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SELF-CONSOLIDATING GROUT FOR CONCRETE MASONRY

TEK 9-2B

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INTRODUCTION

Self-consolidating grout (SCG) is a specially-formulated grout for use with reinforced masonry. It is designed to fill the long, narrow and sometimes highly congested cores of reinforced walls without the need for consolidation and re-consolidation by mechanical vibration or by puddling.

Self-consolidating grout has been used in various parts of the United States, under the grout demonstration panel provisions of *Specification for Masonry Structures* (refs. 1, 2), which is included by reference in the *International Building Code* (refs. 3, 4). The 2008 edition of *Specification for Masonry Structures* (ref. 5), however, includes explicit provisions for SCG.

Unlike conventional grout and conventional concrete, self-consolidating grout (SCG) is a special application of self-consolidating concrete (SCC) that uses aggregates complying with ASTM C 404, *Standard Specification for Aggregates for Masonry Grout* (ref. 6), as specified in ASTM C 476, *Standard Specification for Grout for Masonry* (ref. 7).

Similar to conventional grout, there are two types of self-consolidating grout, coarse and fine, with the latter containing only fine aggregate. Coarse self-consolidating grout has been the most common, although fine SCG is predominant in several specific regions of the U.S.

MATERIALS FOR SELF-CONSOLIDATING GROUT

Self-consolidating grout attains a high flow not from adding more water, but from a careful mix design to create a flowable yet highly cohesive grout that will not segregate and can pass freely through congested reinforcement and narrow openings without "blocking or bridging." SCG must maintain its fluidity without segregation and maintain consistent properties throughout the grout lift. It is composed of aggregates, cementitious materials, water and special admixtures which provide the fluidity and stability to meet performance requirements.

Aggregate Size and Proportion

To obtain the desired filling and placing ability, aggregates

used in SCG should meet the requirements of ASTM C 404, as specified in ASTM C 476. The requirements for coarse aggregate, for use in coarse SCG, are essentially the same as the requirements for No. 8 and No. 89 coarse aggregate in ASTM C 33, *Standard Specification for Concrete Aggregates* (ref. 8): they should be either a Size No. 8 or Size No. 89 gravel, stone or air-cooled iron blast furnace slag with 100% passing the ½ in. (13 mm) sieve and at least 85 to 90% passing the ⅜ in. (9.5 mm) sieve. Fine aggregate, for use in either coarse or fine SCG, is typically Size No. 1, which is a concrete sand as defined in ASTM C 33, but could also be Size No. 2, which is a sand for masonry mortar as defined in ASTM C 144, *Specification for Aggregate for Masonry Mortar* (ref. 9).

ASTM C 476 contains a proportion specification as well as a performance specification for masonry grout. The proportion specification specifies that coarse grout should have fine aggregate in the amount of 2¼ to 3 times the sum of the volume of the cementitious materials and coarse aggregate in the amount of 1 to 2 times the sum of the volume of the cementitious materials. These ASTM C 476 requirements are equivalent to s/a (sand/total aggregate) ratios of approximately 0.50 to 0.60 on an absolute volume basis. By comparison, most self-consolidating concrete mix designs have similar s/a ratios in the 0.50 to 0.60 range.

Cementitious Materials and Minus 100 (0.150 mm) Sieve Content and Composition

Grout is required to have a minimum compressive strength of 2,000 psi (14 MPa) after 28 days of curing (ref. 7). *Building Code Requirements for Masonry Structures* (ref. 10) sets an upper limit on the specified compressive strength of grout at 5,000 psi (34.5 MPa) at 28 days when using strength design of concrete masonry, although experience indicates that many conventional grouts develop strengths greater than this specification limit. Note that actual strengths are somewhat higher than the specified strength to assure compliance.

In the historical context of masonry materials, the term cementitious materials has commonly referred to the cement content (as well as lime in the case of masonry mortars) used in the manufacturing of masonry units, mortar or grout. In the production of SCG, however, the fraction of very fine aggregate particles present in the mix can have a significant influence

on the plastic (and by association, the hardened) properties of SCG, and therefore needs to be considered in the batching of SCG. As such, the ‘powder’ content of an SCG mix, which includes both conventional cementitious materials as well as the very fine aggregate dust smaller than the 100 (0.150 mm) sieve, is monitored to ensure a stable SCG.

Adequate paste content is critical for making stable SCG mixes because the paste forms the matrix in which the particles are suspended. This paste is composed of cementitious materials (including the powder), water and entrained air, if any. The entire powder content of some mixes may contain auxiliary materials including pozzolanic and hydraulic materials, as well as ground limestone and inert fillers. These additions can improve and maintain cohesion and segregation resistance of the mix while lowering the overall cost and helping to control the ultimate strength of the mix.

Although not widely used in the U.S., ground limestone and inert fillers can be very effective in SCG mixes as a means of keeping compressive strengths to the lower range. They should be considered if they are regionally available. Fly ash can also be an effective addition because its use can help enhance the filling ability and slump flow of the mix while providing increased cohesion and reduced sensitivity to changes in water content. Research has shown that slump flow values are increased when the fly ash replacement rates are between 20 and 40% of portland cement (ref. 11). If the goal is to control compressive strengths, Class F fly ash can be effective because it typically does not contribute as much to strength gain as Type C fly ash. GGBFS (Ground Granulated Blast Furnace Slag) has successfully been used in SCG mixes to replace some of the cement, but its high ultimate strength gain usually means that the compressive strengths of these mixes are usually similar (or sometimes higher) than straight cement mix designs.

Research (ref. 12) has demonstrated that coarse SCG mixes could be made with total cementitious materials contents of 750 lb/yd³ (445 kg/m³), and possibly with 700 lb/yd³ (415 kg/m³). By comparison, a typical conventional coarse grout made to the proportion specifications of ASTM C 476 contains about 550 to 700 lb/yd³ (325 to 415 kg/m³) of cementitious materials.

Some limited testing in the NCMA research (ref. 12) demonstrated that fine SCG could be made with total cementitious materials contents in the range of 800 to 850 lb/yd³ (475 to 505 kg/m³). By comparison, a typical conventional fine grout made to the proportion specifications of ASTM C 476 will contain about 700 to 1,000 lb/yd³ (415 to 590 kg/m³) of cementitious materials.

Water Content

The term ‘natural slump’ describes the slump of the grout mix before the polycarboxylate is added. A common procedure for making self-consolidating concrete is to set the initial water target to the amount needed to bring the mix to a ‘natural slump’ of 2 to 4 in. (51 to 102 mm). The polycarboxylate is then added to make the mix fluid enough to obtain the desired slump flow. This would also be an acceptable initial water target for making SCG, although NCMA research (ref. 12) indicated that some of the most successful batches of coarse and fine SCG made with the local materials used in the research had initial water targets that yielded a ‘natural slump’ of 6 to 9 in. (152 to 229 mm) before the polycarboxylate was added.

Admixtures

Admixtures are integral to the production of SCG. The primary admixture used to impart fluidity and stability to the SCG mix is a class of high-range water-reducing admixtures known as polycarboxylates (PC). These long-chain polymers are synthesized to help keep the cement grains dispersed while adding some cohesiveness and stability to the SCG mix.

Another class of admixtures often used to make SCG in conjunction with the PC is the Viscosity-Modifying Admixtures (VMA). VMAs help adjust viscosity and can improve the cohesiveness and stability of the mix while allowing it to flow without segregation. Not all PC and VMA products have the same properties. Some PCs impart substantial amounts of stability and cohesiveness to the mix and are recommended to be used without VMA, while others benefit from the addition of VMA.

In the past (before polycarboxylates), there have been indications that in some situations superplasticizers in grout for masonry structures have not performed well because they exhibited a short pot life, meaning the mix quickly lost fluidity and rapid stiffing would follow. Absorption of mix water into the surrounding masonry also negatively impacted the flow. In high-lift grouting (placing grout into grout columns as high as 24 ft (7.3 m)), enough water could be lost to cause the grout to stiffen and bridge before reaching the bottom of the grout column. With the advent of newer high-range water reducers such as polycarboxylates, however, this problem is no longer evident (ref. 13).

Note that proportioning of SCG is not permitted in the field (ref. 5). However, final adjustment of the mix, in accordance with the SCG manufacturer’s recommendations, utilizing water or the same admixture used in the mix is permitted.

SCG PLACEMENT

Self-consolidating grout is pumped or placed into spaces to be grouted using the same procedures as for conventional grout. Research has shown that with SCG there is no need to first remove mortar fins and protrusions exceeding 1/2 in. (13 mm), as is required for conventionally grouted masonry (refs. 3, 4), since SCG is fluid enough to flow around these small obstructions (ref. 13). However, it is important to note that *Specification for Masonry Structures* currently requires the removal of mortar fins and protrusions exceeding 1/2 in. (13 mm) for both conventional grout and SCG (ref. 5). Note that because SCG is so fluid, it will flow through gaps wider than about 3/8 in. (10 mm). To contain the grout, therefore, it is recommended to mortar the masonry unit cross webs of cells containing grout in partially grouted construction.

In bond beams, SCG will be adequately contained using conventional grout-stop materials, such as plastic mesh. When filling intermediate bond beams using high-lift grouting, place the grout-stop material in the bed joints both above and below the bond beam to prevent the SCG from rising above the bond beam location.

Once the SCG is placed, consolidation and reconsolidation is not necessary with either coarse or fine SCG.

Documented successful lifts of 12 ft 8 in. (3.9 m) have been achieved by filling the grout columns of 8-in. (203-mm) concrete masonry walls in a single lift in less than a minute using a concrete pump (ref. 13). Other undocumented placements

have placed SCG in a single 24-ft (7.3-m) lift. Twenty-four feet (7.3 mm) is the maximum pour height currently permitted by *Building Code Requirements for Masonry Structures* and *Specification for Masonry Structures* (refs. 10, 5). Note also that for SCG, grout lift height can equal the grout pour height.

Blowouts have not been shown to be a problem for conventional masonry units in this research nor in field experience. However, specialty units with reduced or removed webs, such as "H-block" or large pilaster or column units, may require reduced lift heights.

No special curing procedures are required when using SCG. When appropriate, standard hot and cold weather construction provisions should be followed, as for other masonry projects. See *All-Weather Concrete Masonry Construction*, TEK 3-1C (ref. 14), for more detailed information.

SCG QUALITY ASSURANCE AND QUALITY CONTROL

Specification for Masonry Structures (ref. 5) requires SCG to:

- meet the material requirements of ASTM C 476,
- attain the specified compressive strength or 2,000 psi (13.79 MPa), whichever is greater, at 28 days when tested in accordance with ASTM C 1019 (ref. 15),
- have a slump flow of 24 to 30 in. (610 to 762 mm) as determined by ASTM C 1611 (ref. 16), and
- have a Visual Stability Index (VSI) less than or equal to 1 as determined in accordance with ASTM C 1611, Appendix X.1.

The ASTM C 476 material requirements are described in *Grout for Concrete Masonry*, TEK 9-4A (ref. 17). Other quality assurance and quality control provisions related to SCG are described below.

Some methods commonly used for self-consolidating concrete to evaluate passing ability, like the L-Box or J-Ring, are not normally used with SCG because experience indicates that the $\frac{3}{8}$ in. (9.5 mm) maximum aggregate size used in SCG has adequate passing ability in masonry grouting applications.

Compressive Strength Testing of SCG Mixes

The current edition of ASTM C 1019, *Standard Test Method for Sampling and Testing Grout* (ref. 15), addresses the testing of SCG. The procedure for testing SCG is very similar to that for conventional grout, except that SCG is placed in the mold in one lift instead of two and SCG does not need to be rodded.

Slump Flow

The slump flow test method defined in ASTM C 1611/C 1611M, *Standard Test Method for Slump Flow of Self-Consolidating Concrete* (ref. 16) is used to monitor the consistency of fresh, unhardened SCG and its unconfined flow potential. It is particularly useful to assess the batch-to-batch consistency of SCG supplied over time.

Because of the fluid nature of SCG, traditional measures of consistency, such as the ASTM C 143 (ref. 18) slump test, are not applicable to SCG. The slump flow test is an adaptation of the ASTM C 143 slump cone test. In the slump flow test, SCG is loaded into an inverted slump cone in a single lift

without consolidation. The cone is removed and the diameter of the grout slump flow is measured (see Figure 1).

Visual Stability Index (VSI)

VSI, also defined in ASTM C 1611, is performed after the slump flow test to provide a qualitative assessment of the SCG's stability. The SCG patty resulting from the slump flow test is examined for aggregate segregation, bleeding and evidence of a mortar halo (a cement paste or mortar ring that has clearly separated from the coarse aggregate, around the outside circumference of the SCG patty). The SCG mix is then assigned a VSI, from 0 (highly stable) to 3 (highly unstable).

T₂₀ (T₅₀)

Although not required by *Specification for Masonry Structures*, T₂₀ (T₅₀) records the time it takes, during the slump flow test, for the outer edge of the SCG patty to reach a diameter of 20 in. (508 mm) from the time the mold is first raised. It is an optional test for self-consolidating concrete, and is similarly applicable to SCG to provide a relative measure of the unconfined flow rate and an indication of the relative viscosity of the SCG. While the actual target value for T₂₀ (T₅₀) can vary for different SCG mixes, it has value in verifying the consistency between SCG batches delivered to the job site.

Self-Healing Ability 'S' Test

The 'S' test can also be used to help determine the stability of an SCG mix. While this is not a standardized test method, it is adapted from a simple test that is done by some practitioners in the field. There is a common version and a modified version, which gives an indication of the relative segregation resistance of the SCG when subjected to local vibration.

The common self-healing (non-disturbed) test is performed after the slump flow, T₂₀ (T₅₀) and VSI have been recorded. A 10- to 12-in. (254- to 305-mm) 'S' is drawn in the SCG patty with a finger, making sure to scrape off the SCG all the way down to the board. The patty is observed to see if the 'S' will self-heal. In cases where the self-healing is excellent, the SCG flows back together and there is little or no evidence of the 'S' remaining. In cases where the self-healing is poor, the SCG does not flow back together and the 'S' remains very visible with severe aggregate, paste or water segregation.

Due to observations during the NCMA research (ref. 12), a self-healing (after agitate) test was created. After completing the common self-healing test, the SCG patty is vibrated and a



Figure 1—SCG Slump Flow Test

second test, designated self-healing (after agitate), is performed. To vibrate the mix, the side of the slump flow base-plate is lightly kicked or tapped six times with a foot (three on one side followed by three on an orthogonal [right-angle] side). The 'S' test is then repeated and the mix is rated again.

Suitability of Segregation Tests

In the NCMA research (ref. 12); several mixes were used to determine the suitability of self-consolidating concrete segrega-

tion tests on the SCG mixes. Testing was performed to evaluate both the Column Technique for Static Segregation (ASTM C 1610) (ref. 19) and the European Sieve Segregation Test (ref. 20). It was found that these tests were not able to distinguish unstable SCG mixes from stable mixes. It is not clear if this was a function of the particular raw materials used or a general characteristic of coarse SCG mixes. The self-healing (after agitation) test described above was found to be a much better indicator of stable and unstable mixes for SCG.

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