Evaluation of Chace Air Indicator

RICHARD G. HENLEY, DEAN MALKEMUS, DAVID W. FOWLER, and ALVIN H. MEYER

ABSTRACT

An evaluation of the Chace Air Indicator (CAI) was made for use in portland cement concrete construction. The CAI indicated higher values than the pressure method at low air content and lower values at high air content. The CAI readings corrected for mortar content and Chace factors produced values approximately 15 percent higher than the pressure method over all ranges of air content. A regression analysis procedure was used to determine a curve correction to account for the difference between the Chace factor- and mortar-corrected CAI readings and those of the pressure meter. An indication of the reliability of the results was represented by confidence intervals. The CAI does not have sufficient accuracy to measure the air content of concrete for job control purposes.

An investigation of the use of the Chace Air Indicator (CAI) in determining the amount of entrained air in structural portland cement concrete (PCC) is described. The objectives of the investigation are the following:

1. To determine the calibration and correlation requirements for the CAI,
2. To identify the limits or tolerances for the use of the CAI either for job control or as an indicator as it is now used, and
3. To determine whether the CAI can measure the amount of entrained air with sufficient accuracy for job control purposes.

For purposes of this study, job control is defined as "the measurement of the air content of PCC with equal accuracy to that measured by a pressure meter."

The study consisted of a laboratory and a field phase. The laboratory phase permitted the study of many mix design variables under controlled conditions (1). The field phase allowed for testing to establish the effect of normal variations encountered in field operations. The field phase of the study is presented in this paper.

PREVIOUS STUDIES

Bureau of Public Roads, 1957

The Bureau of Public Roads study (2) found the CAI to be useful in determining the approximate amount of entrained air in PCC in the field.

The major conclusions were as follows:

1. The CAI yielded low readings for air content above 6 percent and high readings for air content below 3 percent.
2. Because of the small amount of mortar used in a test, at least three readings should be made for each air-content determination.
3. The CAI is not considered a suitable replacement for the pressure method but is a useful supplementary test.
4. The CAI appears to be most valuable for use in determining uniformity from one batch of concrete to the next when there is no change in the mix design or materials.
5. The CAI can also be used as a rapid check to determine whether the air content is within specification limits.

Virginia Council of Highway Investigation and Research, 1960

A study by the Virginia Council of Highway Investigation and Research (3) compared CAI test results with the results of conventional pressure methods. Data from over 800 field tests were statistically analyzed and compared with results of previous laboratory research. The results of this study were in agreement with previous work and gave a field verification of the laboratory data available at that time.

The principal conclusions of this study were as follows:

1. A mortar correction based on the mortar content of the mix was recommended to account for the fact that only a mortar sample is used in the CAI test as opposed to use of a concrete sample in the pressure method.
2. A curve correction was also recommended to account for the high readings by the CAI for low air content and the low readings for high air content.
3. The CAI was found to be reasonably accurate and moderately precise for the measurement of air content in the field.
4. The accuracy of the CAI is improved with multiple readings.

Texas Highway Department, Materials and Test Division, 1970

The Texas Highway Department (4) investigated the effect of excessive temperature differentials and varying strength concentrations of isopropyl alcohol used with the CAI. This study recommended the following:

1. Seventy percent isopropyl alcohol be used in the CAI,
2. The tests should be performed with care and as rapidly as possible, and

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Department of Civil Engineering, University of Texas at Austin, Austin, Tex. 78712-1076.

3. The alcohol supply should be protected from excessive temperatures to ensure that the alcohol and mortar temperatures will be relatively similar.

Virginia Highway and Transportation Research Council, 1981

The Virginia Highway and Transportation Research Council (5) found poor agreement between the pressure method and the CAI, even after the manufacturer's suggested correction factors had been applied to the CAI readings. The Virginia study revealed that CAI manufacturers do not set strict limits on the tolerances during the fabrication of the instrument; therefore, it was recommended that the Chace factor be determined for all CAIs used for air-content determination. The Chace factor is defined as the volume of one graduation on the stem expressed as a percentage of the volume of the cup. Correction factors were developed for varying Chace factors, varying mortar content, and the high CAI readings for low air content and the low readings for high air content.

The principal conclusions of this study were the following:

1. Varying mortar contents and Chace factors can be corrected for by using the following equation:

$$\text{Mortar correction factor} = [\text{mortar content } (\text{ft}^3/10^3) \times \text{Chace factor}]/27.$$

2. Each CAI should be inscribed with its Chace factor.
3. A test result based on the average Chace-factor-based mortar-corrected and curve-corrected CAI air content for five samples provides the same confidence as is provided by one pressure-method test.
4. CAI readings should be taken as the average of a minimum of two samples.
5. The PCC investigated should be suitable for retrieving representative samples.

As a result of this study, the AASHTO Standard Method of Test for Air Content of Freshly Mixed Concrete by the Chace Indicator (T199-82) was modified to include the following recommended corrections:

1. Test results for the acceptance of concrete will be based on stem readings that have been mortar corrected, Chace-factor corrected, and curve corrected.
2. Test results for the acceptance of concrete will be based on the average of two samples. If the results differ by more than 2 percent, a third sample will be taken and the test results will be based on the average air content of the three samples.
3. Concrete that is determined to be unacceptable by the CAI will not be rejected unless a pressure-method test confirms that the concrete is unacceptable.
4. The pressure-method test will be used to determine whether concrete used in bridge decks meets specifications.

Center for Transportation Research, 1984

The Center for Transportation Research studies (1) represent the laboratory phase of this project. The variables were (a) range of slump, (b) range of air content, (c) range of temperature, (d) type of aggregate, (e) type of cement, and (f) type of admixture. The principal conclusions of these studies were the following:

1. Operator and instrument variabilities were negligible.
2. Two types of correction factor should be applied: a Chace-factor and mortar correction and a curve correction.
3. A curve correction of the form $PM = 0.85X_{mc}$ was produced (the y-intercept of the best-fit line being close to zero) where PM is the pressure-meter reading and X_{mc} is the mortar-corrected CAI reading.
4. The correction to be applied was identical if one or more readings per sample were performed on the same batch. The difference was in the confidence interval indicating the reliability of the results. The 95 percent confidence interval decreased from 3.2 to 1.8 percent as the number of readings increased from 1 to 3.
5. It was observed that addition of high range water reducer at high air content resulted in decreasing air content with time as measured by both the CAI and the pressure meter. Air content measured with either device cannot be considered accurate under these circumstances.
6. Comparison of results with previously established corrections indicated a notable improvement. The confidence intervals were reduced and the best-fit line of data became almost identical to the line of equality between the CAI and the pressure meter.

FIELD TEST PROGRAM

Field Test Variables

The descriptions of the variables under investigation in the field phase of the project are presented in the following paragraphs. A summary of the numerical values obtained in the field is given elsewhere (6).

Variations Within Ready-Mix Trucks Loaded to Different Levels

Samples were taken from ready-mix trucks

1. Loaded to capacity (trucks were considered loaded to capacity if they contained more than 6 yd^3 of concrete) and
2. Loaded to half capacity (if a truck contained less than 6 yd^3 of concrete, it was considered loaded to half capacity).

Samples were taken for each condition when the truck began discharging concrete, when it had discharged half the load, and when it was nearly empty.

Variations Between Ready-Mix Trucks

Samples were taken from different ready-mix trucks during large placements. This allowed the variation in CAI readings from truck to truck to be determined.

Day-to-Day Variations

Samples were taken from 10 trucks per day for 3 days at the same job site to enable the variation in CAI readings from day to day to be determined.

Transit Time

For all samples taken in the field the transit time was recorded. Transit time is defined as the interval between the mix truck loading time and the time that the sample was taken. Analyses were performed to determine the effect of the following delivery times: less than 15 min, greater than 15 min and less than 30 min, and greater than 30 min.

Concrete Mix Temperature

The mix temperature was recorded for all samples taken in the field. The variation between CAI readings and pressure-meter readings was determined for the following categories of mix temperatures: less than 60°F, greater than 60°F and less than 80°F, and greater than 80°F.

Ambient Temperature

The ambient temperature at the time of testing was recorded for all samples. The variations between CAI readings and pressure-meter readings were determined for the following categories of ambient temperatures: less than 60°F, greater than 60°F and less than 80°F, and greater than 80°F.

Slump

A slump test was performed on each sample. The variations between CAI readings and pressure-meter readings were determined for the following categories of slump: less than 3 in., equal to or greater than 3 in. and less than 6 in., and equal to or greater than 6 in.

Variability Between CAI Units

Four different CAI units were used in the field testing program to enable the variation between CAI units to be determined.

Variability Between Operators

Two operators did all the field testing and the variation between operators was determined.

Variation in Mortar Content

The mortar content for all samples was determined by using the concrete mix design sheets furnished by the batch plants and district personnel. The variation between the CAI readings and the pressure-meter readings was determined for variable mortar content.

Air Content

The variations between CAI readings and pressure-meter readings were determined for different ranges of air contents. The actual air content of the sample was assumed to be the pressure-meter reading. The categories of air content investigated were less than 4 percent, between 4 and 6 percent, and greater than 6 percent.

Field Test Procedures

The following procedure was performed on each concrete sample taken in the field:

1. A wheelbarrow was used to take the concrete samples from the ready-mix trucks from the beginning, middle, or end of the discharge. Each sample was taken after mixing and water additions were completed. The truck number was recorded.
2. Slump and pressure-meter tests were performed after a thorough mixing of the concrete sample. Concrete temperature and ambient temperature were recorded at this time.
3. Each of the two operators performed three CAI tests on every concrete sample. The samples of mortar were obtained in the following manner: (a) the surface of the concrete in the wheelbarrow was flattened with a trowel; (b) the flattened surface was then vibrated with the trowel to settle the aggregates, and leave the mortar at the surface; and (c) samples were taken from this mortar-rich surface.
4. The times were recorded for truck arrival, sampling of the truck, pressure-meter reading, and each CAI reading.
5. After all sampling was completed at a job site, the concrete batch ticket [supplied by the Texas State Department of Highways and Public Transportation (SDHPT)] was copied for each truck sampled.

Thirty-seven field visits were made, and 232 batches of concrete were sampled. Six CAI readings and one pressure-meter reading were taken on each sample. A total of 1,392 CAI readings and 232 pressure-meter readings were recorded.

DATA ANALYSIS

Statistical Procedures

Determination of the Variation of Field Conditions

The variations between the average of three mortar-corrected CAI readings and the pressure-meter readings for each of the variables outlined earlier were determined by using statistical analysis. The mean, standard deviation, and coefficient of variation (C_v) of the difference between the average of three mortar-corrected CAI readings and the pressure-meter reading were calculated for each variable. The coefficient of variation is defined as the ratio of the standard deviation to the mean and is expressed as a percentage. It is important to note that the coefficient of variation does not represent a percentage of air content but rather a percentage variability, which gives an indication of the variables that affect the accuracy of the CAI readings.

Regression Analysis

The regression analysis procedure used in this study was presented in a companion study (1). A brief outline of the regression procedure follows.

Data Points

Three CAI tests and one pressure-method test were performed on every sample taken in the field. The mortar-corrected CAI readings or average of readings (X_{mc}) and the pressure-meter reading (PM) of a sample represent the data point for that sample.

The regression procedure was performed on each of the following sets of data points:

1. (X_{mc}, PM), where X_{mc} is the first mortar-corrected reading;
2. (X_{mc}, PM), where X_{mc} is the average of the first two CAI readings; and
3. (X_{mc}, PM), where X_{mc} is the average of the three CAI readings.

Best-Fit Straight Line of Field Data

The best-fit straight line of the field data was found by applying a regression analysis to the points (X_{mc}, PM). This best-fit line is

$$Y1 = (a1)\ X_{mc} + b1 \qquad (1)$$

where a1 and b1 are parameters of the line.

Accuracy of Best-Fit Equation

The difference between Y1, as determined by Equation 1, and the pressure-meter readings (PM - Y1) represents the accuracy of Equation 1. A regression was performed on the set of points [Y1, (PMR - Y1)] to determine the value (d) to be added to Y1 to obtain PM. The linear equation evolving from this regression is

$$d = (a2)\ Y1 + b2 \qquad (2)$$

where a2 and b2 are parameters of the line.

Accuracy of the Sum (Y1 + d)

Because the field data were not perfectly linear, it was necessary to determine the accuracy of the sum (Y1 + d) as a representation of PM. A regression was performed on the set of points [(Y1 + d), PM]. The result of this regression is

$$Y = (A)\ (Y1 + d) + B \qquad (3)$$

where A and B are parameters of the line.

Air Content Equation

The purpose of this analysis was to find an equation for air content (Y) in terms of the mortar-corrected Chace readings (X_{mc}). This is accomplished by combining Equations 1, 2, and 3. This combination gives the final equation for Y:

$$Y = [A\ (1 + a2)\ a1]\ X_{mc} + [A\ (1 + a2)\ b1 + AB2 + B] \qquad (4)$$

Equation 4 can be expressed in simpler terms as

$$Y = S(X_{mc}) + 1 \qquad (5)$$

where S is A (1 + a2) a1 and I is A (1 + a2) b1 + Ab2 + B.

Confidence Interval

A confidence interval of 95 percent was determined for Equation 5. This confidence interval is denoted by 2k, where k is expressed as a percent of air content and is represented by

$$k = 1.96\ (SD)/(n)^{1/2} \qquad (6)$$

where n is the number of Chace readings used in determining X_{mc} and SD is the standard deviation derived from all (PMR - Y1) values.

Results

Variations in Field Conditions

The values of the coefficients of variation (C_V) between the pressure meter and the average of three mortar-corrected CAI readings for the variables outlined in the preceding section are as follows:

1. Ready-mix trucks loaded to different levels:
   a. Trucks loaded to capacity: C_V = 10.4 percent,
   b. Trucks loaded to half capacity: C_V = 12.5 percent,
   c. Sample from beginning of discharge: C_V = 9.7 percent,
   d. Sample from middle of discharge: C_V = 11.2 percent, and
   e. Sample from end of discharge: C_V = 11.5 percent;
2. Variation between ready-mix trucks: the average coefficient of variation between trucks at the same job site: C_V = 8.7 percent;
3. Day-to-day variations: the average coefficient of variation from day to day at the same job site: C_V = 10.3 percent;
4. Transit time:
   a. Less than 15 min: C_V = 11.5 percent,
   b. Between 15 and 30 min: C_V = 15.3 percent, and
   c. Greater than 30 min: C_V = 16.2 percent;
5. Concrete mix temperature:
   a. Less than 60°F: C_V = 27.2 percent,
   b. Between 60°F and 80°F: C_V = 15.5 percent, and
   c. Greater than 80°F: C_V = 16.9 percent;
6. Ambient temperature:
   a. Less than 60°F: C_V = 23.3 percent,
   b. Between 60°F and 80°F: C_V = 14.2 percent, and
   c. Greater than 80°F: C_V = 14.9 percent;
7. Slump:
   a. Less than 3 in.: C_V = 17.2 percent,
   b. Between 3 and 6 in.: C_V = 12.5 percent, and
   c. Greater than 6 in.: C_V = 13.7 percent;
8. Variability between CAI units:
   a. CAI 2: C_V = 5.2 percent,
   b. CAI 3: C_V = 3.1 percent,
   c. CAI 4: C_V = 4.8 percent, and
   d. CAI 6: C_V = 3.2 percent;
9. Variability between operators:
   a. Henley: C_V = 3.9 percent, and
   b. Malkemus: C_V = 2.5 percent;
10. Variation in mortar content:
    a. Less than 13.0: C_V = 11.5 percent, and
    b. Greater than 13.0: C_V = 15.1 percent;
11. Air content:
    a. Less than 4 percent: C_V = 28.9 percent,
    b. Between 4 and 6 percent: C_V = 20.6 percent, and
    c. Greater than 6 percent: C_V = 18.7 percent.

Regression Analysis Results

Field Study

The results of the regression analysis performed on the field data points are presented in this section. The curve-correction equation for the first-stage regression (using one mortar-corrected CAI reading for each data point) is

$$Y = 0.681X_{mc} + 1.02 \qquad (7)$$

with a 95 percent confidence interval equal to 5.6 percent of air content. Figure 1 is a graphic representation of this equation.

The curve-correction equation for the second-stage

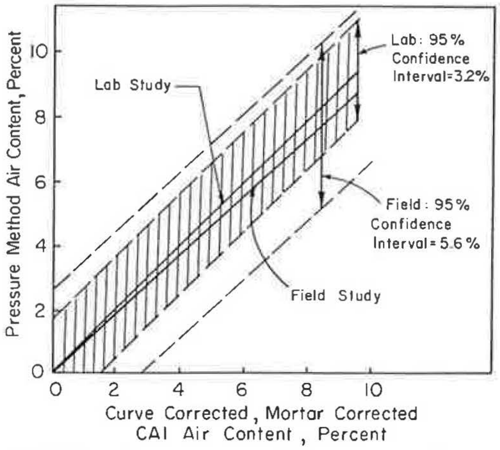

FIGURE 1 Comparison of field curve correction (Equation 7) with laboratory curve correction (Equation 10) (one CAI reading per data point).

regression (using the average of two mortar-corrected CAI readings for each data point) is

$$Y = 0.705X_{mc} + 0.897 \qquad (8)$$

with a 95 percent confidence interval equal to 4.0 percent of air content. Figure 2 is a graphic representation of this equation.

The curve-correction equation for the third-stage regression (using the average of three mortar-corrected CAI readings for each data point) is

$$Y = 0.721X_{mc} + 0.829 \qquad (9)$$

with a 95 percent confidence interval equal to 3.2 percent of air content. Figure 3 shows the results.

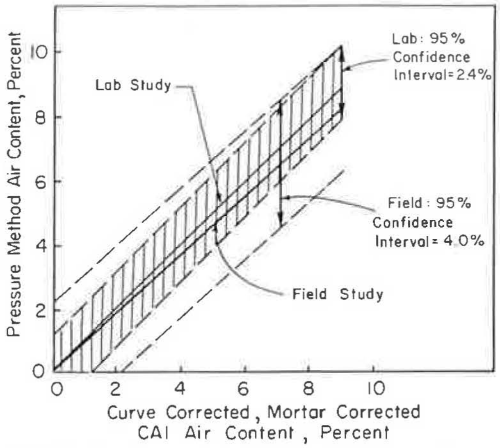

FIGURE 2 Comparison of field curve correction (Equation 8) with laboratory curve correction (Equation 11) (two CAI readings per data point).

Laboratory Study

The results of the regression analysis performed in the laboratory phase (1) are summarized in the following paragraphs.

The curve-correction equation for the first-stage regression is

$$Y = 0.840X_{mc} + 0.068 \qquad (10)$$

with a 95 percent confidence interval equal to 3.2 percent of air content. Figure 1 presents the results of this equation as well as a comparison with Equation 7.

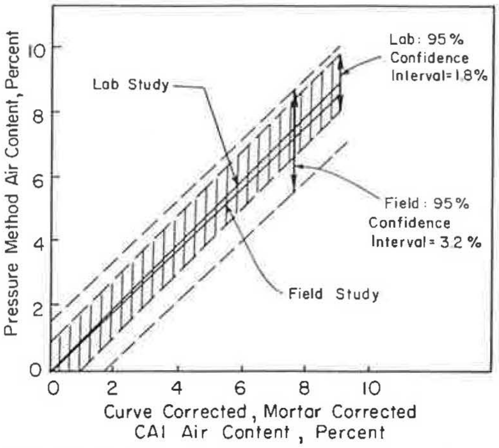

FIGURE 3 Comparison of field curve correction (Equation 9) with laboratory curve correction (Equation 12) (three CAI readings per data point).

The curve-correction equation for the second-stage regression is

$$Y = 0.843X_{mc} + 0.060 \qquad (11)$$

with a 95 percent confidence interval equal to 2.4 percent of air content. Figure 2 is a graphic representation of this equation as well as a comparison with Equation 8.

The curve-correction equation for the third-stage regression is

$$Y = 0.844X_{mc} + 0.064 \qquad (12)$$

with a 95 percent confidence interval equal to 1.8 percent of air content. Figure 3 shows this equation as well as a comparison with Equation 9.

Combined Field and Laboratory Analysis

The regression analysis procedure was applied to the combined laboratory and field data. This analysis was performed because the controlled environment in the laboratory was not a true representation of field conditions and the uncontrolled field environment did not allow for the testing of certain variables, for example, air content greater than 10 percent or ambient temperature less than 40°F.

The curve-correction equation for the first-stage regression is

$$Y = 0.729X_{mc} + 0.534 \qquad (13)$$

with a 95 percent confidence interval equal to 4.8 percent of air content. Figure 4 represents Equation 13 and its corresponding 95 percent confidence interval.

The curve-correction equation for the second-stage regression is

$$Y = 0.780X_{mc} + 0.475 \qquad (14)$$

with a 95 percent confidence interval equal to 3.2 percent of air content. Figure 5 shows Equation 14 and its corresponding 95 percent confidence interval.

The curve-correction equation for the third-stage regression is

$$Y = 0.784X_{mc} + 0.445 \qquad (15)$$

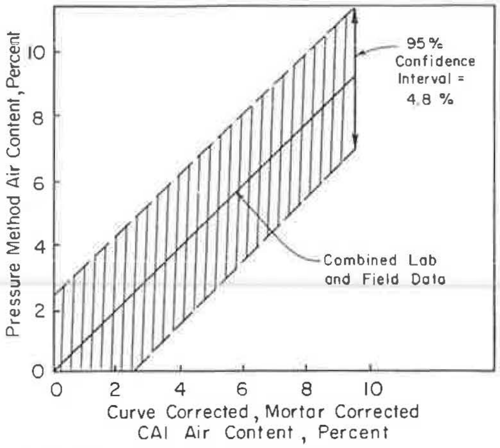

FIGURE 4 Curve correction for combined laboratory and field data (Equation 13) (one CAI reading per data point).

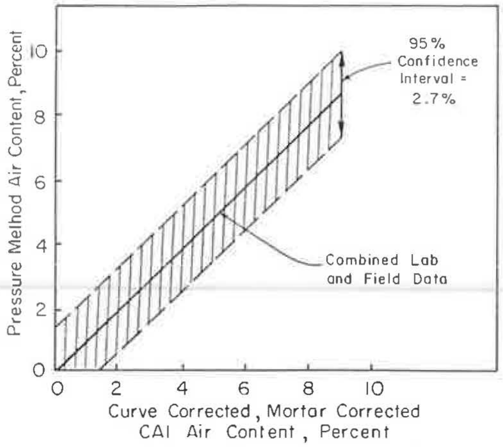

FIGURE 6 Curve correction for combined laboratory and field data (Equation 15) (three CAI readings per data point).

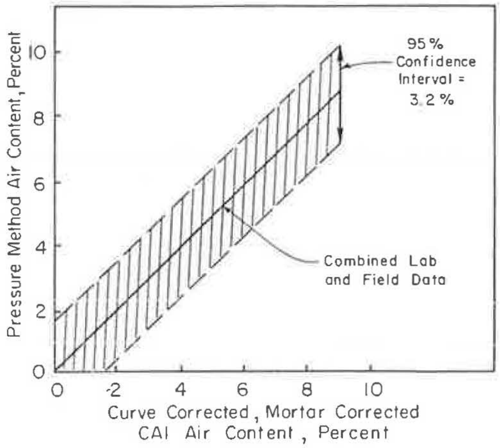

FIGURE 5 Curve correction for combined laboratory and field data (Equation 14) (two CAI readings per data point).

with a 95 percent confidence interval equal to 2.7 percent of air content. Figure 6 represents Equation 15 and its corresponding 95 percent confidence interval.

RECOMMENDED PROCEDURES

Determination of Chace Factor

Manufacturers do not set strict limits on the tolerances during the fabrication of CAIs; therefore, it is necessary to determine the Chace factor for all CAIs to be used in the field. The Chace factor is defined as the volume of one graduation on the stem expressed as a percentage of the volume of the cup. The procedure for determining the Chace factor is as follows:

1. Mercury or a mixture of 50 percent isopropyl alcohol, 50 percent water, and a few drops of liquid detergent should be used.
2. Determine the volume of one graduation on the stem:
   a. Fill the glass indicator with the alcohol mixture about 1/2 in. below the reference line. Insert the rubber stopper and cup into the tube. Invert the CAI and check for air bubbles. Slowly rotate the CAI at approximately a 45-degree angle to release any air bubbles trapped between the cup and stopper or between the glass cylinder and the cup or stopper.
   b. Place the CAI on a level surface.
   c. Fill the stem with the alcohol mixture so that the bottom of the meniscus coincides with the lower mark on the stem.
   d. Using a pipette or syringe graduated to 0.01 ml, measure the volume of alcohol mixture that is required to raise the bottom of the meniscus to the upper mark on the stem.
   e. Divide this volume by the number of graduations on the stem to determine the volume of one graduation (vl).
3. Determine the volume of the brass cup:
   a. Remove the stopper and cup from the tube and dry the brass cup. Make sure the brass cup is clean.
   b. Place the stopper on a level surface. Using a pipette or syringe graduated to 0.01 ml, add the alcohol mixture. Fill the cup until the meniscus levels into a flat plane coinciding with the top edge of the cup. This measurement is the volume of alcohol required to fill the cup (V).
4. Calculate the Chace factor (CF) using the following equation:

$$CF = (vl/V)\ (100) \qquad (16)$$

If the CAI is kept clean, the CF-value will not change as the apparatus ages. A CAI used for over 1,000 readings in this study maintained a constant CF through both the laboratory and field phases. However, if the CAI becomes encrusted with mortar, it should be cleaned or replaced and a new CF calculated.

Every existing and new CAI should be calibrated. The Chace factor should be marked permanently on each instrument.

Determination of Mortar-Corrected CAI Reading

The mortar-corrected CAI reading (X_{mc}) is determined by using the following equation:

$$X_{mc} = [CF\ (MC)/27]\ X_{uav} \qquad (17)$$

where

CF = Chace factor,
MC = mortar content of concrete being tested (ft^3/yd^3), and
X_{uav} = average of one or more uncorrected CAI readings.

To simplify the determination of X_{mc}, it is recommended that the mortar content (MC), as determined by the concrete mix design sheets, be included in the information on the concrete batch ticket delivered by the mix-truck driver to the site inspector.

Determination of Air Content

It is recommended that Equation 15 be used in the determination of air content. This equation was chosen because it is a combination of the laboratory and field study results. Therefore, it should be a reasonable representation of the variables studied in the laboratory and the conditions encountered in the field.

The air content of a sample is determined by applying the following equation:

$$Y = 0.784X_{mc} + 0.445 \qquad (18)$$

where Y is the air content (percent) and X_{mc} is the mortar-corrected CAI reading. The 95 percent confidence interval of 2.7 percent implies that there is a 95 percent probability that the value of the actual air content is between the values of (Y - 1.4) and (Y + 1.4). A 90 percent confidence interval was also computed and is equal to 2.3 percent.

A graphical determination of the air content is also possible. Equation 18 is plotted against a vertical axis representing air content (Y) and a horizontal axis representing mortar-corrected Chace readings. The graph is entered with a mortar-corrected CAI value and a line is projected vertically until the curve for Equation 18 is intersected. The line is then projected horizontally to the vertical axis and the value for air content is determined.

A sample air-content determination using a graphical procedure is given in Figures 7 and 8. Figure 7 shows the 95 percent confidence interval and Figure 8 a 90 percent confidence interval. It is assumed that a mortar-corrected CAI reading of 8.0 was computed. The line projected vertically and horizontally reveals an estimated air content of 6.7 percent. Considering a 95 percent confidence interval, the air content should be in the range from 5.3 percent to 8.1 percent. If a 90 percent confidence interval is preferred, the range of air content is 5.6 to 7.9 percent.

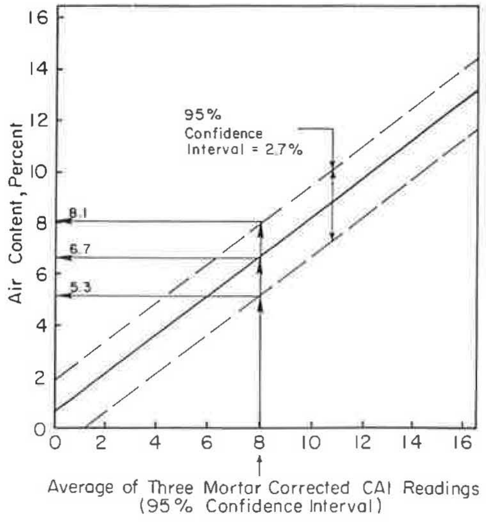

FIGURE 7 Graphical determination of air content: three CAI readings, 95 percent confidence interval.

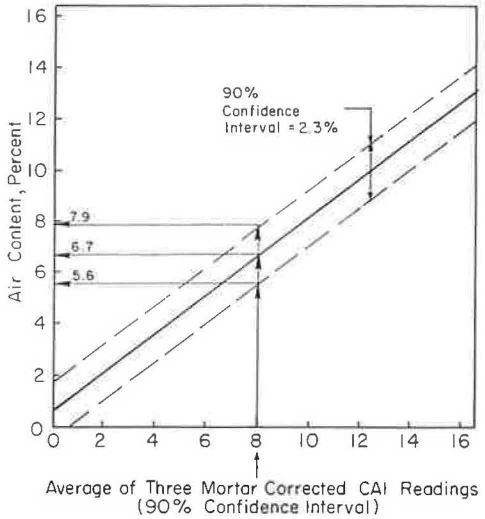

FIGURE 8 Graphical determination of air content: three CAI readings, 90 percent confidence interval.

Air content can also be estimated by using the nomograph in Figure 9. This nomograph accounts for Chace-factor corrections, mortar corrections, and curve corrections. A sample air-content determination is shown on the nomograph. This example assumes a Chace factor of 2.5, a mortar content of 10 ft^3/yd^3, and a CAI reading of 8.5. Given these values, an air content of 6.7 percent is obtained from the nomograph.

SUMMARY AND CONCLUSIONS

Summary

The laboratory phase of the study investigated a wide range of variables, including air-content range, slump range, temperature range, cement type, admixture type, aggregate type, operator variability, and CAI variability (1).

This paper summarizes the field phase of the study (6), which allowed for testing to establish the effect of normal variations encountered in field operations.

Thirty-seven field visits were made and 232 batches of concrete were sampled. Six CAI readings and one pressure-meter reading were taken on each sample. A total of 1,392 CAI readings and 232 pressure-meter readings were recorded.

CAI readings were corrected for mortar content and Chace factor as suggested in a previous study (3). A curve correction was determined by using a regression analysis procedure. Three separate regression analyses were performed to determine curve corrections for the first of three CAI readings, an average of two CAI readings, and an average of three CAI readings.

The results of the field phase were comparable with the laboratory results. The data from the field

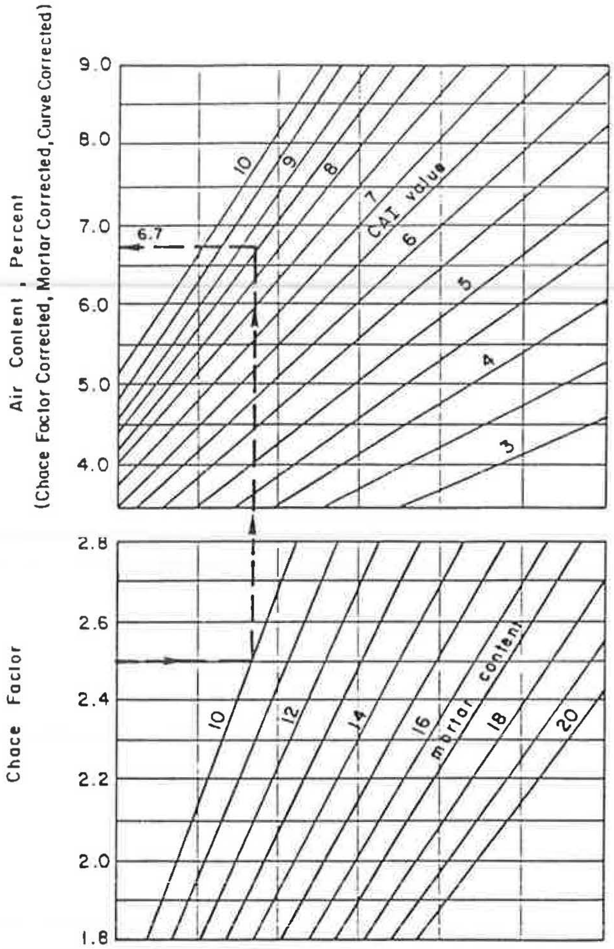

FIGURE 9 Chace-factor conversion nomograph.

and laboratory were combined, and a new curve correction was determined. This curve correction is the recommended equation for air-content determination. Recommended modifications to the CAI test procedure were developed to improve the accuracy of the instrument.

It should be noted that the SDHPT tolerance and the CAI confidence interval preclude the use of the CAI for actual air-content estimation. The SDHPT tolerance for air content of fresh concrete is ±1.5 percent. The 95 percent confidence interval for the average of three Chace-factor and mortar-corrected and curve-corrected CAI readings is 2.7 percent or ±1.4 percent. The difference of ±0.1 percent between the tolerance and confidence interval is not large enough to justify the use of the CAI for the estimation of actual air content.

Conclusions

1. Instrument and operator variability after training were not significant.
2. Recommended modifications to the test procedure improved the precision and accuracy of results.
3. If the recommended procedure for performing a CAI test is followed, the CAI can be used in the field to provide an indication of the range (high, medium, or low) of air content of fresh concrete.
4. The 95 percent confidence interval decreased from 4.8 to 2.7 percent as the number of CAI readings increased from one to three.
5. If the Chace factor of an instrument has been determined, there is no need for daily correlation with the pressure meter.
6. With the present SDHPT tolerances for air content of ±1.5 percent, the CAI is not sufficiently accurate to measure the air content of concrete for job control purposes.

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