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INTERLABORATORY STUDY TO ESTABLISH PRECISION STATEMENTS FOR TEST METHOD C78/C78M-15B, STANDARD TEST METHOD FOR FLEXURAL STRENGTH OF CONCRETE (USING SIMPLE BEAM WITH THIRD-POINT LOADING)

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1. INTRODUCTION

The effect of specimen size on flexural strength (or modulus of rupture) has been reported by several studies over the years[1,2,3,4,5,6,7,8,9,10,11,12,13,14,15]. In a recent study[16], a total of 22 mixtures, containing four different coarse aggregates (limestone, diabase, gravel and granite) with maximum size varying from ¾ in. to 1.5 in. [19 mm to 37.5 mm], were prepared. Two specimen sizes were tested: the standard 6 by 6 by 21 in. [150 by 150 by 533 mm] and a smaller specimen, measuring 4 by 4 by 14 in. [100 by 100 by 355 mm]. The smaller specimens resulted in higher flexural strengths when tested according to Test method C78/C78M, which is in agreement with the previous research mentioned. Although the strength difference between the two specimen sizes was relatively small, it was considered to be statistically significant. In 2014, this study resulted in revisions to AASHTO T23[18] and AASHTO T97[19] so that the use of 4 by 4 by 14 in. beams would be allowed.

In November 2015, changes to Practice C31/C31M-15a[20] and Test Method C78/C78M-15b[17] were also approved (ballot items WK49498 and WK49481, respectively) to accommodate the use of the smaller size beams. During the ballot preparation, it was observed that the precision statement in the previous versions (Test method C78/C78M-15a and earlier) was based on the study by Carrasquillo and Carrasquillo[9]. That study involved a single brand and model of the testing machine and two specimen sizes: 6 by 6 by 20 in. [150 by 150 by 508 mm] and 4.5 by 4.5 by 15.5 in. [114 by 114 by 394 mm]. The use of a single model and brand equipment could have resulted in non-representative precision. In addition, no precision statement was available for the smaller 4 by 4 in.[100 mm by 100 mm] beam size.

Consequently, an interlaboratory study was initiated (ILS #1265) with the primary objective of determining the precision for the Test Method C78/C78M-15b[17] using two beam sizes: 6 by 6 by 21 in. [150 by 150 by 533 mm] and 4 by 4 by 14 in. [100 by 100 by 355 mm]. A task group (Appendix A) was created to design the interlaboratory study. In September 2015, the task group held its first conference call, creating guidelines for the study. The presentation and minutes of the September 2nd conference call can be found in Appendix A.

2. TEST METHOD

The test method used for this ILS is Test Method C78/78M-15b[17]. To obtain a copy of Test Method C78/78M, go to ASTM's website, www.astm.org, or contact ASTM Customer Service by phone at **610-832-9585** (8:30 a.m. - 4:30 p.m. Eastern U.S. Standard Time, Monday through Friday) or by email at service@astm.org.

3. PARTICIPATING LABORATORIES

After the first task group conference call, laboratory solicitation started by reaching out to ASTM C09.61 subcommittee members, WACEL members and laboratories that were

listed in the AMRL website as accredited to perform Test Method C78/78M. After a laboratory agreed to participate, a form was sent so that initial information could be collected. The laboratory form is presented in Appendix A.

Because there were difficulties finding enough Test Method C78/C78M accredited laboratories within driving distance from the casting site, ASTM C09.61 members decided, during the December 2015 meeting, to lift the requirement for Test Method C78/C78M accreditation and to only require the technician to be certified as an ACI strength testing technician. From the 22 participating laboratories, 17 laboratories possessed accreditation for either Test Method C78 or AASHTO T97, three possessed accreditation that did not include Test Method C78 or AASHTO T97 and two did not possess any accreditation, in one of them the technician was ACI certified for strength testing and in the other one, the technician was not certified for strength testing. For this particular laboratory (laboratory 11), data were reviewed carefully and they indicated good repeatability. The accreditation status of each laboratory is shown in Appendix A.

Laboratories representing government agencies, industry, associations and commercial laboratories were selected based on their experience in running Test Method C78/C78M and their testing machines, in terms of brand and model, so a wide range of equipment manufacturers could be included in the program. Priority was given to laboratories located within 4-hour driving from the casting site (considered local laboratories), but a limited number of non-local laboratories were also included.

The following laboratories participated in this interlaboratory study. Laboratories marked with * were considered "local" and laboratories marked with # were considered non-local.

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4. TESTING PROGRAM

The testing plan and data analysis for this study was based on Practice C802-14[21] Standard Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials and Practice C670-15[22] Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials.

Practice C802-14[21] recommends at least 10 laboratories to be included in the ILS, and if not possible, it suggests that the program should be repeated using the same laboratories. Because flexural strength determined in accordance with Test Method C78/C78M[17] is believed to be sensitive to specimen moisture conditions[23,24,25,26], the task group targeted a minimum of 12-13 laboratories located within a 4-h driving distance, so that beams wouldn't have to be shipped, avoiding variability caused by the shipping process. Additional non-local laboratories were allowed to participate but their data were analyzed with additional care.

Practice C802-14[21] recommends using at least three mixtures with different flexural strengths, covering the range found in practice. In addition, it recommends specimens be produced from a single batch of concrete and at one location, avoiding variability not related to the test method. The required number of replicates depends on the number of participating laboratories, with a minimum of three replicates if 10-15 laboratories were to be used. As a result, the task group decided that three replicates should be tested but four beams should be made for each mixture and beam size per laboratory case one of the replicates had to be discarded.

5. DESCRIPTION OF SPECIMENS

5.1. MIXTURE PROPORTIONS

Three flexural strength levels were chosen, so that the range wide range of strengths normally used in different applications would be covered: 450, 600 and 800 psi [3.0, 4.0 and 5.5 MPa]. The mixture proportions were based on mixtures previously used by the Vulcan Materials Company (Springfield plant), with some minor modifications in order to obtain the target strengths at 56 days. The 56-day age was chosen due to the complex logistics of the study and to make sure the beams achieved enough strength before being hauled or shipped to the participating laboratories. Table 1 shows the mixture proportions. Aggregate properties can be found in Appendix B. Nevertheless, once mixtures started being tested, it was observed that the flexural strengths were almost double the target values. For this reason, the mixture 3 testing age was changed to 46 days. In addition, a fourth mixture was prepared but, in order to facilitate the delivery of specimens, only 16 laboratories participated in testing mixture 4. The testing age of mixture 4 was 21 days.