This Research Report is issued under the fixed designation RR: C09-1051. You agree not to reproduce or circulate or quote, in whole or part, this document outside of ASTM International Committee/Society activities, or submit it to any other organization or standards body (whether national, international or other) except with the approval of the Chairman of the Committee having jurisdiction and the written authorization of the President of the Society. If you do not agree to these conditions, please immediately destroy all copies of this document. *Copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. All rights reserved.*

1 July 2017

Committee C09 on Concrete and Concrete Aggregates
Subcommittee C09.45 on Roller-Compacted Concrete

Research Report: C09-1051

Ruggedness Study for ASTM C1849 -17, Test Method for Density and Air Content (Pressure Method) of Freshly Mixed Roller-Compacted Concrete

Technical contact:
Dennis Clute,
USDA-Natural Resources Conservation Service
501 W. Felix St, Bldg. 23
Fort Worth, Texas 76115, USA
dennis.clute@ftw.usda.gov

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

This is a preview. Click here to purchase the full publication.

1. Introduction:

Interlaboratory Study 1006 was conducted to evaluate the ruggedness of and develop a temporary precision statement for C1849, **Test Method for Density and Air Content (Pressure Method) of Freshly Mixed Roller-Compacted Concrete**. The ruggedness evaluation was executed per ASTM C1067-12 to determine the sensitivity of the test method to changes in levels of pertinent operating factors.

48 tests were conducted using a ASTM C231, Type B air meter with replicate tests conducted on 24 different RCC mixtures. The seven factors evaluated were: 1 surcharge mass, 2 apparatus mass, 3 mix proportioning, 4 cementitious materials, 5 aggregate angularity, 6 nominal maximum aggregate size, and 7 absence or presence of air entrainment. Some information on single-operator precision was obtained.

The lab program was conducted in conjunction with testing to evaluate the ruggedness of two other standards (C1170 and C1435) the results of which are reported in separate research reports, respectively RR: C09-1043 and RR: C09-1045.

2. Test Method:

The Test Methods used for this ILS are a draft revision of C1170-08 and C1067-12. To obtain a copy of C1067, 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 Laboratory:

The following laboratory participated in this ruggedness study:

Fall Line Testing and Inspection, LLC
460 East 76th Avenue
Building 4, Unit C
Denver, Colorado 80229, USA

4. **Description of Samples:**

Materials used for this study were the ingredients typically used for making RCC mixtures. Material quality was specified according to the standards annotated in the Materials Quality Table below. Material data sheets for all materials (except water and cement) are included in Annex B.

Water was obtained from the city's potable water supply. No data is provided.

Cement (42 kg (92.6 lb.) sacks of Holcim Portland Type I, II was obtained from a local home improvement store. No data is provided.

The air-entraining agent (AEA) was specified to be "1) synthetic detergents having a chemical description of alkyl-aryl sulfonates and sulfates (e.g., sodium dodecylbenzenesulfonate) or 2) wood derived acid salts (e.g. Vinsol resin) having a chemical description of alkali or alkanolamine salt of a mixture of tricyclic acids, phenolics, and terpenes.". The AEA was specified based on discussion with Jim Hinds and Steve Tatro. Both Mr. Hinds and Mr. Tatro retired from employment with the United States Army Corps of Engineers. They stated that, while working for USACE, they were successful entraining air with either of these types of AEA in RCC mixed in a compulsory pugmill.

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

This is a preview. Click here to purchase the full publication.

MATERIALS QUALITY TABLE

Material	Type or Class	Quality Standard
Portland Cement	Type I or II	ASTM C150
Fly Ash	Class F	ASTM C618
Fine Aggregate		ASTM C33
Coarse Aggregate		ASTM C33
Water		ASTM C94
Air-Entraining Agent (AEA)		ASTM C260

5. **Interlaboratory Study Instructions**

Laboratory participants were emailed the test program instructions. For a copy of the instructions, see Annex A.

6. Description of Equipment/Apparatus[1]:

For information on the equipment/apparatus used, see Annexes A and B.

7. Data Report Forms:

Copies of the data report forms are provided in Annex A with completed forms in Annex B.

8. Statistical Data Summary:

A summary of the statistics calculated from the data returned by the participating laboratories is provided in Annex B and in Section 10. Analysis of Variance.

9. Precision and Bias Statement:

The practice described in ASTM 1067 and employed in this research is not intended to provide information on multi-laboratory precision, but it does provide some information on single-operator precision, which has been used to develop the following temporary repeatability statement.

x.1.2.1 *Air Content* - The single-operator standard deviation has been found to be 0.2 % air by volume of concrete for mixtures with Vebe consistencies, determined per Test Standard C1170/C1170M, below 20s, 0.4 % air by volume of concrete for mixtures with Vebe consistencies over the range from 20s to 30s, and 1.1 % air by volume of concrete for mixtures with Vebe consistencies above 30s. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ from each other by more than 0.6 % air by volume of concrete for mixtures with Vebe consistencies below 20s, 1.1% air by volume of concrete for mixtures with Vebe consistencies over the range from 20s to 30s, and 3.1 % air by volume of concrete for mixtures with Vebe consistencies above 30s.

x.1.2.2 *Density* - The single-operator standard deviation has been found to be 9.8 kg/m^3 [0.6 lb/ft^3]^A for mixtures with Vebe consistencies below 20s, 8.0 kg/m^3 [0.5 lb/ft^3]^A for mixtures with Vebe consistencies over the range from 20s to 30s, and 14.4 kg/m^3 [0.9 lb/ft^3]^A for mixtures with Vebe consistencies above 30s. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ from each other by more than 25.6 kg/m^3 [1.6 lb/ft^3] for mixtures with Vebe consistencies below 20s, 24.0 kg/m^3 [1.5 lb/ft^3] for mixtures with Vebe consistencies over the range from 20s to 30s, and 40.0 kg/m^3 [2.5 lb/ft^3] for mixtures with Vebe consistencies above 30s.

^{A} These numbers represent, respectively, the [1s] and [d2s] limits as described in ASTM Practice C670, for Preparing Precision Statements for Test Methods for Construction Materials.

[1] The equipment listed was used to develop a precision statement for C1849-17. This listing is not an endorsement or certification by ASTM International.

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

This is a preview. Click here to purchase the full publication.

NOTE 13—The precision of this test method using Type A air meters has not been determined.

x.2. Bias – The test method has no bias because the values determined can be defined only in terms of the test method. *ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this research report. Users of this research report are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

This research report is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this research report may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or serviceastm.org (e-mail); or through the ASTM website (www.astm.org).

10. Analysis of Variance:

The practice described in ASTM 1067 and employed in this research evaluates the effects of seven factors (A through G) on the results of a test. It only estimates the main effects of the factors and does not detect the effects of interactions among factors. The draft test standard being evaluated returns two results: 1) the air content as a percentage of the total volume of the concrete and 2) the density of the concrete.

The analysis results in a number for each factor evaluated. This number, termed the "F statistic", is designated F_f, for f = A through G. If F_f is greater than 5.32, the factor f (A through G) has a statistically significant effect. If F_f is shown to be NS it has a value of less than or equal to 5.32 and has no statistically significant effect.

The results of the ANOVA are shown in the tables and further discussed below.

Air Pot %Air

Summary of F Values for All Laboratories, All Materials, and All Factors

Material	Average	Apparatus Mass	Number of Lifts	Proportioning	Cementitious Materials	Coarse Aggregate Shape	NMSA	Air Entrainment
	Percent air by volume	F_A	F_B	F_C	F_D	F_E	F_F	F_G
A	4.06	15.70	NS	840.04	889.09	NS	NS	4706.13
B	3.89	NS	NS	51.70	32.07	NS	NS	342.84
C	4.99	30.11	NS	89.53	NS	39.69	NS	10.14

Air Pot Density

Summary of F Values for All Laboratories, All Materials, and All Factors

Material	Average	Apparatus Mass	Number of Lifts	Proportioning	Cementitious Materials	Coarse Aggregate Shape	NMSA	Air Entrainment
	Density	F_A	F_B	F_C	F_D	F_E	F_F	F_G
A	148.1	NS	NS	98.89	30.31	125.99	81.09	505.88
B	149.3	NS	NS	65.68	NS	151.28	51.14	304.45
C	147.5	57.60	NS	157.10	7.00	167.36	25.60	46.81

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

This is a preview. Click here to purchase the full publication.

F_A – Apparatus Mass
Two hammer/shaft/tamping plate assembles were used, one with a total mass of 44 lb, the other 57 lb. (Note that the dynamic compactive effort varies with hammer size, so a change in hammer mass results in a change in the total compactive effort which is comprised of static and dynamic components).

The apparatus mass had a slightly significant effect on the variation of air content test results of Material A, insignificant effect on the variation of air content test results for Material B, and a significant effect on the variation of air content test results for Material C. For Materials A and B, the effect of apparatus mass was insignificant for the density value; it was significant for Material C. For Materials A and B the range of mass appears to be practically insignificant. It is suggested the full range of mass be allowed, but a note be included in the standard addressing the significance of apparatus mass for mixtures with consistencies over 30s.

F_B – Number of Lifts
The number of lifts was of no significance. Two lifts should be specified rather than three.

F_C – Proportioning
Proportioning significantly affected variation of air and density test results. It is recommended that any lab program designed to further study precision of air content and density, tested per this standard, be designed to report the precision of tests on lean mixtures separately from that of rich mixtures.

F_D – Cementitious Material
The ratio of cement to fly ash had a significant effect on both the variation in air and density tests. A note to this effect may be in order.

F_E – Coarse Aggregate Shape
The shape of the coarse aggregate (rounded or angular) had no significant effect on the variation of air content test results for Materials A & B, but did have a significant effect on the variation of air content test results for Material C. Aggregate shape significantly affected the variation of density results of all three materials. Future lab programs designed to study precision of air content and density test results would benefit from reporting precision of tests on rounded aggregate separately from that of angular aggregate.

F_F – Nominal Maximum Size Aggregate
Changing the NMSA from ¾ inch to 1 ½ inch material had an insignificant effect on the variation of air content test values but significantly affected the variation of density test values. When studying precision of density test results of specimens made according to this proposed standard, reporting values separate for various NMSA would be prudent.

F_G – Air Entrainment
The addition of an air-entraining agent (AEA) had a significant effect on the variation of both air content and density results. Future studies should consider reporting precision for specific ranges of air content or as a percentage of the air content as applicable.

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

This is a preview. Click here to purchase the full publication.

Annex A: Laboratory Instructions and Worksheets

For
ASTM Subcommittee C09.45 Ruggedness Study for
Ruggedness and Precision of

ASTM C1849 – **Test Method for Density and Air Content (Pressure Method) of Freshly Mixed Roller-Compacted Concrete**

Contents of Annex A

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

This is a preview. Click here to purchase the full publication.

Annex A - Attachment A

Study Synopsis

The lab will test a total of 24 batches of concrete (a little more than 300 lbs. per batch or approximately two cubic feet per batch). These batches will be divided into three groups according to their Vebe consistency as follows:

1. Group A shall have a consistency less than 20 seconds.
2. Group B shall have a consistency ranging from 20 to 30 seconds.
3. Group C shall have a consistency greater than 30 seconds.

This study is being conducted to evaluate the ruggedness of three standards, the results for only one of the three standards is being reported in this research report; the results for the other two standards are reported in separate reports. Each batch shall be tested according to the following test procedures:

1. C1170/C1170M-08 - Standard Test Method for Determining Consistency and Density of Roller-Compacted Concrete Using a Vibrating Table (revised to include spacers affixed to the side of the surcharge mass for the purpose of maintaining the annulus space between the surcharge mass and the cylindrical mold)
2. C1435M-08 - Standard Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer (Note, the specified apparatus mass will be exceeded in order to access the effect apparatus mass has on the specimen density and attendant compressive strength.)
3. A draft test method for measuring air content and density of RCC (the subject of this report).
4. C39/C39M-12a - Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
5. C1064/C1064M-11 - Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

Each batch shall be tested a second time by the same operator employing the same apparatus and under the same conditions as the first.

Each batch within each group will be tested under different conditions as shown in the table below.

Conditions for Each Batch

Condition Number	A	B	B	C	D	E	F	G
	Apparatus Mass	Elapsed Time	# of lifts	Lean or Rich	Cem:Pozz	Coarse Agg Type	NMSA	AEA?
	(lb.)	(minutes)	(2 or 3)				(inches)	(yes or no)
1 (9)	low	10	2	lean	25:75	angular	1.5	no
2 (10)	low	10	2	rich	25:75	rounded	0.75	yes
3 (11)	low	30	3	lean	75:25	angular	0.75	yes
4 (12)	low	30	3	rich	75:25	rounded	1.5	no
5 (13)	high	10	2	lean	75:25	rounded	1.5	yes
6 (14)	high	10	2	rich	75:25	angular	0.75	no
7 (15)	high	30	3	lean	25:75	rounded	0.75	no
8 (16)	high	30	3	rich	25:75	angular	1.5	yes

(Note that two conditions are labeled "B" in the table above. Condition B (Elapsed Time) does not apply to this study; it is included in the table because it applies to the study of C1170 which is being conducted in conjunction with this study.)

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

This is a preview. Click here to purchase the full publication.