PCI COMMITTEE SUMMARY REPORT

Interim Guidelines for the Use of Self-Consolidating Concrete in PCI Member Plants

Prepared by

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This summary report presents an overview of the contents of the PCI committee report on Self-Consolidating Concrete (SCC). The full document has been distributed to PCI member producers and is also available for purchase. SCC is an innovative type of concrete that is now being utilized by the precast/prestressed concrete industry. The mix contains an advanced high-range water-reducing admixture, as well as a relatively large amount of fines, that enables the fresh concrete to flow easily into the form and around the reinforcement without segregation, thereby providing a high rate of production, a smooth concrete surface, and a finished product with improved durability.

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INTRODUCTION

In early 2002, a request was made by the PCI Plant Certification Committee to the Technical Activities Committee (TAC) to provide more guidance to precast/prestressed concrete producers on the use of Self-Consolidating Concrete (SCC). The result of that request was that TAC formed a FAST Team to address this subject and charged the Team to develop guidelines on SCC for industry use. The result of that effort is this committee report.

The Interim Guidelines for the Use of Self-Consolidating Concrete (SCC) in Precast/Prestressed Concrete Institute Member Plants is now available from PCI Headquarters. In addition, one hard copy of these guidelines has been sent to the primary contact person in each Producer Member plant.

The FAST Team that was charged with the development of these guidelines included volunteer representatives of admixture suppliers currently active in the provision of admixtures used in the production of SCC in the United States, precast concrete producer representatives that have direct experience in the development of SCC mixes and the use of SCC in precast product manufacture, and representatives of industry consulting engineering firms.

If SCC is being used in a plant or its use is being considered, the committee urges involved producers to obtain copies of the SCC Guidelines, to study them and make them available to plant personnel. SCC can bring important advantages to the precast/prestressed concrete industry; however, as can be seen from a review of the guidelines, SCC is a different type of material than normal high performance concrete, and thus requires attention to a somewhat different set of issues to ensure overall success in its use.

These interim guidelines have been prepared in response to increasing use of and interest in 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" are synonymous.)

SCC is a highly workable concrete that can flow through densely reinforced or geometrically complex structural elements under its own weight and adequately fill voids without segregation or excessive bleeding without the need for vibration to consolidate it. The workability of SCC is higher than the highest class of workability associated with normal high performance concrete typically used in precast/prestressed concrete fabrication plants.

This workability can be characterized by the following properties:

• Filling ability (confined flowability) – 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 mix coarse aggregate, such as the spaces between steel reinforcing bars, without segregation or aggregate blocking. (This property is of concern only in those applications that involve placement in complex shapes or sections with closely spaced reinforcement.)

• Stability (segregation resistance) – The ability of SCC to remain homogeneous during transportation, placing, and after placement.

A concrete mix is classified as SCC if the requirements for all three of the above characteristics are fulfilled. In instances where passing ability is not a concern, this parameter need not be addressed.

SCC has properties that differ significantly from conventional high performance concrete. Thus, some auxiliary tools, such as new characterization and quality control tests and procedures that are adapted to the special properties of the material, are needed.

It is recognized that currently, there are committees within the American Concrete Institute (ACI), the American Society for Testing and Materials (ASTM), and possibly other organizations in North America that are working on definitive consensus standards for this material. It is also noted that the finalization of standards from the traditional industry standards setting groups are at least several years away. Thus, there is a need for these interim guidelines to assist the precast/prestressed concrete industry in moving forward to responsibly incorporate the use of SCC in the fabrication of precast concrete products. It is expected that these interim guidelines will be superceded by industry consensus standards as they are published in the near future.

The guidelines address the use of SCC in PCI precast/prestressed concrete manufacturing plant settings and reference PCI plant quality manuals MNL-116-99, Manual for Quality Control for Plants and Production of Structural Precast Concrete Products, and MNL-117-96, Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products. Construction site use of SCC is not addressed in these guidelines.

The goal of this document is to present the best available information on SCC as it applies to current North American practice. It is recognized that SCC practice is currently evolving as experience with the material is gained in differing circumstances and for different purposes.

These guidelines have been additionally reviewed and commented upon on an expedited basis by selected members of the PCI Technical Activities Committee and the PCI High Performance Concrete Committee.

The body of the SCC Guidelines consists of 93 pages supplemented by 60 pages of appendices for a total of 153 pages.

The following are excerpts from the SCC Guidelines:

DIVISION 1 – INTRODUCTION AND GUIDELINES FOR SCC APPLICABILITY

In the last several years, SCC has gained considerable attention in the concrete industry. Some important questions have been raised regarding this material:

• Is this a new building material or an extension of our existing concrete technology?

• What are the economics and advantages to the precast/prestressed producer? Is SCC for every producer?

• What levels of technology and skill are required to produce consistent quality SCC?

• What is Self-Consolidating Concrete (SCC)?

One definition of SCC is given below:

"A highly flowable, yet stable concrete that can spread readily into place and fill the formwork without any consolidation and without undergoing significant separation."

[Khayat, Hu and Monty]

In 1983, finding sufficiently skilled workers in Japan who could construct durable concrete structures became an industry-wide problem. One solution proposed was to develop concrete that would consolidate under its own weight and not require additional vibration or skilled workers 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 success with the material was in 1988.

The ability of concrete to flow around and through reinforcement under only the energy of its own weight (without vibration) without creating blockage is referred to as the passing ability of the mix. This capability, in conjunction with the absence of the noise associated with vibration within a precast/prestressed concrete plant, creates new production opportunities.

SCC is a high performance concrete in the plastic state. It takes less energy to move the material (lower shear stress) (viscosity) and should not separate or segregate. A material that takes less energy to move will require fewer workers or finishers to produce a quality precast/prestressed concrete unit. SCC has the potential to allow reallocation of manpower and increased production with existing resources.

When SCC is placed in a form, its motion may be a creeping movement or a rapid flow. Because of this style of flow, the surface finish between the form and the concrete can be exceptionally smooth, creating a much-improved form finish over conventional concrete. To take advantage of the properties of SCC, new production considerations come into play. For example, an important factor in capturing the finish advantages is the type of form oil used, as this can significantly affect the surface finish.

Demanding form configurations, irregular shapes, thin sections, and heavily reinforced elements can be produced with confidence using SCC. Producing concrete without vibration results in a greatly improved work environment in the plant. Safety hazards are also reduced in the plant, as use of SCC minimizes the need for workers to walk on the top of the form, and eliminates the cords and hoses associated with concrete vibrators. It has been reported that worker absenteeism and accidents have both seen significant reductions when SCC has been introduced into precast production activities.

Concrete forms also benefit from lack of vibration with increased life cycle. Typically, form vibration is one of the elements that lead to form damage, associated repair requirements, and ultimately to form replacement.

1.2 Product Applicability

What is the applicability of SCC? Where can it be used?

Technically, SCC has many advantages over normal production concrete used in precast/prestressed concrete plants. It is well suited for producing both vertical and horizontal components with block-outs and crowded reinforcement. SCC is applicable for production of architectural and textured surfaces. Some precast plants are reporting using SCC in nearly 100 percent of their production and expect further opportunities for SCC with the industry acceptance of an SCC specification.

SCC will require a higher level of quality control, a greater awareness of aggregate gradation, mix water control, and the use of highly advanced high-range water-reducing admixtures and/or viscosity modifiers.

When looking at SCC costs and benefits versus those of conventional concrete, economic analysis should not be restricted to the material cost of the mix alone. The benefits of SCC will filter throughout a plant with savings in production labor, greater form life, fewer bug holes, less patching, improved work environment and the opportunity of changing production methods by eliminating vibration.

Using SCC in plant production provides the opportunity for improved, more efficient operational procedures. An economic study of SCC use for a specific plant needs to span six months to a year to completely analyze the beneficial impact of SCC production, as modified production methods associated with the use of the material, will continue to evolve over time.

1.3 Changing Production Methods to Take Advantage of SCC Properties

It is expected that significant additional advantages will result from SCC usage as individual producers rethink their production methods in the context of the characteristics of SCC. For example, can the current methods of concrete transportation within the plant be changed to take advantage of the ease of placing SCC? Can the methods of forming and securing internal reinforcement and hardware be revised because they do not have to withstand the forces associated with the vibration/consolidation process?

Can the time associated with concrete placement be reduced, thus allowing more time in the daily cycle for other things? Can more time be made available for curing during the daily production cycle, thus reducing the need for accelerated curing? Are there elements of the current plant layout that the use of SCC will allow to be made more efficient? Can labor be allocated from placement activities to other important activities allowing improvements in efficiency and quality?

1.4 Potential New Product Applications for Elements Cast from SCC

An important aspect of the design of many current precast elements is the ability to place and consolidate concrete within the form and around the internal reinforcement, prestressing strand, and hardware that are incorporated within the element. In some cases, this includes providing space for the insertion of internal vibrators and assurance that there is sufficient space to allow concrete flow. Can the increased flowability of SCC ease any of these constructibility requirements and can element shapes be changed to advantage (made more efficient) as a result?

Can smaller diameter reinforcement on a smaller grid spacing be used to advantage to develop thinner sections that still provide adequate strength and serviceability? Can high strength composite materials be used in combination with thinner sections to produce high value products that are now produced by other segments of industry? SCC may allow the development of new manufacturing processes that can be used to produce new classes of precast concrete elements.

A wide variety of architectural finishes can be accomplished with SCC. As with any new concrete mix, the procedures to attain desired finishes must be developed for new SCC mixes.

If surface finish quality were to be dramatically improved through use of SCC, what new high value products could the precast industry produce? Some examples might be

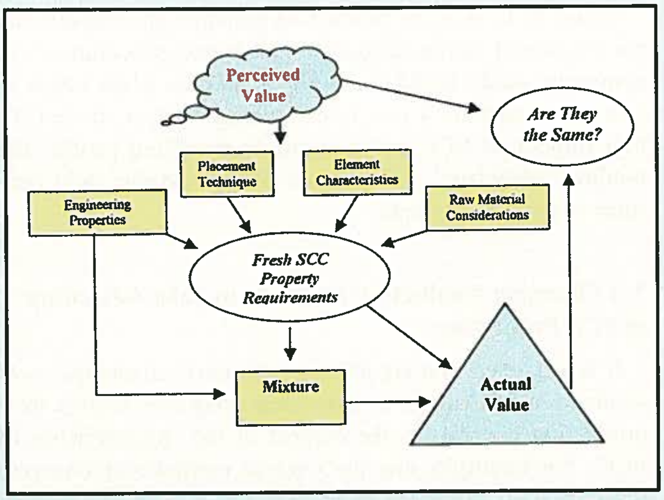

Fig. 3.1. Variables involved in establishing the required fresh SCC properties.

higher value cladding, higher value interior finish elements, and items like sinks and bathtubs. The development of SCC guidelines, specifications, and best practices may lead to the use of SCC in mainstream concrete production.

DIVISION 3 – GUIDELINES FOR THE PRODUCTION QUALIFICATION OF SELF-CONSOLIDATING CONCRETE

From a basic perspective, SCC needs to be both fluid and stable. The required level of fluidity is greatly influenced by the particular application being considered. Therefore, a balanced approach in choosing the correct plastic performance targets for SCC is necessary.

It is the task of the producers to select the appropriate test method(s) for qualification of their SCC mixes. The selected test method(s) will depend on the application of the mix and its resulting characteristics. Different qualifications test methods may be appropriate for different mix applications.

Fig. 3.1 shows the different variables that affect the required fresh SCC properties. Not only are project and raw material variables considered but also economic variables. As can be seen, an initial perceived value drives the user to trial use of SCC. The challenge is to develop a solution where the realized value of SCC usage is equivalent to the perceived value.

This is where the mixture qualification process becomes important. Essentially, the fluidity of SCC is analogous to economic specification of compressive strength; one should design for only that level that is needed for the successful completion of a project.

There are three levels of tests to consider when using SCC:

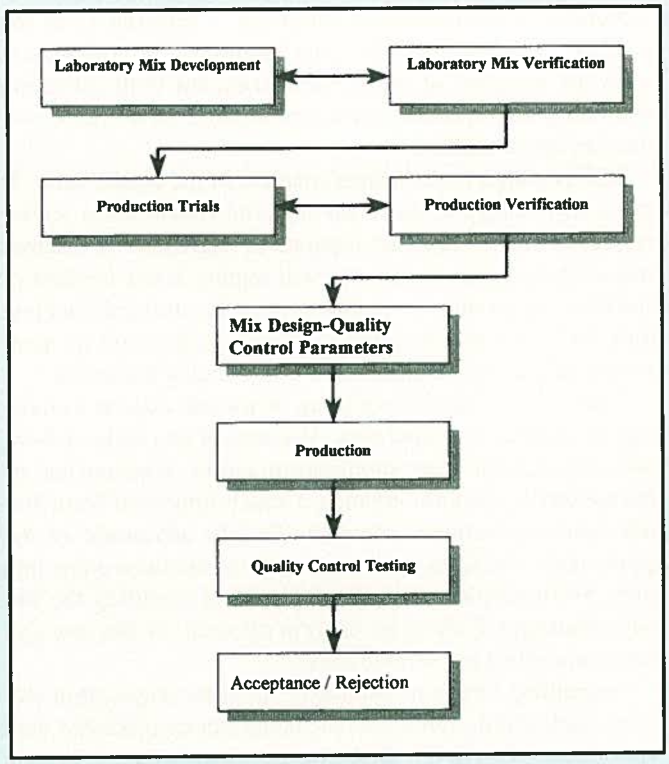

Fig. 3.1.1. Mix qualification process map for SCC.

The first level is that associated with laboratory testing of the mix to determine the initial mix characteristics and confirm the hardened properties of the basic mix design.

The second level of testing is the qualification testing necessary to qualify the mix in the production environment. This level includes qualification of the batching process, the mixing process, the transportation and placement process, and finally the finishing and curing process.

Finally, the third level of testing is that associated with the quality control of the fresh SCC and the confirmation testing to confirm the hardened properties of the SCC.

These levels of testing are schematically shown in Fig. 3.1.1.

CONCLUDING REMARKS

SCC appears to have significant potential for its use in the precast/prestressed concrete industry. As with any new material, there are material properties differences and production process differences that must be understood and appropriately addressed in both design and production activities.

The development and distribution of the PCI SCC Guidelines is one step in furthering the understanding of this material that will allow its appropriate use in the production of high quality precast/prestressed concrete products that meet all of the needs of the industry's many and varied customers.