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Publication of this paper sponsored by Committee on Performance of Concrete.

Abridgment

Accuracy of the Chace Air Indicator

MICHAEL M. SPRINKEL

Results of a study undertaken to quantify and improve the relation between air contents in concrete determined by using the Chace air indicator (CAI) and those determined by using the pressure method are reported. The study revealed very poor agreement between air contents determined by the two methods. The pressure method gave values typically 30 percent higher than anticipated based on the CAI readings. The poor agreement was found to involve relations between the volume of the stems, the volume of the bowls, and the mortar correction factors supplied by the manufacturers of the CAI. Consequently, it was recommended that AASHTO T199-72 be modified to account for these relations so that the CAI can be used to obtain a reasonably accurate indication of the air content of fresh concrete.

Inspection personnel like the Chace air indicator (CAI) (AASHTO T199-72) because of the relative ease with which it can be used. Unfortunately, very poor agreement has been noted between the air contents determined by the CAI and those determined by the pressure method (ASTM C231-75 and AASHTO T152-76). As shown in Figure 1 (1), concrete accepted with the CAI and noted as having an air content of 8 percent, which would be acceptable, could actually have an air content of 12 percent or more, which could cause the concrete to fail the strength test. Frequently, when concrete cylinders have failed the 28-day strength test, subsequent petrographic examinations of the hardened concrete have revealed that the air content was much too high.

The study reported here, which comprised the preparation and testing of 99 batches of pavement and bridge-deck concretes (2, p. 145), was conducted to quantify and improve the relation between air contents determined by the CAI and those determined by the pressure method. The air content of each batch was determined once by using the pressure method, twice by using the CAI to measure the air content of each of two mortar samples obtained by passing a portion of the concrete through a no. 10 sieve (screened samples), and twice by using the CAI to measure the air content of each of two samples obtained by removing mortar from the concrete with a putty knife (unscreened samples).

RESULTS

Figure 1 shows the plots of the average of the CAI determinations on the two unscreened samples as a function of the air content determined by the pressure method, after the data for the CAI have been corrected for the mortar content of the concrete based on the manufacturer's recommended mortar correction factors (MCFs). A relation similar to that shown in Figure 1 was obtained by plotting the average of the CAI determinations on the two screened samples as a function of the air content determined by the pressure method. The data obtained for the screened mortar samples were slightly more variable than those for the unscreened samples: The standard deviation was 0.81 percent as compared with 0.71 percent (1).

Chace Factor

To determine why the CAI was indicating air contents that were much too low, measurements were made of the volumes of the bowls and stems of 36 randomly selected indicators from three manufacturers. The important consideration was the Chace factor, which is defined here as the volume of one graduation on the stem, which represents 1 percent air, expressed as a percentage of the volume of the bowl, which contains the sample of mortar. The measurements revealed that, for CAIs supplied by manufacturers H and C, the average Chace factor was 2.30 and the uniformity was good, exhibiting standard deviations of 0.05 and 0.03, respectively. The CAIs from manufacturer L had an average Chace factor of 1.87, but the variation among the instruments was broad: The standard deviation was 0.46. In fact, one CAI from manufacturer L had a Chace factor of 1.43 (the inside diameter of the stem was relatively small and would produce high stem readings) and another had a Chace factor of 2.51 (the inside diameter was relatively large and would produce low readings). For example, if one used the manufacturer's MCF, which is accurate for a Chace factor of 1.8, a sample of mortar exhibiting an air content of 8.0 percent when checked with the CAI that had the Chace factor of 1.43 would provide an air content of 4.5 percent when checked with the CAI that had the Chace factor of 2.51. It is interesting to note that the American Association of State Highway and Transportation Officials (AASHTO) requires the CAI to be manufactured so that the Chace factor is 2.2. The CAIs from manufacturers H and C are in reasonable compliance with the AASHTO specification (AASHTO T199-72).

Figure 1. Air content determined by pressure method versus mortar-corrected CAI air content based on manufacturer's recommended mortar correction.

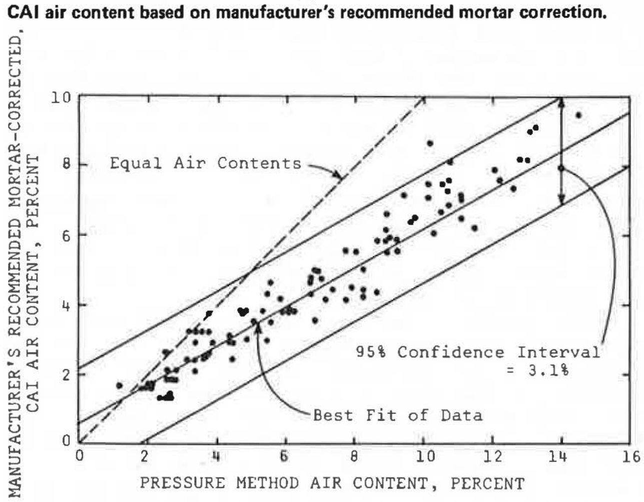
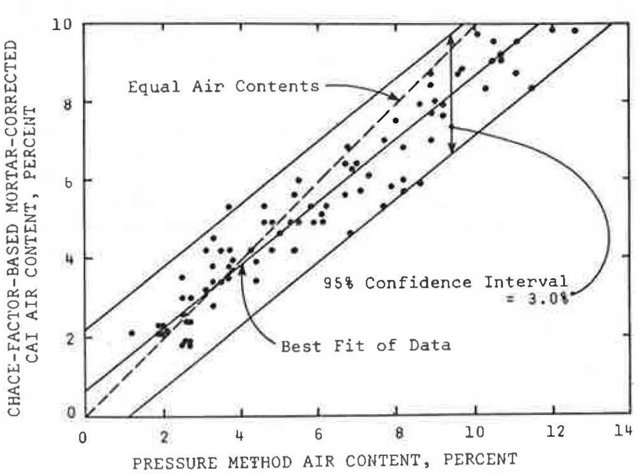


Table 1. Mortar correction factors.

Mortar Content by Volume		Chace Factor[a]				
Amount (ft^3/yd^3)	Percent	1.6	1.8[b]	2.0	2.2	2.4
27	100	1.60	1.80	2.00	2.20	2.40
20	74	1.19	1.33	1.48	1.63	1.78
19	70	1.13	1.27	1.41	1.55	1.69
18	67	1.07	1.20	1.33	1.47	1.60
17	63	1.01	1.13	1.26	1.39	1.51
16	59	0.95	1.07	1.19	1.30	1.42
15	56	0.89	1.00	1.11	1.22	1.33
14	52	0.83	0.93	1.04	1.14	1.24
13	48	0.77	0.87	0.96	1.06	1.16
12	44	0.71	0.80	0.89	0.98	1.07
11	41	0.65	0.73	0.81	0.90	0.98
10	37	0.59	0.67	0.74	0.81	0.89

[a]Volume of one graduation on stem as a percentage of the volume of the bowl.
[b]Factors supplied by the manufacturers.

Figure 2. Air content determined by pressure method versus Chace-factor-based mortar-corrected CAI air content.



The MCFs given in Table 1 were tabulated for use with the typical range of Chace factors. Reading from the left column, on the first line of Table 1 it can be seen that, for a Chace factor of 1.8 and a mortar content of 100 percent by volume (27 ft^3/yd^3), the stem reading is multiplied by 1.8 to get the volume of air. On the seventh line it can be seen that, if the concrete has a mortar content of 56 percent by volume (15 ft^3/yd^3), the air content is read directly since the MCF is 1.0.

The relation shown in Figure 2 is the result of the modification of the stem readings by applying the MCFs to take into account the particular Chace factors of the CAIs used to produce the data. It can be seen in Figure 2 that, once the Chace-factor-based MCFs were applied to the stem readings, there was fairly good agreement between the air contents determined by the CAI and the pressure method, and there was a magnitude of improvement in comparison with the relation shown in Figure 1, which is based on the manufacturer's MCFs.

Curve Correction

The dashed line in Figure 2 is the line of equality, and it can be seen that, even after the Chace-factor-based MCFs are applied, the CAI reads slightly high at low air contents and low at high air contents. The application of another correction, designated "curve correction", improves the agreement between the air contents determined by the CAI and the pressure method. For example, if the Chace-factor-based mortar-corrected air content of an unscreened sample is 8 percent, the curve correction is 1 percent and the actual air content is 9 percent. The curve correction for each Chace-factor-based mortar-corrected CAI air content was determined by subtracting this air content from the pressure-method air content as determined from the equation for the line representing the best fit of the data in Figure 2 by using the data from the CAIs as the independent variable. The equation is

$$PM = (SR)(CF)(MC)(1.164)/27 - 0.308 \quad (1)$$

where

PM = air content determined by pressure method (%),
SR = stem reading, and
MC = mortar content (ft^3/yd^3).

A similar equation for the line representing the best fit of the data for screened samples is

$$PM = (SR)(CF)(MC)(1.138)/27 - 0.869 \quad (2)$$

It is interesting to note that curve corrections based on these two equations are similar to ones reported by the Virginia Highway and Transportation Research Council, the Federal Highway Administration, and the U.S. Army Corps of Engineers in studies made 20 years ago (3).

As can be seen in Figure 3, once the Chace-factor-based MCFs and the curve corrections are applied, the air content determined by the CAI agrees with that determined by the pressure method. Because of the inherent variability of concrete and the small size of the sample used with the CAI, for one operator the standard deviation for the average air content for two unscreened samples, compared with the air content determined by the pressure method, is 0.97 percent. The standard deviation for two screened samples is 1.08 percent, which is 11.0 percent greater than for unscreened samples. Therefore, screening should be avoided if the samples can be obtained without it. A generally accepted standard deviation for a pressure test is 0.6 percent; therefore, the average CAI air content of five unscreened samples provides a confidence level equal to that provided by one pressure test.

Figure 3. Air content determined by pressure method versus Chace-factor-based mortar-corrected and curve-corrected CAI air content.

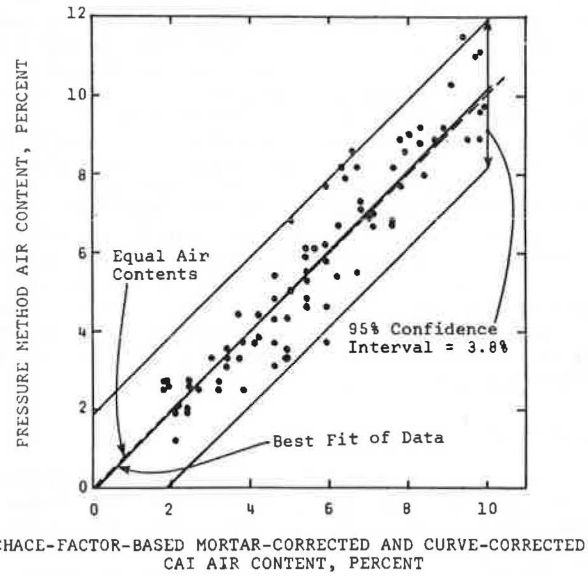
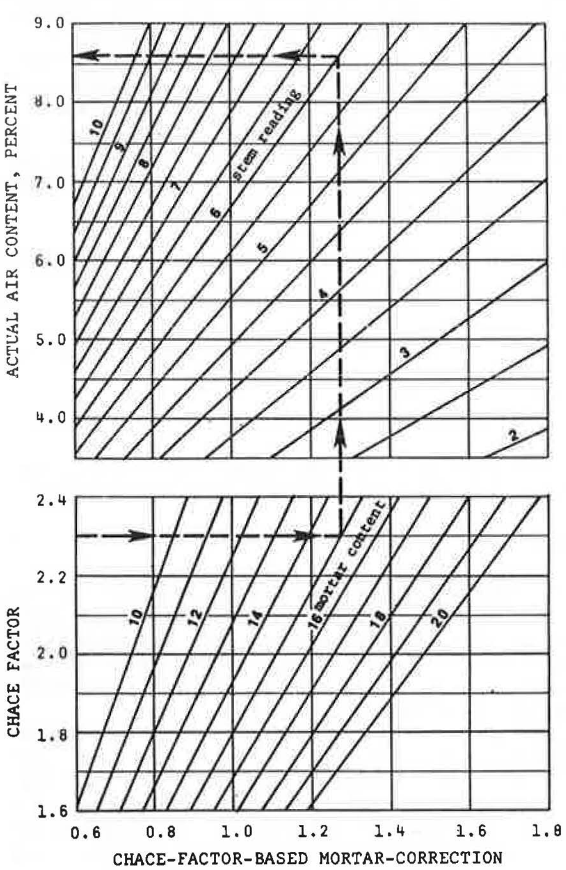


Figure 4. Chace conversion nomograph.



IMPLEMENTATION OF RESULTS

The Virginia Department of Highways and Transportation currently determines the Chace factor of each CAI and furnishes field personnel with CAIs inscribed with the Chace factors. The Chace factor for a CAI can be determined in a few minutes with a 1-mL syringe, such as an insulin syringe, by noting the quantity of alcohol injected into 10 graduations on the stem. Although the volume of the metal cup should not be overlooked, the cups have typically been found to be reasonably uniform in size. The stems tend to vary in size because they consist of drawn glass tubing that is difficult to control in the manufacturing process.

Field personnel are also supplied with the Chace conversion nomograph shown in Figure 4 (1), which allows them to determine the air content without multiplying the stem reading by the Chace-factor-based MCF and without adding the curve correction. As an example of how to use the nomograph, assume that the indicator has a Chace factor of 2.3, the concrete has a mortar content of 56 percent by volume (15 ft^3/yd^3), and the stem reading is 6.0 percent; then the actual air content would be 8.6 percent (Figure 4). If one used the MCF supplied by the manufacturer, the stem reading of 6.0 percent would be reported for the air content, which is 2.6 percent less than the actual air content and represents an error of 30 percent.

Test results for the acceptance of concrete are based on the average air content of two samples and, if the results differ by more than 2 percent, a third sample is taken and test results are based on the average of the three samples. Concrete determined to be unacceptable by the CAI is not rejected unless a test with the pressure method confirms that it is unacceptable. The pressure method is used to determine whether concrete to be placed in bridge decks meets Department specifications. The current practice allows the Department to minimize the work load on the inspector and at the same time to have an acceptable level of assurance regarding the air content of the concrete.

CONCLUSIONS

1. The CAI can be used to provide a reasonably accurate indication of the air content of fresh concrete, when results are based on the average of tests of a minimum of two samples and the results are corrected by using a Chace conversion nomograph that takes into account the Chace factor, curve correction, and MCF.

2. A test result based on the average Chace-factor-based mortar-corrected and curve-corrected CAI air contents of five samples typically provides the same confidence as one pressure test result.

3. AASHTO T199-72 should be revised to incorporate the findings of this study (the revisions will be in the 1982 edition).

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Publication of this paper sponsored by Committee on Batching, Mixing, Placing, and Curing of Concrete.