by L. K. Crouch, Aaron Crowley, James Locum, Blakeslee Eagan and Daniel Badoe

The New 2015 TDOT 204.06 Flowable Fill Specification

NOSTALGIA

It seems like yesterday (but it was about 9 years ago) that I was writing a five part series about the new TDOT 2006 204.06 Flowable Fill Specification (1, 2, 3, 4, and 5). I have heard "Time flies when you are having fun." I have also heard "time goes faster the older you get." Apparently, both are true.

INTRODUCTION

The new Tennessee Department of Transportation (TDOT) Standard Specifications for Road and Bridge Construction January 1, 2015, (6) contain some interesting changes in subsection 204.06 Flowable Fill. This paper highlights some of the changes from the March 1, 2006, specification (7) to the new January 1, 2015, specification. We hope you find the information presented helpful in producing and testing controlled low-strength materials (CLSM) mixtures meeting the new specification. The specific changes from the 2006 to 2015 specification examined are:

1. Return to a Prescriptive General Use Flowable Fill Specification
2. New Inverted Slump Cone Consistency Test
3. Influences of the new Inverted Slump Cone Consistency Test on Mixture Design
4. Relationship between the Inverted Slump Cone Consistency Test and ASTM D 6103 Flow Consistency

RETURN TO A PRESCRIPTIVE GENERAL USE FLOWABLE FILL SPECIFICATION

Three types of CLSM mixtures are still specified depending on the specific application: General Use Flowable Fill; Excavatable Flowable Fill (EFF); and Early Strength Flowable Fill (ESFF). The new 2015 TDOT 204.06 CLSM Specification still encourages both innovation (producer selects proportions for EFF and ESFF) and flexibility (more situations addressed by different CLSM types) in flowable fill applications. However, the new 2015 specification requires a return to prescriptive General Use Flowable Mixture from the 1995 TDOT Standard Specifications (8). The required proportions for the 1995 (and 2015) General Use Flowable Fill Specification are shown in Table 1. 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.

The 24-hour maximum suitability for load application requirement ASTM D 6024 (9) was retained from the 2006 TDOT 204.06 Specification. However, the consistency requirement for General Use Flowable Fill (as well as EFF and ESFF) has been altered and will be discussed in the next section.

NEW INVERTED SLUMP CONE CONSISTENCY TEST

The TDOT 2006 204.06 Flowable Fill Specification required an 8-inch minimum flow determined using ASTM D 6103 Flow Consistency of CLSM (10). The new 2015 TDOT 204.06 Flowable Specification replaces that requirement with an Inverted Slump Cone Consistency Test. The procedure excerpted from the new 2015 specification is shown below:

1. Place an inverted slump cone on a smooth, level surface.
2. Fill the inverted slump cone with a representative sample of the flowable fill without rodding in one lift.
3. Remove the slump cone by lifting it straight up, thus allowing the sample to diffuse on the smooth, level surface.
4. The flowable fill should diffuse into a circular shape having an approximate diameter of not less than 15 inches.

Figures 1 through 3 show the new test procedure when things go well (using a non-air-entrained mixture as an example). The test is similar to ASTM C 1611 Slump Flow of Self-Consolidating Concrete (11). One possible advantage of this test procedure is that it is very likely that all Tennessee concrete technicians have access to an ASTM C 143 (12) slump cone. However, most concrete technicians are less likely to have the 3-by-6-inch open-ended cylinder or pipe required by ASTM D 6103.

Figure 4 shows the test procedure when things do not go well (using a non-air-entrained mixture as an example). The research team named the result shown in Figure 4 "Did Not Flow" (DNF). In a DNF result, the mixture does not form a patty of approximately uniform thickness. The central core is much thicker than the periphery and often leans, cracks, or collapses to one side.

Figure 5 shows a proper flow patty from an air-entrained flowable fill test. Air-entrained flowable fill appears more cohesive and diffuses into a patty more slowly than non-air-entrained flowable fill mixtures. An example of an air-entrained flowable fill mixture failing the new TDOT Inverted Slump Cone Consistency Test is not available.

—*Continued on page 10*

TABLE 1. 1995 AND 2015 TDOT 204.06 GENERAL USE FLOWABLE FILL 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)

Figure 1: Filling the Inverted Slump Cone

Figure 2: Raising the Inverted Slump Cone

Figure 3: Patty Formed by Proper Flowable Fill Diffusion

Figure 4: A "Did Not Flow" Result for an Inverted Slump Cone Consistency Test

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Figure 5: Inverted Slump Cone Consistency Test of an Air Entrained Mixture

INFLUENCES OF THE NEW INVERTED SLUMP CONE CONSISTENCY TEST ON MIXTURE DESIGN

Background

The research team (who could not wait to try out a new test method) developed a preliminary investigation plan. The plan called for at least ten non-air-entrained and ten air-entrained flowable fill mixtures. Six of the non-air-entrained mixtures were TDOT General Use mixtures (a few more water contents were attempted, but only six were reported). The other four non-air-entrained mixtures were variations on a mixture used in a capping study (13, 14). The first five air-entrained mixtures were variations on a mixture used in a previous TDOT study (15). The second five air-entrained mixtures were attempts to increase the range of air and paste contents used in the study.

Procedure and Results

Tables 2 through 5 show proportions and results for most of the mixtures used in the preliminary investigation. Percent paste in the tables was calculated as the sum of the volumes of portland cement, fly ash, water, and actual air divided by total mixture volume expressed as a percent. The actual air content of a non-air-entrained mixture was considered negligible and assumed to be zero for calculating percent paste. All air-entrained mixtures contained a manufacturer's recommended dosage of a powdered CLSM air-entrainer. The actual air content of air-entrained mixtures was determined as per ASTM D 6023 (16).

Analysis of Results

Figure 6 shows the preliminary project flow results plotted versus percent paste.

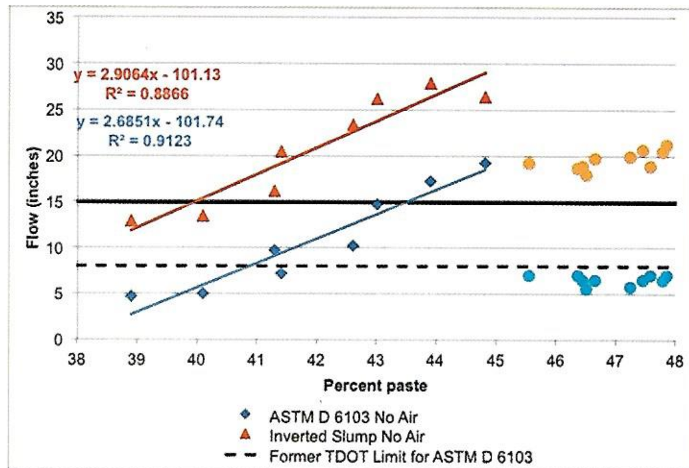

Figure 6: Flow versus Percent Paste

<u>Non-Air-Entrained Mixtures</u>

No TDOT General Use mixture with less than 500-lbs/CY of cementing materials had adequate patty diameter to meet TDOT Inverted Slump Cone Consistency requirements of 15 inches minimum. A number of water contents were tried with mixtures containing 350-lbs/CY of cementing materials (not all shown in Table 2). However, no water content was found adequate. Increasing the water content above a certain level led to rapid segregation.

All four variations of the TTU mixture from the capping study met TDOT consistency requirements. From these preliminary results, it appears that more than 450-lbs/CY of cementing materials and adequate water to produce a paste content of 41 percent or more is required for non-air-entrained flowable fill mixtures containing portland cement and Class F fly ash to meet TDOT consistency requirements. Altering the cementing materials content of non-air-entrained flowable fill mixtures certainly may impact their hardened properties (strength development and excavatability). However, that is a story for another day.

TABLE 2. PROPORTIONS AND RESULTS FOR THE TDOT GENERAL USE MIXTURE

Component	General 350A	General 350B	General 400	General 450	General 500	General 550
Type 1 PC (lbs./CY)	100	100	100	100	100	100
Class F Fly Ash (lbs./CY)	250	250	300	350	400	450
River Sand SSD (lbs./CY)	2800	2740	2686	2632	2579	2525
Water (lbs./CY)	477	500	500	500	500	500
Total Cementing Materials (lbs./CY)	350	350	400	450	500	550
Percent Paste	36.3	37.7	38.9	40.1	41.3	42.6
ASTM D 6103 Flow (inches)	DNF	DNF	4.75	5	9.75	10.25
TDOT Inverted Slump Flow (inches)	DNF	DNF	13	13.5	16.25	23.5

TABLE 3. PROPORTIONS AND RESULTS FOR NON-AIR ENTRAINED TTU MIXTURE

Component	TTU 500-1	TTU 500-2	TTU 500-3	TTU 500-4
Type 1 PC (lbs./CY)	60	60	60	60
Class F Fly Ash (lbs./CY)	440	440	440	440
River Sand SSD (lbs./CY)	2574	2504	2465	2426
Water (lbs./CY)	498	525	540	555
Total Cementing Materials (lbs./CY)	500	500	500	500
Percent Paste	41.4	43.0	43.9	44.8
ASTM D 6103 Flow (inches)	7.25	14.75	17.25	19.25
TDOT Inverted Slump Flow (inches)	20.25	26.25	28.0	26.5

Air-Entrained Mixtures

All 10 air entrained mixtures had an adequate patty diameter to meet TDOT Inverted Slump Cone Consistency requirements of 15 inches minimum. However, none of the 10 mixtures met the former TDOT 8-inch minimum ASTM D 6103 requirement from 2006. Therefore, it may be easier to meet the new consistency requirements than the former (2006) TDOT consistency requirements.

Increasing the water content in an air-entrained mixture (Air mixtures 1-5 or Air mixtures 6 – 8) lowered the air content. However, the net effect on the mixture percent paste was small. It is important to note that only Air mixtures 2 through 5 met TDOT EFF or ESFF requirements of 30 percent maximum air content. It appears that decreasing the portland cement content, even while increasing the w/c ratio, increases the air content (Air mixtures 8 – 10). However, the small amount of results in the preliminary study provides indications as to what to investigate rather than solid conclusions. As previously pointed out for non-air-entrained mixtures, altering the cementing materials content of air-entrained flowable fill mixtures certainly may impact their hardened properties (strength and excavatability). Again, that is a story for another day.

RELATIONSHIP BETWEEN THE INVERTED SLUMP CONE CONSISTENCY TEST AND ASTM D 6103 FLOW CONSISTENCY

Figure 7 shows the preliminary relationships between Inverted Slump Cone Consistency and ASTM D 6103 Flow Consistency for air-entrained and non-air-entrained flowable fill mixtures. Obviously, eighteen points (eight non-air-entrained and ten air-entrained) is not adequate to characterize these relationships.

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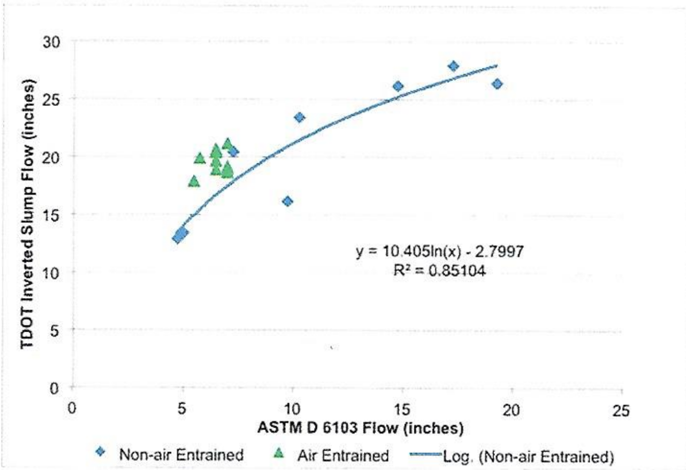

Figure 7: TDOT Inverted Slump Flow versus ASTM D 6103 Flow

SUMMARY

Based on the limited data available from this preliminary study, the new 2015 TDOT 204.06 Flowable Fill Specification:

1. Requires a return to a prescriptive General Use Flowable Fill Specification used in the 1995 TDOT 204.06 Specification

2. Introduces a new Inverted Slump Cone Consistency Test which:
   a. Requires the use of more common concrete testing equipment (ASTM C 143 Slump Cone) than the 3-by-6-inch open-ended cylinder or pipe required by ASTM D 6103
   b. Requires a larger sample size and a larger minimum flow patty diameter than ASTM D 6103
   c. Appears to require more than 450-lbs/CY of cementing materials and adequate water to produce a paste content of 41 percent or more for non-air-entrained flowable fill mixtures containing portland cement and Class F fly ash to meet TDOT minimum consistency requirements
   d. Appears to be easier to meet with air-entrained flowable fill mixtures than ASTM D 6103

DISCLAIMER

The opinions expressed herein are those of the authors and not necessarily the opinions of the Tennessee Department of Transportation or the Tennessee Concrete Association.

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TABLE 4. PROPORTIONS AND RESULTS FOR FIVE AIR ENTRAINED MIXTURES

Component	Air 1	Air 2	Air 3	Air 4	Air 5
Type 1 PC (lbs./CY)	100	100	100	100	100
River Sand SSD (lbs./CY)	2431	2400	2366	2335	2301
Water (lbs./CY)	300	312	325	337	350
Design Air Content (%)	25	25	25	25	25
ASTM D 6023 Percent Air Content (%)	30.5	28.5	27.4	26.7	25.4
Percent Paste	47.6	47.2	47.4	47.8	47.9
ASTM D 6103 Flow (inches)	7	5.75	6.5	6.5	7
TDOT Inverted Slump Flow (inches)	19	20	20.75	20.5	21.25

TABLE 5. PROPORTIONS AND RESULTS FOR FIVE ADDITIONAL AIR ENTRAINED MIXTURES

Component	Air 1	Air 2	Air 3	Air 4	Air 5
Type 1 PC (lbs./CY)	80	80	80	70	60
River Sand SSD (lbs./CY)	2578	2535	2500	2554	2621
Water (lbs./CY)	250	266.5	280	262.5	240
Design Air Content (%)	25	25	25	25	25
ASTM D 6023 Percent Air Content (%)	34.6	32.7	31.6	33.4	34.5
Percent Paste	46.5	46.4	46.6	46.4	45.5
ASTM D 6103 Flow (inches)	5.5	6.5	6.5	7	7
TDOT Inverted Slump Flow (inches)	18	19	19.75	18.75	19.25

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