Florida Method
for
DETERMINING THE RELATIVE VISCOSITY FACTOR OF CEMENTITIOUS MATERIALS USING A DYNAMIC SHEAR RHEOMETER

Designation: FM 5-605

1 SCOPE

1.1 This method covers procedures for determining the relative viscosity factor, RV_f, for cementitious materials.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI units in parentheses are for information purposes only.

1.3 This method may involve hazardous materials, operations, and equipment. This method does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 REFERENCED DOCUMENTS

2.1 Section 938, "Filler Materials for Post-Tensioned Structures," in the 2015 Florida Department of Transportation Standard Specifications for Road and Bridge Construction.

2.2 FDOT Project BDK75-977-39 Final Report, "Development of Laboratory Test Methods to Replace the Simulated High-Temperature Grout Fluidity Test" (2014), Authors Piper, Randell, Brunner, Ferraris, and Hamilton.

2.3 ASTM Standards:

2.3.1 ASTM C702 (2011), Standard Practice for Reducing Samples of Aggregate to Testing Size.

2.3.2 ASTM C1738 (2011), Standard Practice for High-Shear Mixing of Hydraulic Cement Pastes.

3 SIGNIFICANCE AND USE

3.1 This test method is applicable to the determination of relative viscosity factors, RV_f, which are needed to determine if grouts to be used as filler materials for post-tensioned structures produce the desired rheology specified in Section 938 of the FDOT Standard Specifications for Road and Bridge Construction.

3.2 The objective of the test is to evaluate the performance of grouts used for post-tensioning. The performance criterion is that the grouts maintain adequate fluidity for pumping for at least 1 hour at a temperature of 38°C (100°F).

3.3 This test was designed to replace the high-temperature grout fluidity (HTGF) test, which had been required by FDOT for a grout to be placed on the approved products list.

4 APPARATUS

(More details can be found in the references)

4.1 Dry Sample Mixing and Size Reduction Equipment

Acceptable methods for selecting a representative sample of material, from one or more bags of pre-packaged cementitious products, are listed below.

4.1.1 V-Blender (preferred method) - uniformly and intimately blends large samples of dry, free-flowing solids, and enables collection of a high quality, representative sample.

4.1.2 Sample quartering – continually mix and quarter original bulk sample (one or more bags) until the desired representative sample size is obtained (see ASTM C702).

4.1.3 Sample splitter – after thorough mixing of the original bulk sample, a sample splitter can be used to obtain a representative sample of the desired size (see ASTM C702).

4.2 Constant Speed High Shear

4.2.1 Mixer must be capable of mixing at least 500 g of cementitious materials and water.

4.2.2 Mixer must have preset constant speeds of 420 rad/s (4,000 rpm) and 1047 rad/s (10,000 rpm).

4.2.3 The mixing container should have a volume of 1 quart (0.95 liter).

4.2.4 The mixing container should be made of stainless steel, have a tight-fitting lid, and be jacketed to enable heating and cooling from the flow of temperature-controlled water from a circulating water bath.

4.2.5 The blade assembly must be specifically designed for use with the mixer, and be removable for cleaning, weighing, and changing.

4.3 Recirculating, Temperature-Controlled Water Bath

4.3.1 Must be capable of controlling temperature to ±1°C (±2°F) over a temperature range of 5-50°C (41°-122°F).

4.3.2 Must have external supply and return lines for connection to the mixing container to enable flow of temperature-controlled water through the jacket of the mixing container.

4.4 Partial Immersion Thermometer

4.4.1 Must be readable to 0.5°C (1°F) and accurate to ±0.5°C (1°F).

4.5 Cementitious Feeding System

4.5.1 Acceptable methods for feeding cementitious materials into the mixing container are listed below.

4.5.1.1 Vibratory feeder, or

4.5.1.2 Lid-mounted funnel

4.5.2 System must be able to continuously feed all of the cementitious material into the container within 60 seconds.

4.6 Stop Watch

4.6.1 Must be accurate to ±1 second over a 60-second interval.

4.7 Analytical Balance

4.7.1 Must have a capacity of at least 1 kg (2.2 lb),

4.7.2 Must be readable to 0.01 g (2.2 x10^{-5} lb), and

4.7.3 Must have an accuracy of 0.01 g (2.2 x10^{-5} lb).

4.8 Scraper

4.8.1 The scraper must have a semi-rigid rubber blade about 75 mm long and 50 mm wide (3 in. by 2 in.) that tapers to a thin edge about 2 mm (0.08 in.) thick, and

4.8.2 The handle must be about 150 mm (6 in.) long.

4.9 Dynamic Shear Rheometer (see BDK75-977-39 Final Report)

4.9.1 Must have cup and ribbon configuration for testing post-tensioning grouts.

4.9.2 Vendor software must control

4.9.2.1 Testing temperature,

4.9.2.2 Angular velocity (based on the desired shear rate),

4.9.3 Vendor software must, using the angular velocity and torque data, calculate and record

4.9.3.1 Shear rate,

4.9.3.2 Shear stress, and

4.9.3.3 Plastic viscosity.

5 PROCEDURE

5.1 Cementitious Material Sampling and Storage

5.1.1 Record all manufacturing information from the product packaging (manufacturing date, lot number, shelf life, recommended water ranges, etc.).

5.1.2 Using a V-blender (preferred method) or a combination of manual mixing and sample size reduction (quartering or sample splitter), thoroughly mix the contents of one or more bags of cementitious material, and divide into appropriately sized samples (about 400 g

[0.88 lb]) each (see 5.5.2).

5.1.3 Store samples in properly labeled (all necessary product information, sampling date, sample number, etc.), air-tight containers, such as zippered plastic bags, until tested.

5.2 High Shear Mixing (Modified procedure is based on ASTM C1738)

5.2.1 Set temperature and flow rate on circulating water bath so that after mixing the paste will be 38°C (100°F) for the planned rheology measurements. This may require several trial runs to establish the proper settings.

5.2.2 Weigh enough dry cementitious material so that, when mixed with the correct amount of water, the total sample weight will be 500 ± 10 g (1.102 ± 0.022 lb). Add the dry cementitious material to the cementitious feeder and set aside until needed.

5.2.3 Weigh the correct amount of water (use the midpoint of the water addition range listed by the manufacturer on the product packaging), add it to the mixing container, and begin mixing at the first preset mixer speed of 420 rad/s (4,000 rpm). Periodically stop mixing, remove lid, and check water temperature until the water has reached the setpoint temperature. Adjust the temperature setting and/or flow rate of the circulating bath, if needed, to reach the setpoint temperature.

5.2.4 When the setpoint water temperature is reached, start mixing at the preset speed of 420 rad/s (4000 rpm) and then begin uniformly feeding the dry materials from the cementitious feeder over a period of 50 to 60 seconds.

5.2.5 Immediately after dry material addition is complete, attach lid, begin mixing at the second preset speed of 1047 rad/s (10,000 rpm), and follow the procedure below.

5.2.5.1 Mix at 1047 rad/s (10,000 rpm) for 30 seconds.

5.2.5.2 Stop the mixer and rest for 2 minutes. In the first 15 seconds after stopping, remove the lid and scrape down the container sides. Measure the paste temperature and, if needed, adjust the water bath temperature to reach the correct test temperature. Replace the lid for the duration of the rest period.

5.2.5.3 Mix again for 90 seconds at the second preset speed of 1047 rad/s (10,000 rpm) immediately after the rest period.

5.2.5.4 Stop the mixer and remove the lid. Measure and record the paste temperature. If the water bath temperature was properly adjusted, the paste temperature should be very close to the test temperature. The mixed paste is now ready for use.

5.3 Dynamic Shear Rheometry

The method described below is for an analytical rheometer with features similar to the TA Instruments AR 2000ex Dynamic Shear Rheometer using a calibrated cup and helical ribbon-testing configuration. Vendor software should control testing temperature, angular velocity (based on the desired shear rate), and calculate and record shear rate, shear stress, and plastic viscosity, using the angular velocity and torque data. The viscosity calculated for the cup and ribbon geometry requires a calibration adjustment to obtain the correct viscosity values; however, the use of a relative viscosity factor (see table below) eliminates the need to calculate the calibration factor.

5.3.1 Set DSR temperature control to 38°C (100°F).

5.3.2 Install the calibrated cup and helical ribbon for testing grouts.

5.3.3 Pour the mixed grout into the cup until the top surface is even with the rim of the cup

5.3.4 Pre-shear the grout for 30 seconds at a shear rate of 165 s^{-1}.

5.3.5 Shear grout for 60 minutes at a shear rate of 50 s^{-1} with the measurement frequency set to 1-second intervals.

5.4 Clean-up

5.4.1 Remove, take apart, and thoroughly clean the blade assembly. Thoroughly clean the mixing container.

5.4.2 Thoroughly clean the cup and helical ribbon.

5.5 Calculation of RV_f

5.5.1 The final relative viscosity factor (RV_f) can be calculated as follows:

$$\boldsymbol{RV_f = \frac{viscosity_{60}}{viscosity_{45}}}$$

Where: RV_f is the 60-min viscosity divided by the 45-min viscosity.