INTERNATIONAL

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Standard Guide for Comparing Performance of Concrete-Making Materials Using Mortar Mixtures[1]

This standard is issued under the fixed designation C1810/C1810M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

NOTE—Previously balloted and approved Appendix X1 was included and the year date changed on Aug. 11, 2020.

1. Scope*

1.1 This guide provides information on how to compare the relative performance and potential incompatibility of combinations of concrete-making materials. Performance tests on fresh and early-age properties of mortar mixtures can be useful indicators of concrete performance using similar materials. The performance tests described in this guide include mortar-slump, mortar spread, mortar-workability retention, time of setting, air entrainment, and hydration kinetics.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with this guide. Some values only have SI units because the inch-pound equivalents are not used in guide.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* **Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause burns to skin and tissue upon prolonged exposure.[2]

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C70 Test Method for Surface Moisture in Fine Aggregate
C125 Terminology Relating to Concrete and Concrete Aggregates
C128 Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate
C185 Test Method for Air Content of Hydraulic Cement Mortar
C305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
C403/C403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C494/C494M Specification for Chemical Admixtures for Concrete
C566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying
C778 Specification for Standard Sand
C1679 Practice for Measuring Hydration Kinetics of Hydraulic Cementitious Mixtures Using Isothermal Calorimetry
C1777 Test Method for Rapid Determination of the Methylene Blue Value for Fine Aggregate or Mineral Filler Using a Colorimeter
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids
IEEE/ASTM SI 10 American National Standard for Metric Practice

2.2 *ISO Standard:*[4]

ISO 679 Cement–Test Methods–Determination of Strength

[1] This guide is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.48 on Performance of Cementitious Materials and Admixture Combinations.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

***A Summary of Changes section appears at the end of this standard**

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *mortar-slump*—vertical distance between the original and displaced position of the center of the top surface of mortar when tested with the mortar-slump mold.

3.2.2 *mortar-spread*—distance of lateral flow of mortar from the mortar-slump test.

3.2.3 *mortar-slump retention time*—the duration of time over which the mortar mixture maintains at least 50 % of its initial mortar-slump.

3.2.4 *up-front addition of admixture*—concurrent addition of admixture with the mixing water to the dry materials of the mortar mixture.

3.2.5 *delayed addition of admixture*—addition of admixture at least one minute after the initial mixing of cementitious materials and water.

3.2.6 *workability index*—relative indicator of workability calculated as the sum of the mortar-slump and mortar spread minus 100 for measurements in SI units, and minus 4 for measurements in inch-pound units.

4. Significance and Use

4.1 The results of mortar mixture tests can be suitable for comparing the relative performance of combinations of concrete-making materials such as fine aggregate, chemical admixtures, supplementary cementitious materials (SCMs), water, and hydraulic cement. Furthermore, this guide can be useful to identify unexpected performances due to combination of various materials. The relative trends in performance observed with the mortar method may suggest relative performance in concrete mixtures batched with the same materials and relative mixture proportions.

4.2 While there are a number of ways to proportion and mix mortar mixtures, two procedures described in this guide have been used extensively for evaluating the performance of admixtures. Method A enables evaluation of materials using mixture proportions that correspond to specific job conditions; whereas Method B can be used as a general mixture using fixed amounts of a standard sand, cement, and supplementary cementitious materials.

5. Apparatus

5.1 The following equipment is used for the mortar preparation and testing:

5.1.1 *Mixer with Paddle and Bowl*—A table-mounted mixer meeting the requirements of Practice C305.

NOTE 1—Similar mixers with larger capacity are acceptable if the same mixer is used for preparing all mixtures that will be compared.

5.1.2 *Timer,* able to measure a total time of at least 60 min with an accuracy of 1 s.

5.1.3 *Scraper,* consisting of a rubber blade attached to a handle about 150 mm [6 in.] in length, with a blade of about 75 mm long [3 in.], 50 mm [2 in.] wide, and tapered to a thin edge about 2 mm [0.08 in.] thick.

NOTE 2—A kitchen tool known as a plate and bowl scraper may conform to these requirements.

5.1.4 *Balance,* of sufficient capacity to measure the mass of materials to the nearest 0.5 g.

5.1.5 *Spoon and Tamper*—Conforming to Test Method C185.

5.1.6 *Pointed Mortar Trowel*—Having a steel blade 100 to 150 mm [4 to 6 in.] long with straight edges. The edges when placed on a plane surface shall not depart from straightness by more than 1 mm [0.04 in.].

5.1.7 *Plastic Syringes (without needles),* 1 to 250 mL capacity, with markings readable to ±5 % of capacity.

5.1.8 *Mortar-slump Mold*—With a top opening of 50 mm [2 in.], bottom opening of 100 mm [4 in.], a height of 150 mm [6 in.], and wall thickness of at least 2 mm [0.08 in.].[5] The tolerance for height and diameter is ±2 mm [1⁄16 in.].

5.1.9 *Plastic Ring,* 12.5 mm [½ in.] thick by 250 mm [10 in.] diameter with a 70 mm [2.75 in.] diameter hole in the center.

NOTE 3—The ring fits over the mortar-slump mold to hold the mold on to the base plate and to catch mortar overflowing as it is added to the mold.

5.1.10 *Funnel*—The mold described in Test Method C128 or other suitable funnel for filling mortar-slump mold.

5.1.11 *Base Plate*—Square, non-absorbent, at least 300 mm [12 in.]. The plate shall be sufficiently flat so that there is no leakage of mortar at the base of the slump mold during the filling process.

5.1.12 *Steel Tamping Rod,* 9.5 mm [3⁄8 in.] diameter by 300 mm [12 in.] long with rounded ends.

5.1.13 *Ruler,* at least 300 mm [12 in.] long.

5.1.14 *Calipers,* 300 mm [12 in.] readable to 1 mm [0.05 in.].

5.1.15 *Nominal 400 mL Brass Cup,* or similar size container with a known volume.

5.1.16 *16 mm [5⁄8 in.] diameter Tapping Stick,* made of hard wood, 150 mm [6 in.]) in length.

5.1.17 *Sieve,* 4.75 mm (No. 4) as described in Specification E11.

5.1.18 *Thermometer*—The thermometer shall be capable of measuring the temperature of the fresh mortar to ± 0.5 °C [±1 °F]. ASTM liquid-in-glass thermometers having a temperature range from −20 to 50 °C [0 to 120 °F], and conforming to the requirements of Thermometer 97F (or 97C) as prescribed in Specification E2251 are satisfactory. Other thermometers of the required accuracy, including the metal immersion type, are acceptable.

6. Mortar Mixture Proportions

6.1 Two methods are described for proportioning mortar mixtures. Method A is adapted from specific job mixture proportions, and Method B is based on fixed proportions,

[5] The sole source of supply of the apparatus known to the committee at this time is Certified Material Testing Products, Palm Bay, Fl., under the name, Mini Steel Slump Cone. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

which can be suitable for the evaluation of various concrete-making materials other than coarse aggregate. Make multiple batches of mortar using the same mixture proportions to provide sufficient material to perform all the required tests.

6.1.1 *Method A, Mortar Proportioned Based on Job Concrete Mixture Proportions:*

6.1.1.1 Express the proportions of the concrete materials of the job mixture in SI units of kg/m^3 as quantities suitable for the mortar mixture by multiplying the masses of cement, supplementary cementitious material (SCM) (if used), sand at saturated-surface-dry (SSD) condition, and water by a factor of 3. (Multiplying the mixture components by a factor of 3 results in a mortar batch having volume sufficient to perform a number of tests.) Omit the coarse aggregate. The resulting quantities are in units of gram and mL and represent the batch proportions. Increase or decrease the factor as necessary to provide the amount of the mortar needed for the intended tests and the capacity of the mixer. Do not overload the mixer. If additional mortar is needed, make additional batches or use a larger mixer. If the concrete mixture proportions are reported in inch-pound units, first convert to SI units. Obtain proportions in SI units by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10 for measurements made in other units.

NOTE 4—As an example, a concrete mixture proportioned in inch-pound units is converted to a mortar mixture as shown in the table below:

Material	Concrete Mixture Proportions		Mortar Mixture Proportions SI units, g
	inch-pound units (lb/yd^3)	SI units (kg/m^3)^A	
Cement	517	307	921^B
Fine Aggregate	1244	738	2214^B
Coarse Aggregate	1845	1096	Omit
Water	251	149	447^B
MRWR^C	7.6 oz/100 lb	496 mL/100 kg^D	4.6 mL^E
AEA^F	0.2 oz/100 lb	13.0 mL/100 kg	0.12 mL^E
		Dilute 1/100	12.0 mL^F

^{A} lb ⁄cy × 0.5933 = kg/m^3.
^{B} Mixture proportion, kg/m^3 × 3 expressed as grams.
^{C} MRWR—midrange water reducer.
^{D} fl oz/100 lb × 65.2 = mL/100 kg.
^{E} (mL ⁄100 kg × 0.921 kg)/100 = mL for mortar mixture.
^{F} Air-entraining admixture (AEA). Diluting the AEA by a factor of 100 provides a measurable quantity.

6.1.2 *Method B, Mortar Proportioned Based on Mortar Fraction of Specification C494/C494M Concrete Mixture:*

6.1.2.1 Prepare the reference mortar mixture with 600 ± 5 g of cementitious material, 1350 ± 5 g of one of the following sand: (*a*) standard sand conforming to ISO 679; (*b*) a blend of 675± 3 g of graded sand and 675 ± 3 g of 20-30 sand conforming to Specification C778, or (*c*) an alternative sand such as the job sand. Add sufficient water to obtain a mortar-slump of 50 to 125 mm [2 to 5 in.].

NOTE 5—A stock concrete sand may be used for Method B.

6.2 For subsequent mixtures prepared by either by Method A or Method B, partially or totally replace materials in the reference mortar mixture to test the effect of these materials on selected mortar properties such as mortar-slump, mortar-slump retention, time of setting, and air content.

6.3 If a chemical admixture is to be used, measure the amount of admixture by volume or mass. If measuring by volume, use a syringe of sufficient volume. If comparing the performance of chemical admixtures with different oven-dried residue contents, compare their performance based on either an equal oven-dried residue content by mass of cement or equal volume by mass of cement.

NOTE 6—Adding the correct amount of a low-dosage chemical admixture, such as an air-entraining admixture, is facilitated by first diluting the admixture by a factor of 10 to 100. Include the water from the diluted admixture in the total water content of the mortar mixture proportions.

7. Sand Preparation

7.1 For Method A, use job proportions and job sand. For method B, use sand meeting one of the requirements in 6.1.2.1.

7.1.1 For the standard sand conforming to ISO 679 or the blend of 675 ± 3 g of graded sand and 675 ± 3 g of 20-30 sand conforming to Specification C778, determine the relative density (specific gravity) for the SSD condition and absorption of the sand in accordance with Test Method C128. Use the absorption value to determine the quantity of water to be added to the mortar mixture to bring the sand to the SSD condition.

7.2 For alternative sand sources, prepare the sand as follows:

7.2.1 For concrete sand, pass the sand through a 4.75 mm (No. 4) sieve.

NOTE 7—Sieve size is identified by its standard designation in Specification E11.

NOTE 8—Particles larger than 4.75 mm can cause possible damage to the mixer shaft.

7.2.2 Blend the sieved sand and protect it from moisture evaporation during the measuring and batching sequence.

7.2.3 Determine the relative density (specific gravity) SSD and absorption of the sand in accordance with Test Method C128.

7.2.4 Determine the free moisture content of the sand in accordance with either Test Method C70 or C566, and adjust the masses of sand and water to be added accordingly. If sand is drier or wetter than the SSD condition, correct for absorbed or excess moisture in the mortar mixture proportions.

7.2.5 Measure the mass of the sand required for each batch, place the sand into a container, and keep the container covered with an airtight lid until time of mixing.

7.3 For tests to be performed at 23.0 ± 2.0 °C [73 ± 3 °F], store all the materials at 23.0 ± 2.0 °C [73 ± 3 °F] for sufficient time to equilibrate within that temperature range prior to the start of mixing.

7.4 For mixing to be performed at other temperatures, allow all the materials to equilibrate at that temperature prior to mixing.

8. Batching and Mixing

8.1 Measure the mass of the water and cementitious materials required for each batch.

8.1.1 Potable water shall be used as the reference water when evaluating job mixing water.

8.2 To evaluate admixtures under up-front batching condition, add the required admixture to the mixing water. Stir the solution to disperse the admixture. Add admixtures that are not compatible in concentrated form, such as solutions of calcium salts and certain air-entraining and set retarding admixtures, separately during the batching procedure.

8.3 Before the addition of materials, dampen the mixing bowl and paddle by wiping down with a wet paper towel.

8.4 Add all sand to the mixing bowl followed by the cementitious materials.

8.5 Mix for 10 s at slow speed, 140 ± 5 rpm.

8.6 To test delayed addition of admixtures, add the admixture (or the diluted solution of admixture) 1 min after the dry material comes in contact and is mixed with the batch water.

8.7 With the mixer operating at slow speed, add the entire amount of mixing water within 5 s. Start the timer, and record the time when the water is added.

8.8 Once all the water is added, stop the mixer and change to medium speed, 285 rpm ± 10 rpm.

8.9 Continue mixing for 5 min, then stop the mixer.

8.10 Scrape the bottom and sides of the bowl and mix any dry material by hand into the bulk mortar for 30 s. Let the mortar remain undisturbed until the 8 min mark.

8.11 At the 8 min mark, start mixing for 1 min at medium speed, 285 rpm ± 10 rpm. Stop the mixer, remove the paddle, measure and record the mortar temperature, and measure the mortar slump in accordance with 9.1.

8.12 If the mortar-slump is less than 50 mm [2 in.] or greater than 125 mm [5 in.], discard the batch, and make a new mortar mixture with a lower or higher amount of water, as appropriate.

8.13 If mortar-slump retention is to be determined, return the mortar used for the mortar-slump and air content tests to the mixing bowl, and continue mixing at slow speed for 15 min increments, stopping to perform mortar-slump, mortar-spread, air content, and the temperature of the mortar after each 15 min period. Continue until the mortar-slump is less than 50 % of the initial mortar-slump.

9. Test Methods

9.1 *Mortar-slump and Mortar-spread:*

9.1.1 Dampen the mortar-slump mold and base plate by wiping with a moist towel. Place the mold on the base plate. Place the plastic ring over the slump mold. Fill the mold with mortar using two layers of equal volume. Tamp each layer 15 times with the tamping rod. Screed off excess mortar from the top of the mold with the trowel. Remove any excess mortar that may have fallen on the base plate. Lift the mold up from the base plate in one steady motion within 2 to 3 s.

9.1.2 Measure the mortar-slump by turning the mold upside down and setting it next to the slumped mortar. Do not disturb the mortar specimen during the measurement process. Place the tamping rod across the bottom of the inverted slump mold so that it extends over the slumped mortar. Using the ruler, measure straight down from the bottom of the tamping rod to the top of the original displaced center of the slumped mortar. Record the vertical slump of the mortar to the nearest 1 mm [1⁄16 in.].

9.1.3 With the calipers, measure the diameter of the horizontal flow or spread of the mortar at two locations, 90° apart. Calculate the average spread and record to the nearest 1 mm [0.05 in.].

NOTE 9—Mortar slump and mortar-spread are empirical indicators of ease of mortar flow. The workability index, which is the sum of the two measurements minus 100 for measurements in SI units or minus 5 for inch-pound units, may be used as an optional single indicator of mortar workability.

9.1.4 If mortar slump retention time is desired, continue mixing and testing the mortar in accordance with 8.13.

9.2 *Air Content of Mortar Mixture:*

9.2.1 Measure and record the mass of the empty 400 mL brass cup, or similar size container of known volume, to the nearest 0.5 g.

9.2.2 Using a spoon or scoop, place the mortar into the 400 mL brass cup, or similar size container with a known volume, in three equal layers. Tamp each layer 20 times with the tamper around the inner surface of the cup. The long face of the tamper should always coincide with the radius of the cup. Complete tamping each layer in one revolution of the cup. Use only sufficient pressure to fill the measure and eliminate voids.

9.2.3 After the cup is filled, lightly tap the sides of the cup with the side of the tamping rod at five different points spaced equally around the outside of the cup. Screed the mortar to a flat surface, flush with the top of the cup, using a trowel in a sawing motion. Make two passes completely across the cup in two directions at right angles to each other. Complete the filling and strike-off procedures within 90 s. Wipe off excess mortar from the sides and the top rim of the cup.

9.2.4 Measure and record the mass of the filled cup to the nearest 0.5 g.

9.2.5 *Calculate the Density*—Determine the density of the mortar (D) as follows:

$$D = (M - C) / V_c \quad (1)$$

where:

D = density, g/mL,
M = mass of mortar and cup, g
C = mass of empty cup, g, and
V_c = measured volume of cup, mL.

9.2.6 *Calculate the Total Mass Batched*—Determine the total mass of materials used to batch the mortar ($W1$) as follows:

$$W1 = C + P + S + W \quad (2)$$

where:

$W1$ = total mass of materials batched, g,
C = cement, g,
P = supplementary cementitious material (SCM), g,
S = sand at SSD condition, g, and

W = water, g, which includes the added mix water, water from the chemical admixtures, and moisture from the sand in excess of the moisture content for the SSD condition of the sand. If the sand has less water than required for the SSD condition, adjust the value of W by subtracting the water required to bring the sand to the SSD condition.

9.2.7 *Calculate the Volume of Mortar Batched*—Determine the volume of mortar (Y) as follows:

$$Y = W1 / D \tag{3}$$

where:

Y = volume of mortar in the batch, mL,
$W1$ = total mass of materials batched, g, and
D = density of mortar, g/mL.

9.2.8 *Calculate the Absolute Volume of Materials Batched*—Determine the absolute volume (V) of the materials in the mortar batch as follows:

$$V = (C / c) + (P / p) + (S / s) + W \tag{4}$$

where:

V = absolute volume of all materials batched, mL,
C = mass of cement, g,
c = relative density (specific gravity) of cement,
P = mass of SCM, g,
p = relative density (specific gravity) of SCM,
S = mass of sand in SSD condition, g,
s = relative density (specific gravity) of sand in SSD condition, and
W = mass of water, g.

NOTE 10—All the terms on the right side of Eq 4 are actually divided by the density of water, which is assumed to equal 1 g/mL. For simplicity, this factor has been omitted from the equation.

9.2.9 *Calculate the Air Content, %, of the Mortar*—Determine the air content of the mortar (A) as follows:

$$A = [(Y - V) / Y] \times 100\ \% \tag{5}$$

where:

A = air content, %,
Y = volume of mortar in the batch, mL, and
V = absolute volume of all materials batched, mL.

9.3 *Time of Setting*—Make penetration measurements and determine the times of initial and final setting in accordance with the Procedure and Calculation sections of Test Method C403/C403M.

9.4 *Hydration Kinetics*—If required, measure the hydration kinetics of the mortar mixture according to Practice C1679.

10. Report

10.1 The mortar method, mixture proportions used for the mortar mixtures and identifying information about each material.

10.2 The mortar-slump, mortar-spread, air content, mortar temperature, and times of initial and final setting.

10.3 If determined, report the mortar-slump retention time.

10.4 If determined, provide the plot of thermal power versus time.

11. Precision and Bias

11.1 *Precision*—Table 1 shows the pooled, single-operator standard deviations for mortar-slump, mortar-spread, and air content obtained in one laboratory using four mortar mixtures and three replicate determinations. The ranges in values of the measured properties are indicated in the second column.

11.2 *Bias*—There is no accepted reference material suitable for determining the bias in this guide, therefore, no statement on bias is made.

12. Keywords

12.1 air content; cementitious material-admixture interactions; hydration kinetics; mortar; mortar-slump; mortar-spread; time of setting

TABLE 1 Single-operator Standard Deviations

Test Method	Range in Values	Standard Deviation
Mortar-slump	50 to 100 mm [2 to 4 in.]	0.8 mm [0.03 in.]
Mortar-spread	110 to 165 mm [4.3 to 6.5 in]	0.9 mm [0.04 in.]
Air content	1 to 8.5 %	0.10 %

APPENDIX

(Nonmandatory Information)

X1. APPLICATION OF MORTAR TESTS

X1.1 General

X1.1.1 The mortar methods described in the guide are typically used to either help predict a possible change in performance when an alternative concrete-making material will be used for concrete production, or to investigate an unexpected and undesired performance resulting from incompatibilities among certain materials. Mortar testing can be especially useful if sufficient quantities of materials to make concrete mixtures are not available.

X1.1.2 The maximum benefit from this guide can be realized when the relative performance from mortar tests can be correlated with concrete test results when using the same materials. Such correlations can be achieved when unexpected performances, such as high air content, delayed set, or high or low slump, are observed with field concrete mixtures as well as mortar mixtures proportioned using either Method A or Method B. A major challenge to establish such correlations is the availability of the field materials associated with the unexpected performance. Sometimes, the unexpected performance occurs with several deliveries of concrete for a particular job, whereas the loads before and after the unexpected performance exhibit normal performance.

X1.1.3 Tests of mortar mixtures are expected to be more sensitive to changes in concrete-making materials due to lower variability in the preparation of the materials and mixing protocol compared with commercial scale concrete production. Therefore, performance differences observed between mortar mixtures may not be observed with concrete mixtures. The precision of the mortar tests covered in this guide are indicated in Table 1. These values are useful in determining if observed differences in test results between two mixtures are statistically significant.

X1.2 Case Study—Clay in Sand

X1.2.1 The following case study illustrates one of the various ways that mortar mixtures can be used to investigate material incompatibility issues observed in the field and make modifications to mixture proportions to address the problem. In this case, the problem was an incompatibility between a clay-bearing sand and a polycarboxylate (PCE) high-range water-reducer (HRWR). Note that if the clay were in the coarse aggregate, mortar testing using the field sand would not be able to identify the problem unless the coarse aggregate were crushed to a fine aggregate.

X1.2.2 The performance of chemical admixtures can be affected by certain properties of the concrete-making materials, including fine aggregate. This application of the mortar method involved determining the cause of a relatively high addition rate of PCE HRWR compared with that of a naphthalene sulfonate formaldehyde condensate (NSFC) product. The original concrete mixture design called for a NSFC-based HRWR, but the admixture was changed to a PCE-based HRWR to take advantage of improved slump retention performance. A common dosage ratio between NSFC and PCE products to achieve a target slump is 3 to 1 based on volume of admixture per mass of cement, that is, mL/100 kg [oz/100 lb] cement. However, with the concrete producer's materials, the dosage ratio was 2 to 1, making the use of the PCE product uneconomical. Field samples of cement (code Field) and sand (code RLT) were provided to investigate the cause of the relatively high dosage of the PCE HRWR needed to achieve the required slump.

X1.2.3 The investigation began by reproducing the reported high dosage problem using proportioning Method B because no mixture proportions were provided with the samples of cement and sand. The mortar mixture proportions were 600 g cement and 1350 g of dry RLT sand or standard sand conforming to ISO 679 (code LAB). The admixture properties, addition rates, and the amounts used for the mortar batches are as follows:

X1.2.3.1 *NSFC HRWR*—Oven-dried residue = 40 %; specific gravity = 1.22; addition rate = 785 mL/100 kg cement = 785 mL/100 kg ×1 kg/1000 g × 600 g/batch × 1.22 = 5.7 g of NSFC liquid admixture/batch of mortar. The NSFC HRWR was added with a 1-min delayed addition.

X1.2.3.2 *PCE HRWR*—Oven-dried residue = 30 %; specific gravity = 1.10; addition rate = 260 mL/100 kg/cement = 260 mL/100 kg × 1 kg/1000 g × 600 g/batch × 1.10 = 1.7 g of PCE liquid admixture/batch of mortar. The PCE HRWR was added with the mix water.

X1.2.4 Eight mortar mixtures were made in which the field and laboratory cement and sand were changed systematically. Table X1.1 shows the eight mixtures that were made and the resulting workability properties. For mixtures 2 and 5, the dosage of the PCE admixture was about ⅓ of the dosage of the NSFC admixture used for mixtures 1 and 4. For mixture 3, the dosage of the PCE admixture was increased to achieve the same workability as achieved with the NSFC admixture. Mixtures 6, 7, and 8 were made with standard sand.

X1.2.5 The results from this study indicate: (*1*) the mortar tests reproduced the poor PCE dosage efficiency reported in the field as indicated by the lower workability of mixture 2 compared with mixture 1; (*2*) mixtures 1 and 3 show that to maintain similar workability the ratio of NSFC to PCE HRWRs is 5.7/3.4 = 1.7 compared with the typical ratio of 3; (*3*) comparison of mixtures 2 and 5 shows that the field cement does not appear to be a factor relative to the poor PCE dosage efficiency; and (*4*) comparison of mixture 7 and 8 shows that with the standard sand similar workability was obtained at a ratio of NSFC to PCE ratio equal to 5.7/1.7 = 3.4.

X1.2.6 Follow-up tests performed with the bulk RLT sand and portion finer than 75 µm found relatively high methylene blue values (MBV) of 1.3 and 3.0, respectively, indicating the presence of a significant amount of clay. The bulk lab sand has an MBV less than 0.01, and 0.096 for the portion finer than 75 µm. MBV values were determined by Test Method C1777. Subsequent studies found that PCE HRWRs can be absorbed rapidly and irreversibly by smectite type clay, [6,7] thus requiring a higher than normal addition rate to achieve a target workability.

[6] Jeknavorian, A., Jardine, L., Ou, C., Koyata, H., and Folliard, K., "Interaction of Superplasticizers with Clay-Bearing Aggregates," Seventh CANMET/ACI International Conference Superplasticizers and Other Chemical Admixtures in Concrete, Berlin, *ACI SP* 173-04, 1997, American Concrete Institute, pp. 55–82.

[7] Ng, S., J. Plank, "Interaction mechanisms between Na montmorillonite clay and MPEG-2 based polycarboxylate superplasticizers," *Cement and Concrete Research*, Vol 42, No. 6, 2012, pp. 847–854.

TABLE X1.1 Mortar Slump, Mortar Flow, and Workability Index for Mortar Mixtures Prepared According to Method B

Mix #	Cement	Sand	Water, g	NSFC, g	PCE, g	Mortar Slump	Mortar Flow	Workability Index[A]
1	Field	RLT	300	5.7		110	145	155
2	Field	RLT	300		1.7	70	96	66
3	Field	RLT	300		3.4	112	147	159
4	Lab 170	RLT	300	5.7		108	142	150
5	Lab 170	RLT	300		1.7	68	101	69
6	Field	LAB	300	5.7		133[B]	180	213
7	Field	LAB	270	5.7		113	150	163
8	Field	LAB	270		1.7	111	149	160

[A] Workability Index = Mortar Slump + Mortar Flow – 100
[B] Exceeds the 125 mm value specified in 8.12.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C1810/C1810M – 20) that may impact the use of this standard. (Approved Aug. 11, 2020.)

(1) Added new Appendix X1.

Committee C09 has identified the location of selected changes to this standard since the last issue (C1810/C1810M – 19) that may impact the use of this standard. (Approved June 15, 2020.)

(1) Added new subsection 8.1.1.