Visual Stability Index (VSI) Rating Test Method – A test (ASTM C1611) involving the visual assessment of the slump flow patty to visually evaluate several parameters of stability.

Viscosity modifying agent (VMA) – A material that, when added to concrete, changes the viscosity and improves the stability of the mixture at a constant fluidity.

Water-cementitious materials ratio (w/cm) – The ratio of the mass of free water to the mass of cementitious materials.

Water sensitivity – The amount of free water variation that causes the characteristics of an SCC mixture (primarily the stability) to change from the acceptable range to the unacceptable range.

Workability – That property of freshly mixed concrete or mortar that determines the ease and homogeneity with which it can be mixed, placed, consolidated, and finished.

Yield stress –The minimum stress required to make the concrete flow.

CHAPTER 1
Introduction and guidelines for SCC applicability

1.1 Introduction

Self-consolidating concrete (SCC) is continuing to gain attention and popularity, particularly in the precast concrete industry. These guidelines have been developed to aid in establishing current best practices for use of SCC technology. Several tests are described herein to verify aspects of behavior and performance of SCC. Some of these tests, while not required, are highly recommended.

SCC originated in Japan in the 1980s. At that time, finding sufficiently skilled workers who could construct durable concrete structures had become an industry-wide problem. One proposed solution was to develop concrete that would consolidate under its own weight and not require additional vibration or skilled labor to fully consolidate the plastic concrete. Professor Hajime Okamura (University of Tokyo, now Kochi Institute of Technology) originally advocated SCC in February 1986, and the first successful use with the material was in 1988 (Okamura 2003).

Self-consolidating concrete (SCC) is defined by the American Concrete Institute (ACI 237) as "A highly flowable, nonsegregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation."

However, not all flowing concrete is SCC. Many producers today have adjusted concrete to enhance workability beyond that of conventional concrete. Even though such mixtures are highly flowable, they usually require some vibration for proper consolidation. Flowing concrete is defined as concrete with a spread of less than 20 in. (50 mm) when measured by the slump flow test (ASTM C1611). This type of concrete should be tested as conventional concrete; therefore, all traditional consolidation requirements apply for test sample preparation.

1.2 Benefits of using SCC

Technically, SCC has many advantages over conventional production concrete used in precast, prestressed concrete plants. It is well suited for producing both vertical and horizontal components with block-outs and congested reinforcement. SCC can be used in architectural and structural elements. The following are some of the more notable benefits of using SCC:

1.2.1 Quality

Some of the quality-related benefits associated with SCC include increased strength and durability potential, passing ability, consolidation, and finish. SCC is typically considered a high-performance concrete, producing higher strengths and improved durability in comparison with an equivalent conventional concrete. High-performance is typically attributed to the low water-cementitious materials ratio, higher cementitious materials content, and better consolidation that is usually associated with SCC.

The ability of concrete to flow around and between reinforcing bars under its own weight (without vibration) and without creating blockage is referred to its passing ability. Elaborate form configurations, irregular shapes, thin sections, and heavily reinforced elements can be produced with confidence using SCC due to its excellent passing