A Field Investigation of the AE-55 Air Indicator

HOWARD H. NEWLON, JR., Highway Research Engineer, Virginia Council of Highway Investigation and Research, Charlottesville

The results of a statewide experiment to compare the AE-55 air indicator for concrete with conventional pressure methods are presented. The data from 835 comparative tests with various materials and operators are statistically analyzed and compared with results of limited laboratory studies previously given by Grieb and Mather (HRB Bull. 176). The results of the present study are in agreement with previous work and give a field verification of laboratory data.

From the comparison some estimate of the reliability can be made, as well as the effect of using an unscreened sample. As a result of this study the indicator is being supplied to inspectors for use in control of air in concrete.

●THE rapid determination of the properties of concrete and concrete materials has received increased attention in recent years as evidenced by the development of such items and procedures as the Kelly ball penetrometer for determining consistency, the impact hammer for estimating strength, and the quick chemical test for alkali reactivity of aggregates. A method to replace the sometimes laborious procedure for determining air content of concrete has recently received attention as a result of the patenting of a relatively simple device, designated the Chace AE-55 Air Indicator, which uses the principle of volumetric displacement of entrained air from a small mortar sample.

The method was developed to afford a means of air content determination which, although somewhat less precise than more conventional methods, would enable an inspector to perform more tests and thus exercise closer control of concrete uniformity. Because of its simple design, the AE-55 is less susceptible to mechanical difficulties than is more conventional equipment although it is susceptible to breakage. The method is not intended to replace pressure, volumetric, or gravimetric methods for laboratory determinations, but rather to serve as an aid in field control. Its small size, low cost, and convenience have caused favorable comment concerning its use.

The indicator which is composed of two sections, is shown in Figure 1. One part is a glass cylinder similar to a filtration crucible holder. This cylinder is about 1 in. in diameter and 3 in. long and tapers to a stem ¼ in. in diameter and 3 in. long. This stem is marked by 11 equally spaced graduations. The second part of the indicator is a brass cup approximately ¾ in. in diameter by ½ in. deep. This cup is attached to a rubber stopper which fits into the glass cylinder. Either of two types may be supplied by the manufacturer. As shown in Figure 2, the more recent type, designated "B" and shown in the lower part of the figure, has a ground fluted end, whereas the older type "A" has a plain end.

A determination of air content may be made in approximately 2 to 3 min. using about 3.7 ml of mortar from the concrete mix. The test procedure consists of securing a sample of mortar from the mix and rejecting material retained on a No. 10 mesh sieve. Many times in actual practice this screening is omitted and the sampling consists of working excess mortar to the surface and removing it with the fingers or a small trowel,

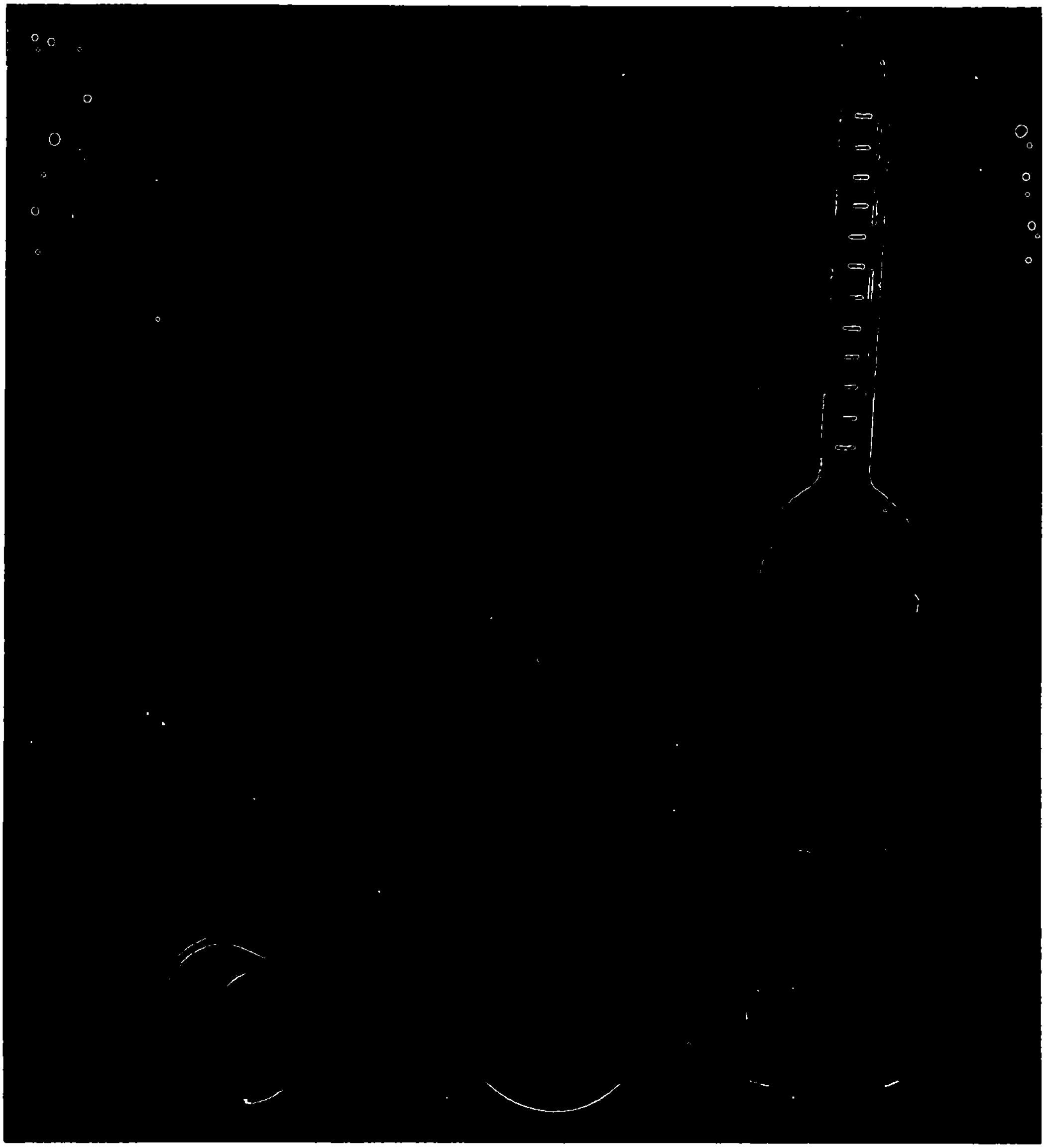

Figure 1. Chace AE-55 air indicator.

rejecting any obviously large particles. The brass cup is filled with this material and rodded with a small wire (normally a paper clip). The mortar is struck off and the cup placed in the glass tube which has previously been filled to the designated level with alcohol. The device is then gently agitated to remove entrained air and the difference in alcohol level is recorded in terms of number of spaces. Based on the mortar content of the concrete mix, a correction factor is applied to the reading to obtain the air content of the mix. The complete test procedure and correction factors supplied by the manufacturer are contained in the Appendix.

For several years the indicator has been given limited use by inspectors and materials engineers on various projects throughout Virginia as well as in other states. While little quantitative data are available, the reaction to the indicator generally has been favorable.

Published data concerning comparisons of the AE-55 indicator with other methods are not extensive. In 1956, Grieb reported a study of the accuracy of the AE-55 conducted in the laboratory of the Bureau of Public Roads (1). The test series consisted of determining the air content of 84 different laboratory concrete mixes by means of pressure and gravimetric methods and comparing the results with those obtained with the AE-55 indicator. These mixes utilized different cements and aggregates, and air contents ranging from 1 to 9 percent as recorded by the pressure method. The values obtained with the AE-55 indicator by two different operators were in good agreement with those obtained by means of the pressure method for air contents between 3 and 7 percent. For values of air content less than 3.0 percent as determined by the pressure meter, the AE-55 gave results averaging about 1.0 percentage point high. For air contents of more than 6.0 percent the AE-55 indicator gave values averaging somewhat more than 1.0 percentage point low. Grieb presented a correction curve indicating the amount by which the AE-55 should be corrected to bring the readings into agreement with the pressure values. It should be noted that the samples in these tests were taken without screening and that the mortar correction was not applied to the data.

Figure 2. Available types of AE-55 indicator, type "B" on left.

Tests of 107 batches of concrete were made at the Waterways Experiment Station and reported by Willetts and Kennedy (2). The results of these tests were in substantial agreement with those reported by Grieb with the exception that the differences between the AE-55 and pressure values at high air content were not as large. The samples in this study were screened through a No. 10 sieve.

Early work with the AE-55 used in the concrete laboratory of the Virginia Council of Highway Investigation and Research substantiated the results of both the above studies for air contents between 4 and 7 percent. In these tests different operators made only one determination on an unscreened sample, and it was found that 85 percent of the time the air content as determined with the AE-55 was within ± 0.5 percentage point of the line of average relationship established for the AE-55 and the pressure method (3). Only one determination out of 38 varied by more than one percentage point.

Following the laboratory work the AE-55 was utilized in connection with a study of paving mixers conducted during the summer of 1958 on two different projects, one using type III cement and a gravel aggregate, the other a crushed stone and type II cement (4). Again with different operators making only one determination it was found that the air content determined by the AE-55 was within ± 0.5 percentage point of that obtained by the pressure method 84 percent of the time based on the distance of the readings from the line of average relationship. All of the 32 determinations were within 1 percent of the average line.

The general agreement of the results of these preliminary investigations with those of previous studies was encouraging, but it was felt that sufficient data were not available to warrant conclusions regarding the reliability of the device. It appeared from a study of the results that the mortar correction supplied by the manufacturer might not be as important for unscreened samples as a correction related to the percentage of air observed with the AE-55.

To investigate further the reliability of the AE-55 indicator an experiment was designed to provide for a statewide test of the device by the personnel normally charged with the responsibility for determining air content. It was felt that such a coordinated test would result in a quick and definitive evaluation of the device and its possible application for highway use under various conditions. For accomplishing this evaluation a study was conducted cooperatively by the Field Forces of the Virginia Department of Highways and personnel of the Virginia Council of Highway Investigation and Research.

The purposes of this study were:

1. To evaluate the AE-55 air indicator as a field device for the determination of the air content of structural and paving concrete mixes.
2. To compare the AE-55 indicator with conventional pressure methods.
3. To investigate any correction factors which might be necessary to make the AE-55 determinations consistent with pressure meter readings.

TEST PROGRAM

Many practical considerations affected the design of the test because it was desired that it be conducted in connection with normal concreting operations and with a minimum of interruptions thereto. Variations due to operator error, materials, and biases of various kinds could not be practically eliminated but a study of the results indicates that these items did not affect the over-all reliability of the data in any significant degree.

While data were secured from several sources simultaneously, for ease of presentation the study is divided into two parts. Series I is a laboratory investigation of the AE-55 indicator. This study was conducted in connection with other laboratory projects in that the air contents of test batches were determined by means of the AE-55 and pressure methods. Since the mixes tested were not designed to have extreme air contents, the range of air contents was rather small, 3.0 to 7.6 as measured by the pressure method. For each batch tested, two determinations of the air content were made with the pressure meter as required by ASTM C231-56T, while one determination was made with the AE-55. Various operators were utilized during the testing program. The aggregate used in the concrete mixes was not changed and seven brands of type II cement were employed. One hundred and three batches were sampled.

Series II consisted of the studies on regular construction projects conducted cooperatively by Field and Research personnel. Tests were performed in connection with normal construction operations by the inspector assigned to the job, following a uniform procedure, while utilizing his normal schedule and equipment, that is, the meter currently in use was employed in addition to the AE-55. The pressure meters employed were calibrated prior to their use in the testing program.

From the batches designated for test, two samples were secured. On each sample, a pressure meter was used to make two determinations of air content in accordance with ASTM C231-56T, while two determinations were also made with the AE-55 indicators. This procedure was repeated until 40 samples had been tested, giving 80 comparative determinations.

On certain projects it was necessary that more than one operator perform the determinations. While the variation due to operators was not considered a variable in the design of the experiment it is possible from the data to evaluate certain operator differences for specific jobs.

A summary of the pertinent information concerning each project in Series I and II is given in Table 1. Throughout the report reference is made to the projects by numbers. It will be noted that projects one through nine involved a large number of samples and are referred to as major projects. Projects 10 through 13 were minor projects on which it was not possible to run a complete set of tests. Project nine includes all work done in Series I.

ANALYSIS

The data obtained from the comparative trials in Series I and II were analyzed by accepted statistical procedures. A regression analysis was performed on the uncorrected data from each individual project and for all of the projects considered as a whole. A linear regression was used since preliminary tests showed that a curvilinear regression was not necessary.

TABLE 1

DESCRIPTIVE DATA FOR TEST PROJECTS

No	Date of Tests	No. of Tests	Type of Meter (age)	Operators	Mortar Content Cu Ft/Cu Yd	Type CA	Type FA	Range of Air Content (%)
1	4-1-59 4-8-59	80	Protex (1)	3	14	C. S	N S. [1]	2.2-5.8
2	5-19-59 7-28-59	80	Protex (new)	1	15	C. S.	S. S. [2]	4.6-7 7
3	5-20-59 7-7-59	80	Protex (new)	5	15	C. S.	S S	3 0-5 8
4	6-3-59 6-15-59	80	Protex (1)	3	14	Gr	N S	3 6-5 9
5	5-15-59 5-20-59	80	Washington (5)	3	15	Gr	N S.	3.2-4 6
6	5-23-59 7-14-59	80	Protex (1)	4	15	C. S	N. S.	3.2-5.9
7	9-24-59 9-25-59	72	Washington (8)	2	14	Gr	N S	0 5-7.0
8	7-14-59 11-2-59	80	Protex (1)	5	14	C S.	N S	3 0-7.0
9	3-19-58 Present	103	Protex (1)	3	13	Gr	N S.	3.0-7 6
10	5-22-59 8-6-59	48	Protex (?)	4	14	C. S	N S.	3 0-5.8
11	6-19-59 7-23-59	18	Protex (new)	1	14	C. S.	N. S.	3.2-4.7
12	10-1-59 Present	14	Protex (?)	2	15	C. S	S S	2.3-5.6
13	5-19-59 6-25-59	20	Protex (2)	1	15	Gr.	N. S.	3.2-4 7

[1]Natural sand
[2]Stone sand

A correction similar to that of Grieb (1) was prepared from the uncorrected data, and the data were corrected by means of this curve with and without application of the mortar correction. Similar regression analyses were performed on these data. The uncorrected readings were used since indications are that the mortar correction is not applicable to observations on unscreened samples.

In addition to being used in the regression analyses, the data were grouped by ranges of air content as determined by the pressure method and the deviations of the individual AE-55 readings from those obtained with the pressure meter were determined. From the data the various statistical quantities were computed for both corrected and uncorrected cases which enabled a direct comparison with values of previous investigators.

RESULTS

The results of the regression analysis are shown in Figure 3 in which the line of average relationship is given for the uncorrected data from all projects in Series I and II, along with lines denoting the standard error of estimate. The line of average relationship is expressed by the equation $Y = 0.95 + 0.749X$, in which Y denotes the AE-55 reading and X the corresponding reading obtained by the pressure meter. The area bounded by standard error lines (0.5 percent of air) contains 72.9 percent of the 835 readings while 94.0 percent of the readings are within 2 standard errors (1 percent of air). It should be noted that many of the points represent more than one determination. Also, 72 percent of the readings fall within 0.5 percent of air based on the line of equality, rather than the line of average relationship, and within 1.0 percent 92 percent of the time. The number of extreme points falling above the upper limit was approximately equal to the number falling below the lower limit when considered from the line of average relationship; however, considered from the line of equality, the number falling below was considerably greater than that falling above.

It can be seen that the line of regression indicates that at low air contents the AE-55 tended to give higher readings than the pressure meter while at high air contents the AE-55 generally read lower. The reason for this tendency of the AE-55 to read high at low air contents and low at high air contents is not definitely established but it is felt that the tendency is related to the method of sampling. The meter was intended to be utilized with a screened sample which would be relatively uniform. The taking of the sample without screening is influenced by the consistency of the mix, since mixes of low air content are stiffer than comparable mixes having a higher air content. Samples taken from the latter mixes would have a larger proportion of water and would thus tend to give lower air contents. Samples taken from the stiffer mix would tend to have a higher proportion of solid constituents and thus would be expected to give higher air contents. It is also possible that the rodding of the stiffer mixes did not give consolidation comparable to that for the wetter mixes and resulted in more entrapped air.

The lines of average relationship based on the uncorrected data for the nine major projects are shown in Figure 4. The significant fact to be gained from this plot is that the tendency of the meter to read high at low air contents and low at high contents was found for eight of the nine projects. The consistency of the indications from project to project would indicate that a correction curve could be prepared which would correct the readings to equivalent pressure meter values.

Although certain limitations of the method are apparent, the approach of Grieb was followed by which the AE-55 indications were grouped according to pressure readings as given in Table 2.

The difference in average air content as determined by the AE-55 and the pressure method is plotted as a function of the average pressure reading in Figure 5. For comparison, values obtained by previous investigators are shown. Considering all of the factors which could affect the results, the agreement between the data obtained by the

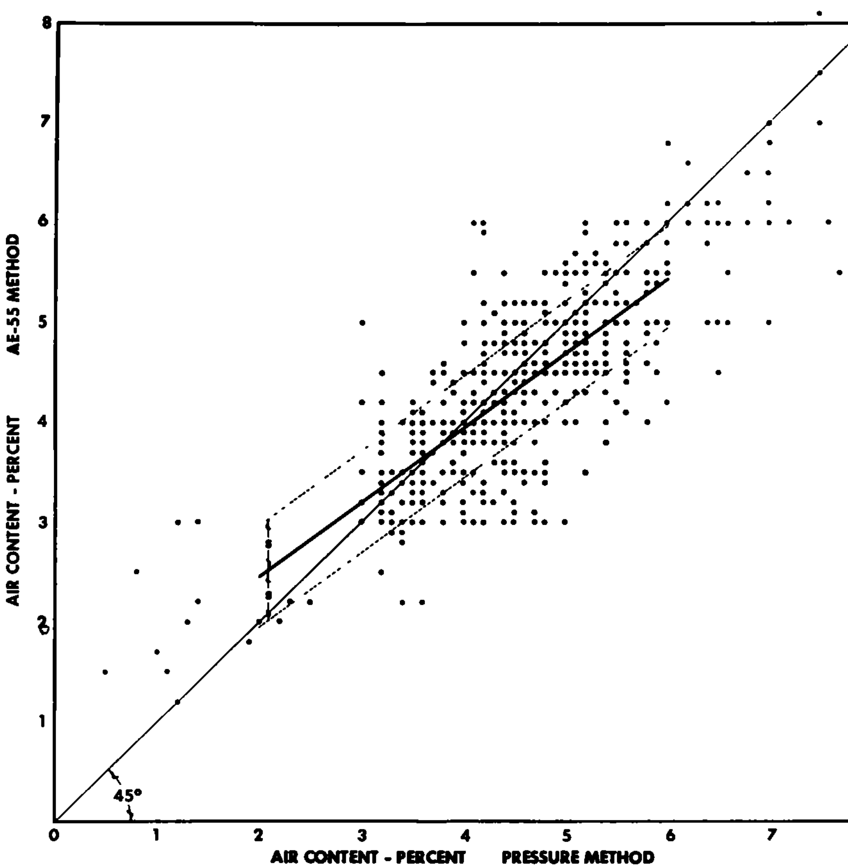

Figure 3. Plot of uncorrected determinations, Series I and II.

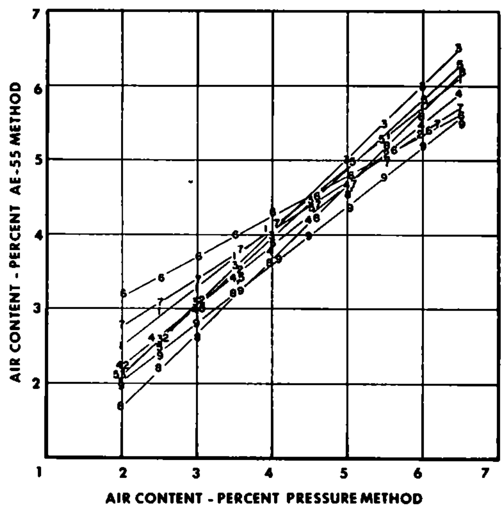

Figure 4. Regression lines from nine major projects, uncorrected data.

TABLE 2

DATA GROUPED BY PRESSURE READINGS

Range (pressure method)	No. of Samples	Average Air Content (%) Pressure Meter	AE-55	Difference	Range of Differences	Std. Dev.
0.0 - 0.9	2	0.6	2.0	+1.4	+1.0 to +1.7	0.495
1.0 - 1.9	9	1.3	2.2	+0.9	-0.1 to +1.8	0.726
2.0 - 2.9	5	2.2	2.1	-0.1	0 to -0.3	0.114
3.0 - 3.9	181	3.5	3.6	+0.1	-0.8 to +2.0	0.305
4.0 - 4.9	328	4.4	4.2	-0.2	-1.8 to +1.9	0.500
5.0 - 5.9	255	5.3	4.9	-0.4	-2.0 to +0.8	0.448
6.0 - 6.9	38	6.2	5.6	-0.6	-2.0 to +0.8	0.638
7.0 - 7.9	17	7.2	6.4	-0.8	-2.2 to +0.6	0.672

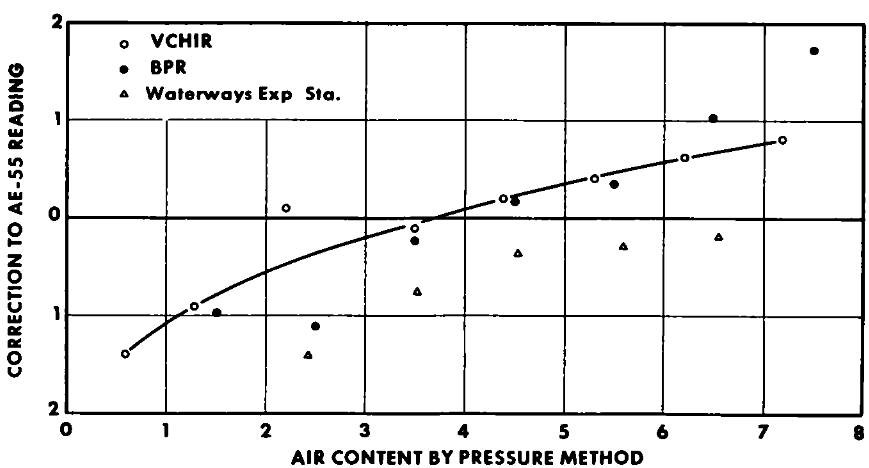

Figure 5. Correction as a function of the pressure method.

different laboratories is striking, especially that between the data from this test and the data from the Bureau of Public Roads test. It should be kept in mind that these two studies were made on unscreened samples. The shape of the curve for the data obtained by Willetts (2) on screened samples is similar but a higher AE-55 air content is indicated as would be expected. The large difference between the values at 2 to 3 percent air is probably a result of an insufficient number of samples. It should be noted that the data from this study represent more samples than do those of previous studies.

The results indicate that the data obtained in independent investigations are compatible and that some correction curve which would allow AE-55 readings to be expressed as equivalent pressure readings might be of value. Figure 6 contains the correction necessary to cause agreement between the AE-55 and pressure readings plotted as a function of the AE-55 indications. Again the readings of previous investigators are shown for comparison. As stated previously, the correction curve for this study is in substantial agreement with that of the BPR study. While the number of data points are limited it will be noted that the WES study, which involved a screened sample, does not show the same trend. It is probable that the WES data would be corrected best by a constant factor.

A curve of best fit was constructed through the points and the corrections indicated by this curve were applied to the data both uncorrected and after application of the mortar correction. The regression lines obtained from the data in Series I and II for the four conditions are shown in Figure 7 along with values for the coefficient of correlation and standard error of estimate. It will be noted that the application of the curve correction did not affect the degree of correlation significantly but reduced the precision as measured by the error of estimate. It would appear that the uncorrected data gave a better measure of air content than attempts at correction for the projects considered as a whole.

The coefficients of correlation, r, and standard errors of estimate, s, for each project are given in Table 3. In the cases where values are not given the mortar content of the mix was 15.0 cu ft/yd and the mortar correction was not applicable. A study of the results from the major projects of Series I and II given in Table 3 will show that the degree of correlation was reasonably constant among projects with the exception of project six on which the coefficient of correlation was 0.58. The data from this project were studied carefully and it was determined that the total number of tests was divided among several operators. When 40 tests conducted by one operator were considered, it was found that his data showed a correlation coefficient of 0.85 and a standard error of 0.24. The results obtained by the other operators showed a lower coefficient.

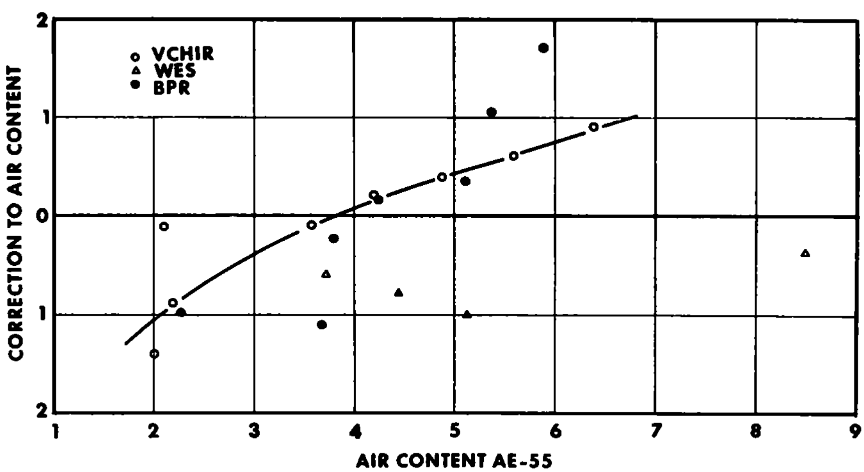

Figure 6. Correction as a function of the AE-55.

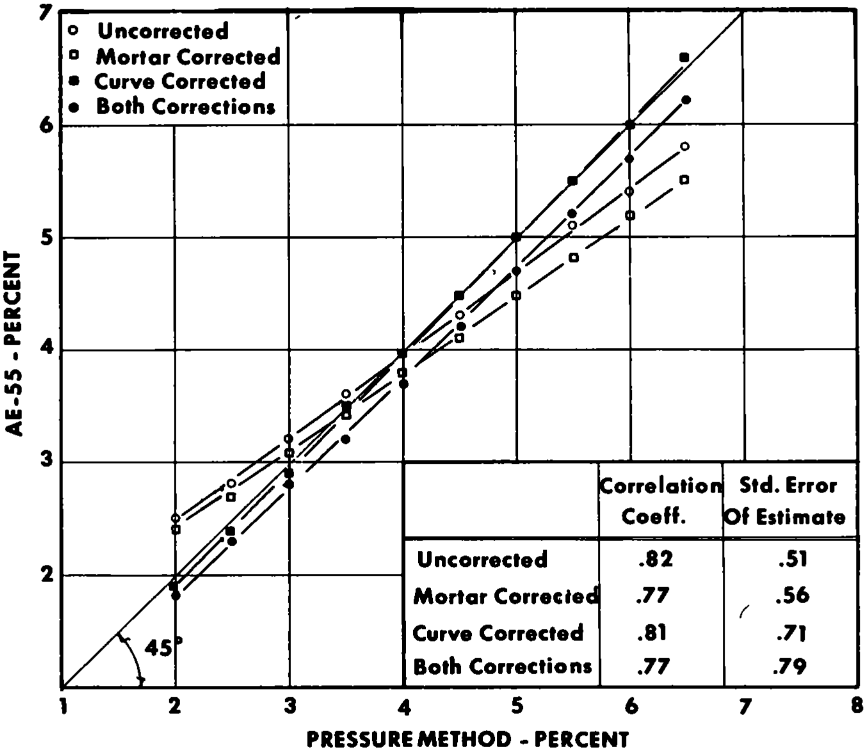

Figure 7. Regression lines from all projects, Series I and II.

TABLE 3

RESULTS OF ANALYSES—SINGLE OBSERVATION

Project	No. of Samples	Uncorrected r	Uncorrected s	Mortar Corrected r	Mortar Corrected s	Curve Corrected r	Curve Corrected s	Both r	Both s
1	80	0.78	0.50	0.78	0.45	0.79	0.71	0.79	0.67
2	80	0.85	0.31	-	-	0.93	0.29	-	-
3	80	0.92	0.29	-	-	0.91	0.41	-	-
4	80	0.69	0.47	0.69	0.44	0.62	0.71	0.69	0.62
5	80	0.89	0.17	-	-	0.72	0.38	-	-
6	80	0.58	0.47	-	-	0.59	0.64	-	-
7	72	0.88	0.67	0.74	0.88	0.88	0.97	0.89	0.90
8	80	0.78	0.59	0.78	0.56	0.78	0.82	0.78	0.77
9	103	0.74	0.61	0.72	0.62	0.73	0.86	0.72	0.89
10	48	0.85	0.39	0.85	0.36	0.85	0.54	0.81	0.60
11	18	0.93	0.18	0.95	0.17	0.93	0.27	0.93	0.26
12	14	0.89	0.55	-	-	0.92	0.66	-	-
13	20	0.59	0.33	-	-	0.58	0.48	-	-
1-13	835	0.82	0.51	0.77	0.56	0.81	0.71	0.77	0.79
1- 9	735	0.80	0.52	0.76	0.57	0.80	0.73	0.76	0.81
1- 8	632	0.83	0.48	0.81	0.50	0.83	0.67	0.80	0.70

Similar analyses of the other projects showed no such variation among operators since apparently the techniques utilized by the various operators were the same.

While no specific operator variable was included in the experiment, the consistency of the data among projects would seem to indicate that the effect of operator variations is not great. It was obvious during the study that a certain amount of technique was necessary in using the AE-55; however, it was observed that once an operator got a feel for the device, through comparative readings with a pressure meter, his accuracy improved. There is no reason to believe that the differences among operators will be great provided an established procedure is followed carefully.

It will also be noted from Table 3 that the mortar correction had little effect on the correlation coefficient as would be expected. The precision as measured by the standard error of estimate was improved slightly in five of the seven cases. However, in only one case did the application of the mortar correction change the standard error by as much as 0.1 percent of air, and this was an adverse change.

It would be expected that samples taken without screening would be less uniform than screened samples and so more variation in the readings would be expected. Because the mortar correction is intended to correct for the fact that larger particles are not included in the sample, it would follow that the tendency for large particles to be included in the unscreened sample would make application of the mortar correction questionable. It appears that the mortar correction supplied by the manufacturer is not applicable for unscreened samples.

The correction made by using the curve shown in Figure 6 also resulted in little change in the accuracy as measured by the correlation coefficient. Furthermore, the precision was increased only slightly in one case and was significantly reduced in many. Based on the average air contents given in Table 5, the correction was beneficial in five of the eight cases. The application of both corrections reflected the effect of each

TABLE 4

RESULTS OF ANALYSES OF DATA—AVERAGE OF TWO OBSERVATIONS

Project	No. of Samples	Uncorrected		Mortar Corrected		Curve Corrected		Both	
		r	s	r	s	r	s	r	s
1	40	0.81	0.48	0.83	0.55	0.82	0.66	0.81	0.63
2	40	0.92	0.23	-	-	0.91	0.30	-	-
3	40	0.95	0.24	-	-	0.94	0.33	-	-
4	40	0.76	0.40	0.74	0.39	0.73	0.58	0.75	0.53
5	40	0.93	0.14	-	-	0.94	0.18	-	-
6	40	0.63	0.43	-	-	0.64	0.57	-	-
7	36	0.89	0.65	0.89	0.58	0.89	0.91	0.89	0.90
8	40	0.80	0.57	0.81	0.57	0.80	0.80	0.82	0.58
1-8	316	0.85	0.45	0.83	0.46	0.86	0.61	0.82	0.63

individual one. This does not mean that such corrections are not necessary. To the contrary, the consistency of the trends shown in Figures 4 and 5 would indicate the desirability of such corrections. It is felt that the curve shown in Figure 6 needs modification at the extreme values because of the small number of samples on which it is based. It was noted that application of the curve correction for readings in the middle portion generally had a beneficial effect.

From information supplied by the personnel who performed the tests, it appears that a determination can be made in from two to five minuted with the AE-55, whereas a similar determination with a pressure method would take from 15 to 20 min. It would seem then that it would not be burdensome to require two AE-55 determinations on each sample. In order to investigate the effect of two determinations on accuracy

TABLE 5

AVERAGE AIR CONTENTS DETERMINED FOR FIELD PROJECTS

Project	Samples	Pressure	Uncorrected	Mortar	Curve	Both
1	40	4.52	4.50	4.41	4.71	4.24
2	40	5.24	4.95	-	5.36	-
3	40	4.34	4.39	-	4.59	-
4	40	4.47	4.23	3.93	4.39	3.93
5	40	3.94	3.85	-	3.91	-
6	40	4.77	4.68	-	5.00	-
7	36	4.66	4.52	4.20	4.67	4.26
8	40	5.21	4.86	4.73	5.21	4.72
1-8	316	4.64	4.50	4.40	4.73	4.50

and precision, the average of two AE-55 determinations from the same sample was compared with the average of the corresponding pressure values for the same sample. The results of this analysis are given in Table 4. The data from the laboratory study were eliminated since no repeat determinations were made. Comparison of these correlation coefficients with those in Table 3 will show that in almost every case the effect was to increase both the accuracy and precision although some of the increases were very modest. Thus it appears that a repeat determination would be desirable.

Aside from the consideration of the correlation existing for the various projects, it is interesting to note from Table 5 that the average AE-55 air content on the major field projects differed from that determined by the pressure method by a maximum of 0.3 percent of air. The data in Table 5 are for the average values; however, the same project average would be found if the individual readings were used in computing the average.

The results of the field tests were most encouraging and resulted in the use of the AE-55 indicator by inspectors on jobs throughout the state. Several questions relative to the use of the indicator still warrant study however. Two of the most important are the necessity for using a screened sample and the effect of using the different types of indicators shown in Figure 2.

From the results of the tests reported in this paper as well as previous work (1) it appears that determinations made on samples taken without screening give a sufficiently accurate indication of the air content. It has been found from additional laboratory tests that air contents determined from screened samples are generally higher than those obtained either from unscreened samples or from pressure methods, even when the mortar correction is applied.

All tests reported in this paper were made with the plain (type A) indicator. Additional laboratory tests have indicated that the fluted type of indicator (type B) gives a higher air content than does the plain type. Additional study is needed in this area.

CONCLUSIONS

From the field and laboratory studies as well as consideration of previous studies the following conclusions appear justified.

1. The AE-55 indicator is a reasonably accurate, moderately precise device which is adequate for field measurement of air content of concrete.
2. Under field conditions the AE-55 determination requires about ¼ to ⅓ the time of a pressure determination. In addition to the money represented by this saving, it is felt that the performing of more tests will result in better control of entrained air.
3. Based on a large number of samples, the average air content as determined by the AE-55 will be within ½ percentage point of air as compared with the pressure method.
4. A repeat determination is advisable.

5. While the preparation of the mortar sample by screening would possibly result in more uniform determinations, the results of these tests indicate that for field use sufficient accuracy is obtained with unscreened samples.

6. From this study it appears that the air content as determined on an unscreened sample will be within ½ percentage point of air as determined by pressure methods approximately 70 percent of the time and within 1 percentage point of air about 95 percent of the time based on the correlation line given in this study.

7. If the sample is screened, application of the correction based on the mortar content is possibly desirable.

8. If the determination is made on an unscreened sample, the mortar correction is not necessary.

9. For unscreened samples, the AE-55 indicator tends to give high readings at low air contents and low readings at high contents. Within the range of 3 to 7 percent air there appears to be little difference between the AE-55 and the pressure method.

10. The fragility of the device is a definite disadvantage but this is partially offset by its low cost and freedom from mechanical defects.

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Appendix

MANUFACTURER'S DIRECTIONS FOR USE OF AE-55 AIR INDICATOR[1]

Fill metal cup with cement mortar paste, excluding particles larger than No. 10. Use a narrow blade to pick up mortar. Do not wet screen. Rod material in cup to compact mortar. Strike off excess even with top of cup.

Hold finger over stem opening and fill large end with isopropyl alcohol to line on glass (alcohol may be inserted in the stem opening after stopper is inserted, with syringe or dropper if desired).

Insert stopper in tube, invert indicator and adjust liquid level to top line of stem making sure that all air bubbles are removed and that the stopper is firmly inserted.

Place finger over stem opening to prevent loss of any liquid and gently roll the indicator from vertical to horizontal several times until all the mortar has been dissolved out of the cup into the alcohol.

With indicator in vertical position carefully remove the finger from the opening

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[1]Pat. pending.

and count the number of spaces from the top to the new liquid level. In the case of mixes with 15 cu ft of mortar the number will directly represent the percentage of entrained air in a cubic yard of the concrete. For different mortar content refer to the table below.

When ready to empty the instrument, care should be exercised to invert the glass to flush out particles of sand from between the glass and metal to prevent jamming when removing the stopper.

Wash and clean the assembly immediately after use with clean water.

CONVERSION TABLE

For following mortar contents per cubic yard multiply the stem readings by the following constants:

10 c.f. by 0.67	19 c.f. by 1.26
11 c.f. by 0.73	20 c.f. by 1.33
12 c.f. by 0.80	21 c.f. by 1.39
13 c.f. by 0.86	22 c.f. by 1.46
14 c.f. by 0.93	23 c.f. by 1.52
15 c.f. by 1.00	24 c.f. by 1.59
16 c.f. by 1.07	25 c.f. by 1.66
17 c.f. by 1.13	26 c.f. by 1.72
18 c.f. by 1.20	27 c.f. by 1.78