The SCC Test: Inverted or Upright?

By Paul Ramsburg

One of the most significant limitations of using self-consolidating concrete (SCC) in the United States concerns the apparent lack of established test standards to quantify its physical properties. In order for SCC to be accurately specified and to ensure quality, uniform standards must exist that can be accepted and used by all in the industry. Although there are many methods under development, it is important to appreciate that none of the test methods for SCC has been standardized yet.

One test that has been widely accepted by those working with SCC is the slump flow test method. The slump flow is used to evaluate the horizontal free flow of SCC in the absence of obstructions. First developed in Japan for use in assessment of underwater concrete, this method is based on ASTM C143, the test method for determining slump. It is an indication of fluidity, or filling ability. It can be argued that the completely free flow, unrestrained by any boundaries, is not representative of what happens in practice in concrete construction, but the test at very least can be used to assess consistency from batch to batch. Slump flow has been standardized by several Japanese and European agencies, and will be the first test method for SCC to be published by ASTM International.

To determine the slump flow, a slump cone (also known as an Abrams cone—the same apparatus as in ASTM C143) is placed on a moist non-absorptive surface and filled with fresh SCC. The cone is lifted in 2 to 4 seconds, at a height of 6 to 12 inches, and the concrete flows out under the influence of gravity. Two perpendicular measurements are taken horizontally across the spread of concrete and the average is reported.

There are two procedures for filling the Abrams cone—it may be in the upright position or inverted. Inverting the test apparatus is not a new or unfounded concept. The German document "DafStb Guideline for Self-Compacting Concrete" states in section M.1.6.2, "The slump flow value alternatively also may be determined with the cone mold turned over, as a result of which filling it is facilitated and the floating up of the slump funnel is hindered." Very few producers have evaluated the two procedures, and most follow what their admixture sales representative has instructed. This likewise goes for many specifiers, who've seen little more than very elaborate presentations.

The inversion process

Why invert the cone? Perhaps those actually producing and testing SCC on a regular basis can best answer that question. The most common statement that you will hear is "it is easier," but how so? Filling is accomplished more easily by pouring the sample into the larger opening, and this reduces spillage. Though if filling were the only issue, this could be overcome with a readily available funnel manufactured to fit the standard slump cone.

Also, the lid of a plastic 5-gallon bucket with a 6-inch opening cut in the center can be placed over the upright cone to catch any spillage that may occur. By placing the apparatus in an inverted position

A technician performs the inverted slump flow test on an elevated flow board.

PHOTOS: PAUL RAMSBURG

The cone and the technician are firmly planted.

A technician has to twist for the sample and bend to fill the upright cone.

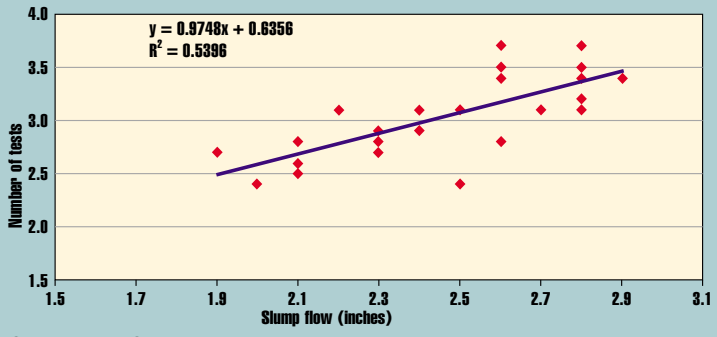
the cone can be maneuvered without the producer's feet coming into play. Most producers using the inverted method agree the weight of the concrete in the cone holds it downward so that a person does not have to stand on it. With the cone inverted, a Plexiglas "flow board" can be elevated so there is no need to bend over. And if your feet are not tied down, you are free to move around instead of stretching and twisting for the next scoop of concrete.

One ready-mix producer states, "Most will find they prefer upside down once they try it." This was found to be true with a Lafarge ready-mix representative participating in the development of the statistical statement for the ASTM standardized method. Originally he was opposed to the idea of an inverted cone, even though he had never conducted the test in that manner. While performing multiple slump flows with the upright cone, with his feet planted and twisting for the wheelbarrow, he noticed the person performing the inverted method was able to momentarily leave the

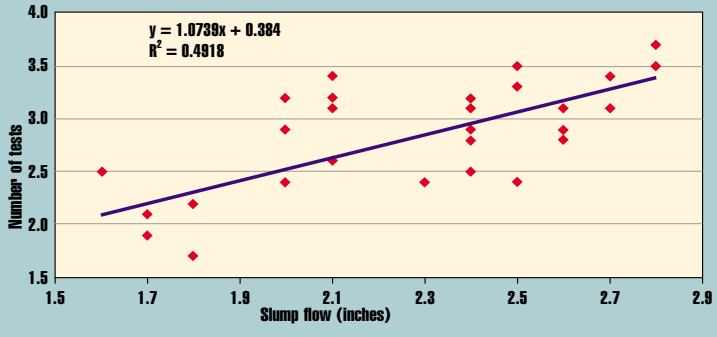
Although no standards have been established, testing slump flow is an everyday reality.

Inverted and Upright Comparisons

Slump flow <25 inches



Slump flow >25 inches



The three categories of SCC mixes tested are: less than 25 inches flow, greater than 25 inches flow, and greater than 25 inches flow with noticeable segregation or bleeding. Noted in these charts are the compared results of both the slump flow and T-50 for 30 tests each. This is a statistical summary of inverted versus upright methods.

SOURCE: PAUL RAMSBURG AND CELIK OZYILDIRIM

cone and did not have to twist and stretch for the sample.

This industry professional walked away as a fan of the inverted method. Even if ergonomic safety was the only reason to consider the inverted method, shouldn't that be enough? It is possible for one technician to conduct the slump flow in either position, though some users say they need two technicians for the upright version.

Some have a concern with the stability of the cone while inverted, though most producers have not had a problem with overturning the cone. Pressure can be applied if necessary, as opposed to holding the upright cone in position.

Considering the options

What about confusion that may be caused by standardization of an option within the method? People who express this concern are selling short the individuals that make up our industry. How many specifiers, engineers, or producers do you know who are confused about the choice given to them for determining air content in fresh concrete? Not only are there two methods to measure this property, but one of these (ASTM C231) gives you the choice of two procedures. By briefly thumbing through the standards, you'll find it is not uncommon for ASTM to allow for options.

Not only do various European guidelines attempt to standardize the inverted and upright slump flow methods, but also PCI's "Interim Guidelines for the Use of SCC in PCI Member Plants" documents them both.

A recent survey conducted by representatives of Oldcastle Inc., Fredericksburg, Va., resulted in more than 150 responses from concrete producers who are using, or have used, SCC in numerous applications, including both precast and ready-mix. Among those respondents approximately 45% use the slump cone upright and 55% inverted. Four of those producers have conducted comparison tests between the two procedures, each of them concluding that the procedure "did not affect the outcome of the spread."

A solid batting average

Correlation testing conducted at the Oldcastle facility has shown that there is no difference in results between the two cone positions. Three mix designs with three different performance levels were evaluated: less than 25 inches flow, more than 25 inches flow, and more than 25 inches with noted segregation and bleeding. In the 30 tests of less than 25 inches flow the average difference was less than ¼ inch, with a standard deviation of ¾ inch. As the flow values increase both the average difference and the standard deviation decrease dramatically.

A statistical analysis of the three sets of 30 tests would determine any difference between the upright and inverted methods. Based on the Paired T-test at the 5% significance level (alpha = 0.05), there is no difference in the averages between positions of the cone. Based on the F-test at the 5% significance level, there is no difference in the variability of test results between the upright and inverted slump flow methods.

Tests currently are being conducted with aggregate more dense than the average concrete constituents, as well as lightweight aggregate. These tests are exhibiting similar results.

A representative from Euclid Chemicals, Cleveland, responded to the survey by saying, "In our tests, there was no difference in the results one way or the other, but I can see that in certain cases a higher head pressure could make a difference—maybe more on the T-50."

That brings us to how the position of the cone may affect other test methods that can be conducted along with the slump flow. Three basic properties of SCC should be tested in the qualifying and/or control stage. These are workability (fluidity), segregation resistance, and passing ability (resistance to blocking). Relative viscosity also may be measured to quantify the approach to the segregation threshold. To measure all these properties efficiently, and without the need for cumbersome specialized equipment, a Japanese ring (J-ring) may be combined with the slump flow, Visual Stability Index (VSI), and T-50 methods, and may be conducted concurrently.

Is It Slumping, Spreading, or Both?

While there is no denying the differences between standard concrete and self-compacting concrete, how to talk about SCC remains an open issue.

First, its name. Compaction is the behavior cited in a 2002 document developed by EFNARC, the European Federation of Producers and Contractors of Specialist Products for Structures (*www.efnarc.org*), entitled "Specification & Guidelines for Self-Compacting Concrete." Meanwhile, ASTM International refers to consolidation in the working title of its new "Standard Test Method for Slump Flow and Stability of Hydraulic-Cement Self-Consolidating Concrete," expected to be finalized sometime this year. Fortunately, "SCC" works in both cases.

In describing test results, however, the differences in terminology are more persistent. Because SCC has a very high slump—one might even say it puddles—standard slump measurements offer a poor basis of comparison. Instead, SCC producers measure the average diameter of the concrete's lateral flow. While the term "spread" is widely used to describe this measurement, the ENFARC guidelines consistently refer to it as "slump flow." Likewise, the ASTM draft standard makes numerous references to slump flow, but also defines and uses the term spread.

While slump flow appears likely to become the description used in codes and specifications, people discussing SCC are probably going to talk about spread; in practice, the terms are synonymous.

In order to ascertain the tendency of SCC to block a ring with a diameter of 12 inches, to which metal rods are fastened and distributed uniformly over the entire circumference, the J-ring is placed around the slump cone and the flow test is conducted as it is unconfined. If the slump cone is inverted it can be used without modification. Otherwise the flanges must be removed, requiring that a user possess two slump flow cones.

The VSI is a qualitative visual test that compares photographs and descriptions of mixes with various degrees of segregation and bleeding. How does the inverted method affect the VSI? A representative from Grace Construction Products, Cambridge, Mass., describes his experience: "Some of our people have noticed that the stone tends to pile up in the middle of the slump-flow spread when the inverted cone is used," he says. "Thus, the inverted cone could be viewed as a more rugged test for segregation."

The T-50 is a simple means to quantify the relative viscosity of a mix. Using the same equipment as the slump flow method, a measurement of the time for the SCC to spread to 20 inches is recorded. The timing starts immediately as the cone is lifted and stops when any part of the concrete specimen touches the 20 inches mark placed on the flow board. There is concern that this test is somewhat arbitrary due to the difficulty of starting and stopping a clock while conducting the slump flow. The small amount of possible intervals, only a few seconds, also plays into the issue.

The Oldcastle correlation testing shows a logical increase in T-50 time with the inverting of the cone. This is largely due to the fact that the specimen is starting from a 4-inch diameter instead of 8 inches. This could possibly improve the T-50, with a greater number of intervals; small differences in relative viscosity could be more noticeable. As the slump flow values increase, the variance in the T-50 was found to be less obvious. When considering the statistical analysis it appears that there is no difference in the fast flowing system (segregated mix), but as the flow slows the difference becomes significant. In further testing it will be determined whether a value could be added to the T-50 equation to correlate the methods.

Various testing methods

The EFNARC document makes this assessment: "This is a simple, rapid test procedure, though two people are needed if the T-50 time is to be measured." Two admixture suppliers and several departments of transportation confirm that even though it is possible for this to be a one-man test, most often two technicians are used. Surprisingly the vast majority of those SCC producers surveyed responded to a question about the T-50 with "what is T-50?" Although this test is relative to specific sets of materials, and we know too little about it to ever specify a certain value, it can be a valuable tool to producers during the mix qualification process.

We have entered a new era of concrete, where rheology must be considered. In the future we will speak more in terms of "yield stress" and "viscosity," and less about "workability." More elaborate and definitive test methods will be developed to assess these characteristics, but just as there is the trusty slump test, so there will be the slump flow.

It's obvious there always will be some controversy surrounding this issue. Everyone will have a preferred way of performing the slump flow test method. Should ASTM and other standards developers allow for an option of either the upright or inverted cone? The Virginia Transportation Research Council makes a great point, when asked whether the industry should have this option: "Which one we use and what values we require are up to us." Both the inverted and the upright slump flow procedures are well-established methods, regardless of concerns over how they correlate. They should be standardized and the choice of which procedure to use left up to those who specify, contract, or produce.

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For the complete comparison data and statistical comparison, visit www.rotondo precastva.com *and click on 'special projects.' For more information on SCC, the new publication* Conference Notes, First North American Conference on the Design and Use of Self-Consolidating Concrete *can be found at* www.wocbookstore.com.