Test Methods to Assess Fiber Segregation in Ultra-High Performance Concrete

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Abstract

Fiber segregation affects the homogeneity of ultra-high performance concrete (UHPC) products and thus may negatively affect the mechanical properties of the UHPC in critical portions of any fabricated UHPC component. Practitioners need to be able to assess the fresh property performance of UHPC to avoid fiber segregation. However, there is no readily available, widely accepted method for real-time evaluation of fiber segregation. This study examined the applicability of existing ASTM standards for conventional concrete, including the static segregation column test (ASTM International 2021) and static segregation resistance using the penetration test (ASTM International 2020). The research team investigated a modification to the testing procedures and apparatus to make the tests more applicable to UHPC-class materials.

Keywords: Quality control, test methods, fiber segregation

1. Static Segregation Column

ASTM C1610 assesses the static segregation of self-consolidating concrete by measuring the coarse aggregate content at the top and the bottom portions of a cylindrical column (ASTM International 2021). The height of the column is 26 in. (660 mm) tall, and the diameter is 8 in. (203 mm) long. The column mold is divided into three sections, 6.5 in. (165 mm) lengths on each end and 13 in. (330 mm) in the middle. A sample of freshly mixed concrete is placed in the cylindrical column without tamping or vibration. The material is allowed to stand undisturbed for 15 ± 1 minute. Afterward, portions of concrete from the top and bottom sections are removed and washed. The masses of coarse aggregate in the top and the bottom sections are measured after the aggregates have achieved a surface-dry condition.

In this study, a similar procedure was used for UHPC-class materials to measure the masses of steel fibers at the top and bottom portions of the column to determine the percent static segregation. Figure 1a shows the testing apparatus. The diameter of the column was made 3 in. (76 mm) long to reduce the amount of material required to perform the test. The height of the column and the testing procedure were in accordance with ASTM C1610 (ASTM International 2021). A magnet within a removable plastic sheath was used to separate the steel fibers from the rest of the material during the washing procedure. The fibers were placed in an oven for at least 2 hours before taking the mass measurements.

2. Static Segregation Resistance

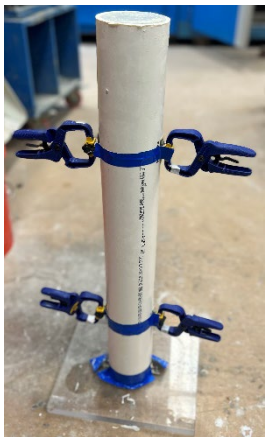
ASTM C1712 provides a rapid assessment of static segregation resistance of self-consolidating concrete (ASTM International 2020). The test does not measure static segregation resistance directly but provides an assessment of whether static segregation is likely to occur. According to the test method, a hollow, cylindrical penetration apparatus is placed on top of an inverted slump cone filled with concrete. After the concrete has stabilized for 80 ± 5 seconds, the test is started; the penetration depth is measured after 30 seconds. The penetration depth measurement is then used to correlate the degree of static segregation resistance.

A similar approach was used in this study for UHPC-class materials with some modifications. An inverted slump cone was not required; alternatively, a 4-by-8-in (102-by-203-mm) cylinder mold was used as a container for the UHPC mixes. Figure 1b shows the testing apparatus for static segregation resistance. Furthermore, since the exposed surface of UHPC may start hardening and prevent the penetration apparatus from freely penetrating the material, the test should be performed immediately after the mold is filled with the fresh material.

3. Discussions and Conclusions

Table 1 presents the static segregation results of three UHPC mixes assessed according to ASTM C1610 and ASTM C1712 with the modifications proposed in this paper. The first UHPC mix included the original mix design recommended by the manufacturer; the second and the third mixes included the same UHPC mix design with additional water content to create mixes in which segregation was likely to occur. According to the results of ASTM C1610, the percentage difference between the mass of fibers at the top and the bottom of UHPC-1 and UHPC-2 were relatively small, indicating the mixes were less susceptible to fiber segregation, while UHPC-3 showed a high static segregation value. Furthermore, the results of the ASTM C1712 test indicated that each UHPC mix had the following static segregation resistance category: UHPC-1 (resistant), UHPC-2 (moderately resistant), and UHPC-3 (not resistant) (ASTM International 2020).

The fresh material testing results were compared to the results of a visual assessment of hardened 3-by-6-in. (76-by-152-mm) cylinders that were cast for each UHPC and then longitudinally sectioned (figure 2). Results of the visual assessment indicated that there was no sign of fiber segregation in UHPC-1 and UHPC-2 (figure 2a and 2b) and significant fiber segregation at the top of the sample in UHPC-3 (figure 2c). Visual assessments were consistent with the results of the fresh material testing. Therefore, the research team concluded that the modified versions of both the ASTM C1610 and C1712 test methods were appropriate for assessing fiber segregation in UHPC-class materials. However, the ASTM C1712 test method requires less time and material and provides a more rapid result. As a result, this test method may be a more practical way to assess the suspension of fibers in fresh UHPC materials.


(a) Source: FHWA.


(b) Source: FHWA.

Figure 1. Testing apparatus for (a) static segregation column test and (b) static segregation resistance test.

Table 1. Static segregation test results.

Mix Number	ASTM C1610 Test Results	ASTM C1712 Test Results
UHPC-1	Weight of fibers (top): 121.0 g Weight of fibers (bottom): 122.2 g Static segregation: 0.98 percent	Penetration depth: 0.23 in. (6 mm) Static segregation category: Resistant
UHPC-2	Weight of fibers (top): 114.0 g Weight of fibers (bottom): 118.6 g Static segregation: 3.96 percent	Penetration depth: 0.42 in. (11 mm) Static segregation category: Moderately resistant
UHPC-3	Weight of fibers (top): 32.5 g Weight of fibers (bottom): 201.7 g Static segregation: 144.5 percent	Penetration depth: 1.34 in. (34 mm) Static segregation category: Not resistant


(a) Source: FHWA.


(b) Source: FHWA.


(c) Source: FHWA.

Figure 2. Visual assessment of hardened samples (a) UHPC-1, (b) UHPC-2, and (c) UHPC-3.

4. References

- Standard Test Method for Static Segregation of Self-Consolidating Concrete Using Column Technique, ASTM C1610/C1610M-21, ASTM International, Volume 04.02, West Conshohocken, PA, 2021.
- Standard Test Method for Rapid Assessment of Static Segregation Resistance of Self-Consolidating Concrete Using Penetration Test, ASTM C1712-20, ASTM International, Volume 04.02, West Conshohocken, PA, 2020.