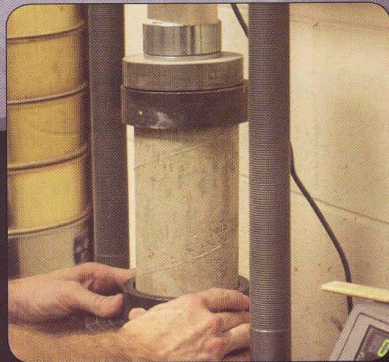


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*The Driver
Simulator*



TDOT 204.06 CLSM SPECIFICATION

A Five Part Series On The New

TDOT 204.06 CLSM Specification

Part 1: Changes from the 1995 to the 2006 Specification and Why They Came About

L. K. Crouch, Brian Egan and Steve M. Hall

The new Tennessee Department of Transportation (TDOT) Standard Specifications for Road and Bridge Construction March 1, 2006 (1) contains in subsection 204.06 a Controlled Low-strength Material (CLSM) Specification which is very different from the 1995 version. This paper is the first in a five part series of technology transfer articles. We hope you find the information presented helpful in producing CLSM mixtures meeting the new specification. In the first article, changes from the 1995 to 2006 specification are examined as well as the supporting information which led to the changes. Parts 2 through 5 in the series will examine:

2. Excavatable Flowable Fill (EFF) Mixtures for 2006 TDOT 204.06
3. Early Strength Flowable Fill (ESFF) Mixtures for 2006 TDOT 204.06
4. Sustainable CLSM Mixtures for TDOT 204.06
5. The Future of CLSM in Tennessee

Philosophy

The CLSM specification in subsection 204.06 of the 1995 TDOT Standard Specifications (2) was more progressive than some other DOT CLSM specifications. A minimum flow value (similar to ASTM D 6103 (3) as shown in Figure 1) of 8-inches was recommended. The contractor (producer) was allowed to select Class C or Class F fly ash for the mixture. Further, the contractor (producer) could use approved chemical or air-entraining admixtures to achieve the desired flow. However, like the CLSM specifications of many DOTs across the country at that time (and several today), the 1995 TDOT 204.06 CLSM Specification was prescriptive and restrictive. A prescriptive CLSM specification is simply a recipe for making flowable fill. Prescriptive specifications have the advantage of letting the specifying agency know

what to expect. However, prescriptive specifications limit flexibility and discourage innovation. The 1995 specification was restrictive in that a one-size-fits-all approach was used.

The new 2006 TDOT 204.06 Specification is neither prescriptive nor restrictive. Performance-related properties rather than proportions are specified. Three types of CLSM mixtures are specified depending on the specific application: General use flowable fill; Excavatable flowable fill (EFF); and Early strength flowable fill (ESFF). Further, ground granulated blast furnace slag (GGBFS) has been added to the list of allowable cementing materials. The new 2006 TDOT 204.06 CLSM Specification encourages both innovation (producer selects proportions) and flexibility (more situations addressed by different CLSM types) in flowable fill applications.

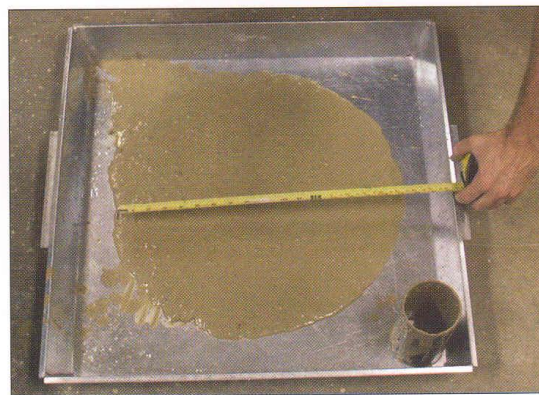


Figure 1. Flow Test

TDOT 204.06 CLSM Specification

Aggregate Gradation Requirements

TDOT 204.06 references TDOT 903.01(f) for flowable fill aggregate requirements. The TDOT 903.01(f) fine aggregate requirements (percent passing by weight) for both the 1995 and 2006 specifications are shown in Table 1.

The change in the allowable percentage passing the No. 200 from 10 to 20 percent is very important. An International Center for Aggregates Research (ICAR) industry survey in the 1990s indicated that the greatest challenge faced by the aggregate producers dealt with by-product fines, often referred to as screenings (4). The National Aggregates Association and National Stone Association concurred, by-product fines were one of the industry's highest priorities. Industry leaders estimated in 1993 that more than 200 million tons of quarry by-products were generated (5). Today the yearly production of by-product fines is estimated to be over 1 billion tons annually. It is difficult to find viable

uses for by-product fines, most construction and highway specifications limit the percent passing No. 200 to five or less. The combination of large supplies and small markets has resulted in millions of tons of screenings accumulating in stockpiles. ICAR identified flowable fill as a promising market for high volumes of by-product fines (6).

Research sponsored by Rogers Group, Inc. (7, 8, 9, 10) in 1996 showed that high-fines limestone screenings with up to 21 percent passing the No. 200 were a viable aggregate for air-entrained excavatable CLSM. Later research sponsored by TDOT, the Tennessee Concrete Association (TCA), the Combustion Byproduct Recycling Consortium (CBRC), and the Kentucky Ready Mixed Concrete Association (KRMCA) (11, 12, 13, 14) showed that high-fines limestone screenings were also viable aggregates for non-air-entrained excavatable and rapid set CLSM mixtures.

Table 1. Aggregate Gradation Requirements

Size	1995 Specification	2006 Specification
19-mm (3/4 inch)	100	--
12.5-mm (1/2 inch)	--	100
75- μ m (No. 200)	0-10	0-20

CLSM Types

The 1995 TDOT 204.06 Specification recognized only one type of CLSM; the proportions are shown in Table 2. The specification recommended a minimum 8-inch flow. Chemical and air-entraining admixtures were allowed. The new 2006 TDOT 204.06 Specification recognizes three

types of CLSM; the performance-related properties required are shown in Table 3. Research sponsored by TDOT, TCA, and the KRMCA helped to establish requirements for the "Excavatable" and "Early Strength" CLSM Types (11, 12, 14).

Table 2. 1995 TDOT 204.06 Proportions

Component	Amount
Portland cement, Type 1	100 lbs.
Fly ash, Class C or F	250 lbs. minimum
Fine aggregate	2800 lbs.
Water	60 gallons (approximate)

Table 3. 2006 TDOT 204.06 Property Requirements

Performance-Related Property	General Use	Excavatable	Early Strength
Consistency	8" min.	8" min.	8" min.
Load application (ASTM D 6024) (15)	24 hours max.	24 hours max.	6 hours max.
Air content, if air entrained (ASTM D 6023) (16)		30% max.	30% max.
Compressive Strength @ 24 hours (ASTM D 4832)* (17)			30-psi min.
Compressive Strength @ 28 days (ASTM D 4832)*		30-psi min.	
Compressive Strength @ 98 days (ASTM D 4832)*		140-psi max.	

* - may use 4x8 inch cylinder molds; preferred capping method is wet-suit neoprene in rigid retainers;

CLSM Testing

Suitability for Load Application

The earliest time that a new CLSM placement is capable of supporting a construction load is important so that the project can proceed as rapidly as possible (especially if traffic is interrupted). Early in CLSM history (actually the specification is still used in Kentucky), CLSM was considered to be ready for load application if it could support foot traffic. Since there are a wide variety of sizes of people and shoe geometries, ASTM modified an older concrete consistency test, the Kelly Ball, to provide a more standard measure of suitability for load application. The suitability for load application test (15) requires 5 drops of a 30-lb hemispherical steel ball in the same location (see Figure 2). If the indentation is greater than 3-inches in diameter or has water in the bottom, the CLSM is considered to not be ready for load application. Confirmation that one drop of the ball was sufficient was obtained at the 9/23/02 Algood, Tennessee Demo when TCA Board Member Denny Lind volunteered to drive a club-cab pickup onto a CLSM trench that had just passed the (1-drop) ball drop test. Even though the first author was quite concerned, Figure 3 shows that everything turned out well.



Figure 2. ASTM Ball Drop Test

TDOT 204.06 CLSM Specification



Figure 3. Full Size Club-cab Pickup on Early Strength Flowable Fill (ESFF) Trench at 2 hours 40 minutes

Compressive Strength

The footnotes of Table 3 show a TDOT preference for capping with wet-suit neoprene in rigid retainers. ASTM D 4832 (17) currently permits three types of capping for CLSM cylinders: sulfur mortar (18), gypsum plaster (18), and unbonded neoprene restrained by rigid retainers (19). These methods were developed for PCC cylinders and all produce good estimates of PCC potential strength. However, these methods are inappropriate for CLSM cylinders. Sulfur mortar and gypsum plaster methods often result in cylinder damage during capping due to the low strength of CLSM cylinders. Fifty to seventy (50-70) durometer neoprene pads are far too stiff at low stress levels, which are common in testing CLSM cylinders. The neoprene pads essentially act as a rigid plate rather than a capping material. An unbonded capping system using a much softer neoprene (wet-suit neoprene) in rigid retainers was developed (see Figure 4). The softer neoprene is more malleable at lower stress levels. Research by Brown and Crouch (20, 21) showed the new unbonded capping system to be statistically (lower standard deviation), and logistically (economy, productivity, safety) superior and to produce higher (more realistic) average compressive strengths at 28-days.



Figure 4 (a). Wet-suit Neoprene Capping System

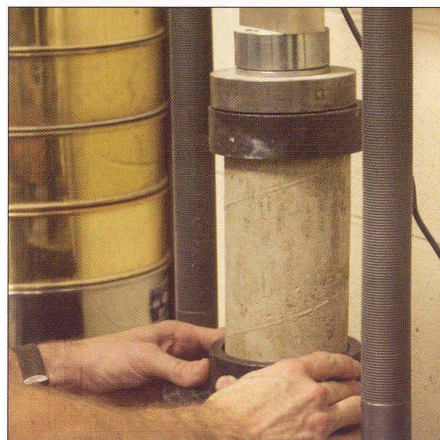


Figure 4 (b). Preparing for a Compressive Strength Test

The footnotes of Table 3 also state that 4x8 inch cylinder molds may be used. Green CLSM cylinders are very fragile. The use of 4x8 inch cylinder molds makes handling and storage much easier and much safer for the specimens. Although not part of the 2006 TDOT 204.06 CLSM Specification, TCA recommends using 4x8 inch wax-coated cardboard molds (see Figure 5). The wax-coated cardboard can be peeled away from the fragile green CLSM cylinders. Demolding is much easier and safer than with standard plastic cylinder molds. The authors also are aware that vertically scored (with a sheetrock knife) plastic 4x8 inch cylinder molds have been used successfully.

The 2006 TDOT 204.06 Specification has compressive strength requirements for excavatable flowable fill (EFF) and Early Strength Flowable Fill (ESFF). For the EFF, these strength requirements were based on research data and are intended to insure that the material gains sufficient strength early on (30-psi in 28 days), but does not gain too much strength (140-psi in 98 days) such that it is not excavatable in the future if needed. The ESFF has a "quick" strength gain requirement (30-psi in 24 hours), such that loads can be quickly applied. An emergency subgrade repair where the pavement must be opened to traffic as soon as possible is an example of a situation where loads need to be applied quickly.

Air Content

ASTM D 6023 Standard Test Method for Unit Weight, Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low Strength Material (CLSM) is very similar to ASTM C 138 (22) for concrete. However, CLSM unit weight and air tests are not consolidated by rodding, but rather placed in one layer without rodding and then struck off. The equations for gravimetric air content are identical to those used in ASTM C 138 and therefore an ACI Certified Field Testing Technician Grade 1 should have the equipment and skills needed for determining the gravimetric air content of CLSM mixtures.

The 2006 TDOT 204.06 Specification allows mixtures to be air entrained, but does not require it. The maximum allowable air content for EFF and ESFF mixtures is 30 percent.

Demonstration Test Trench

The 1995 TDOT 204.06 CLSM Specification did not require the producer to construct a demonstration test trench. However, 2006 TDOT 204.06 Specification requires a 3-ft wide by 3-ft deep by 8-ft long test trench during the mixture design process of EFF and ESFF CLSM mixtures. The purpose of the trench is to demonstrate that the proposed CLSM mixture will meet TDOT 204.06 performance criteria. Figure 6 shows a test trench from the Knoxville demonstration of ESFF 11/01/02.



Figure 5. Wax-coated Cardboard 4x8 inch CLSM Molds



Figure 6. Test Trench at the Knoxville ESFF Demonstration 11/01/02

TDOT 204.06 CLSM Specification

Summary

The 2006 TDOT 204.06 CLSM Specification:

1. Is versatile and flexible in recognizing the need for different types of CLSM mixtures for different applications;
2. Encourages innovation on the part of ready mix producers and contractors through specifying performance-related properties rather than proportions;
3. Is proven and practical by being based on years of research including numerous field demonstrations and tests;
4. Is rigorous and safe by requiring demonstration test trenches for EFF and ESFF CLSM mixtures prior to use;
5. Fosters government industry cooperation by being based on research co-sponsored by TCA and members of the Tennessee concrete industry;

6. Encourages sustainability by allowing by-product supplementary cementing materials;
7. Encourages sustainability by allowing high-fines screenings as aggregate;
8. Is progressive and practical by specifying a cylinder capping method superior to current ASTM methods for CLSM.

Availability

The new TDOT 2006 Specifications for Road and Bridge Construction:

1. Can be viewed on-line at <http://www.tdot.state.tn.us/construction/specs.htm>
2. Can be downloaded free in the PDF format
3. Can be purchased as a book on the TDOT website

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