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FINAL REPORT

AIR CONTENT OF CONCRETE PAVEMENTS PRODUCED IN CONVENTIONAL VERSUS 30-SECOND MIXERS

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16 Abstract

Cores were obtained from eight undamaged locations with conventional and short mixing times in equal number. These cores were divided crosswise of the length into thirds, as top, middle, and lower portions. The pieces were further divided lengthwise removing the vertical, middle ¾ to 1-inch piece for polishing. The polished pieces were analyzed by image analysis giving air content based on areas. All nine pieces of each core were then observed for petrographic information on aggregates used, condition of the paste, relation of fine and coarse aggregates in the paste, air content distribution and its relation to the other components of the concrete.

Petrographic observations indicate that aggregates and paste are well distributed. What is easily observable about the air content is the large number of large, irregularly shaped air voids. With closer observation, smaller air voids in the size ranges for entrained air needed to protect the concrete from freezing and thawing damage are minimally present. The air content analyses indicate these sizes are minimally present in the lower two sections and subminimally present in the top third of the pavement. Also, the three zones of the cores indicate different amounts of total air content as well as differing in amounts of entrained and entrapped air. One separate related core analyzed from a damaged zone showed indications of chemical attack and freeze/thaw damage after saturation with water.

Mixer times with vibrator locations during placement relative to the cores has provided some information not available in simple comparisons of mixer times. Short mixer times provided more entrained air but with a larger standard deviation in measurement. Regular mixer times yielded slightly less entrained air but with a smaller standard deviation.

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Final Report

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THE KANSAS DEPARTMENT OF TRANSPORTATION
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Chapter 1

Introduction and Methods

Full depth 4-inch cores from pavements constructed with two different mixer times have been evaluated from 10 sites to assess the effect of mixer times on concrete. Each of the 40 cores, four from each site, were divided crosswise of the length into thirds into top, middle, and bottom portions, each about 4 inches in length. Each portion was further divided lengthwise to produce a vertical 3/4 to 1.0- x 4- x 4-inch piece for polishing. The polished specimens were analyzed by linear traverse for air content by a protocol similar to ASTM C-457 recording only entrained air content. The air content of voids larger than 1mm was not recorded in the linear traverse analyses. In a companion study, the same pieces were also analyzed for air content using image analysis. Since size and distribution of all the air voids was important in assessing the influence of mixer times, the method chosen to provide data for this study was the image analysis procedure. Comparisons of the processes and results of the two procedures will be forthcoming in another report. The nine pieces of each core were observed for petrographic information on concrete condition, aggregate condition, relation of fine and coarse aggregates in the paste, and air content distribution and its relation to the other concrete components. The following discussion and graphs will identify the sites by numbers one through 10 but the complete information on location of each site, project number and the discussion identification number is found in Appendix A.

Chapter 2

Petrographic Analysis

Each project site has been constructed with either a regular mixer time of 45 seconds or a shorter time of 30 seconds. Twenty cores were analyzed for each mixer time. Half of the cores from each site were taken between vibrator locations and the remaining half on vibrator locations. Other factors in the construction of the concrete varied, such as the sources for the limestone, coarse aggregate, fine aggregate, cement, and also the proportions of coarse to fine aggregates used in the mixes. While there were some minor differences to be seen among the cores, overall the same general comments can be made for all of the sites. There was no evidence of coarse aggregates causing distress in the concrete. Both the coarse and fine aggregates were well distributed throughout the specimens. Both mixer times produced nonsegregated, well-blended concrete from the aggregates and cement. The cores showed similar variations in the size and distribution of air voids from top to bottom. Generally, the top portion contained subminimal (less than 4 percent) entrained air and excess (more than 2 percent) entrapped air, the middle and bottom portions had minimal entrained air and excess entrapped air.

Chapter 3

Results

Average entrained air (1-mm dia. or smaller) contents by sites for each portion of the cores (top, middle, bottom) and the total air content (entrained air summed with air voids over 1-mm in size) are presented in Figures 1 to 6. There is very little difference between short and regular mixer times in these data. Large excesses of entrapped air are notable. Some comments need to be made concerning aggregate mix proportions and cores from some of the sites. The Sites 4 and 10 are from the same project with the location of Site 4 in a good performing area and 10 designated as performing poorly. The lower entrained air in the top portion for Site 10 can account for the difference in performances seen. The mix proportions of Site 5 are the same as used for Sites 4 and 10. There is no site using a different mixer time to compare with Sites 4, 5 and 10. The Sites 1 and 2 with short mixer time and Site 3 with regular time use the same mix proportions. The data indicate that the longer time may result in less entrained air while the shorter the time may contribute to excessive large voids. Comparison between other aggregate proportions is not available.

Figures 7 to 9 graphically present the average entrained air content by site and core portion but represent the standard deviation of the data of each site by the size of the data point shown. Similarly, both entrained and total air contents are shown in Figures 10 to12. Figure 13 presents the data for the sites by whole core averages. In this graph, the top, middle, and bottom air contents have been averaged to present the point for each site. Note that when averaged, the entrained air content looks better since the subminimal content of the top portion is averaged with the higher content of the lower portions. Again the size of the point represents the standard deviation for each site.

Chapter 4

Discussion and Conclusions

Conclusions for performance based on differences in mixer times from these data are suspect since the differences between mixer times is not significant. What can be seen is that the overall and total air content does not reflect optimal targeted air content. In either entrapped or entrained air void sizes, the amounts are not those desired for quality concrete.

A core from a deteriorated portion of pavement from a related site was also analyzed. In this core, the centerline was weathered and raveling, showing signs of chemical as well as freeze/thaw damage. It was determined that in this core, broken joint seal and the presence of backer rod was allowing water to accumulate and saturate the immediately surrounding pavement. The protection of minimal air entrainment was overcome, allowing the freeze/ thaw damage and accelerating chemical damage in the saturated concrete. The analysis revealed that this core was very much like the cores reported in this study but collected in a deteriorated location.

Since vibration can influence air content, the data for mix times were averaged for values found on vibrator paths and those found between vibrator paths. The averaged data with standard deviations are found in Table 1. By averaging the air contents by portion of the core and location relative to vibrators, there is some simplification of information. In general, shorter mixer times produced higher entrained air content but with a higher standard deviation . The longer mixer times produced smaller entrained air contents and slightly smaller deviations. Shorter mixer times produced fewer subminimal (less than 4 percent entrained air) averages as seen in this data.

4.1 Conclusions

The pavement concrete used for this question proved to be marginal for entrained air content. While the per cent entrained air averaged about 4 percent for the sites in general, this is minimal for durable concrete in this climate. This is evidenced by the longitudinal cracking on centerlines where backer rod has trapped moisture allowing saturation and freeze/thaw damage to occur. Also, the site designated as performing poorly had less entrained air content than the others indicating that the lower limit of protective air content had been found. Also there is excessive entrapped air incorporated in most of the pavement samples. Those being evident, can enough information be found in the study data to indicate whether 30 second or 45 second mixer time is the better choice? The separation of averages based on vibrator locations produces indications that the short mixer time provides some little more entrained air than the regular mixer time. Even this can be suspect since the standard deviations for the data indicate there are only slight differences in the two processes in terms of entrained air.

4.2 Implementation

No implementation of one mixer time over the other can be recommended at this time. Once a body of more current data has been collected and analyzed for air voids in plastic concrete mixes, there may be more useful information on which to base a recommendation

Appendix A

Tables and Figures

TABLE 1: Selected Sites for Coring

Site	Project & Highway	Description notes
1	99-K 5633 I-70	Wabaunsee Co. W. of Maple Hill W.B. Driving Lane Short Mix Time, QC/QA, 60% SG, 40% CA
2	81 K1143 I-70	Riley Co. East Bound Lanes, Short Mix Time, QC/QA, 60% SG, 40% CA
3	99-K 5628 I-70	Wabaunsee Co. West and East Bound Driving Lanes Regular Mix Time, QC/QA 60% SG, 40% CA
4	89-K 2445 I-70	East of downtown Topeka W.B. passing lane (Good Area), Regular Mix Time, 65%SG, 35% CA
5	89-K 2454 I-470	West of Gage Overpass (Bad Area) Regular Mix Time, 65% SG, 35% CA
6	K 3216 US50	E.B.D.L. MN/CS Co. line N.E. to 2.7 mi. NE of R.S. 1076 Short Mix Time, 50%SG, 50% CA
7	87-K 4460 K-96	SG Co. W.B.D.L. West Jct. K-296 S.E. to existing 4 lanes @ Short Mix Time QC/QA
8	78 K-4457 K-96	Reno Co. E.B.D.L., by Haven Shillstone Design
9	105 K 0988 I-435	Wyandotte Co. Far E.B.P.L. @Leavenworth Rd. Center Line Still good in this area.
10	89-K-2445 I-70	East of downtown Topeka W.B. passing lane. (Bad Area), Regular Mix Time, 65%SG, 35%CA

TABLE 2: Summaries of Sites for Comparison

SITE	MIX TIME seconds	PROPORTION SG / CA	ENTRAINED AIR CONTENT averages for top / middle / bottom	ENTRAPPED AIR CONTENT averages for top / middle / bottom
1	30	60 / 40	3.35 / 3.55 / 4.66	1.54 /5.07 / 4.88
2	30	60 / 40	4.25 /4.07 / 5.07	2.12 / 4.70 / 5.17
3	45	60 / 40	3.64 / 3.83 / 4.27	2.00 / 3.32 / 5.24
4	45	65 /35	3.78 / 4.10 / 4.90	5.73 / 6.50 / 7.23
5	45	65 / 35	3.72 / 3.93 / 4.71	6.95 / 9.20 / 5.40
10	45	65 /35	2.84 / 3.08 / 3.92	4.60 / 6.65 / 6.64
7	30	70 /30	3.93 / 4.26 / 3.66	5.74 / 6.88 / 5.12
9	45	70 / 30	3.32 / 3.52 / 4.84	3.38 / 5.03 / 4.99
6	30	50 / 50	3.53 / 4.41 / 4.31	3.93 / 5.90 / 4.52
8	30	optimized	3.74 / 3.53 / 3.98	4.57 / 6.86 / 5.02
			average for 30 seconds	average for 30 seconds
			3.76 / 3.96 / 4.33	3.58 / 5.88 / 4.94
			average for 45 seconds	average for 45 seconds
			3.46 / 3.69 / 4.53	4.53 / 6.14 / 5.90

TABLE 3: Averages of Entrained Air Content by Percent for Vibrator Locations and Short or Regular Mixer Times

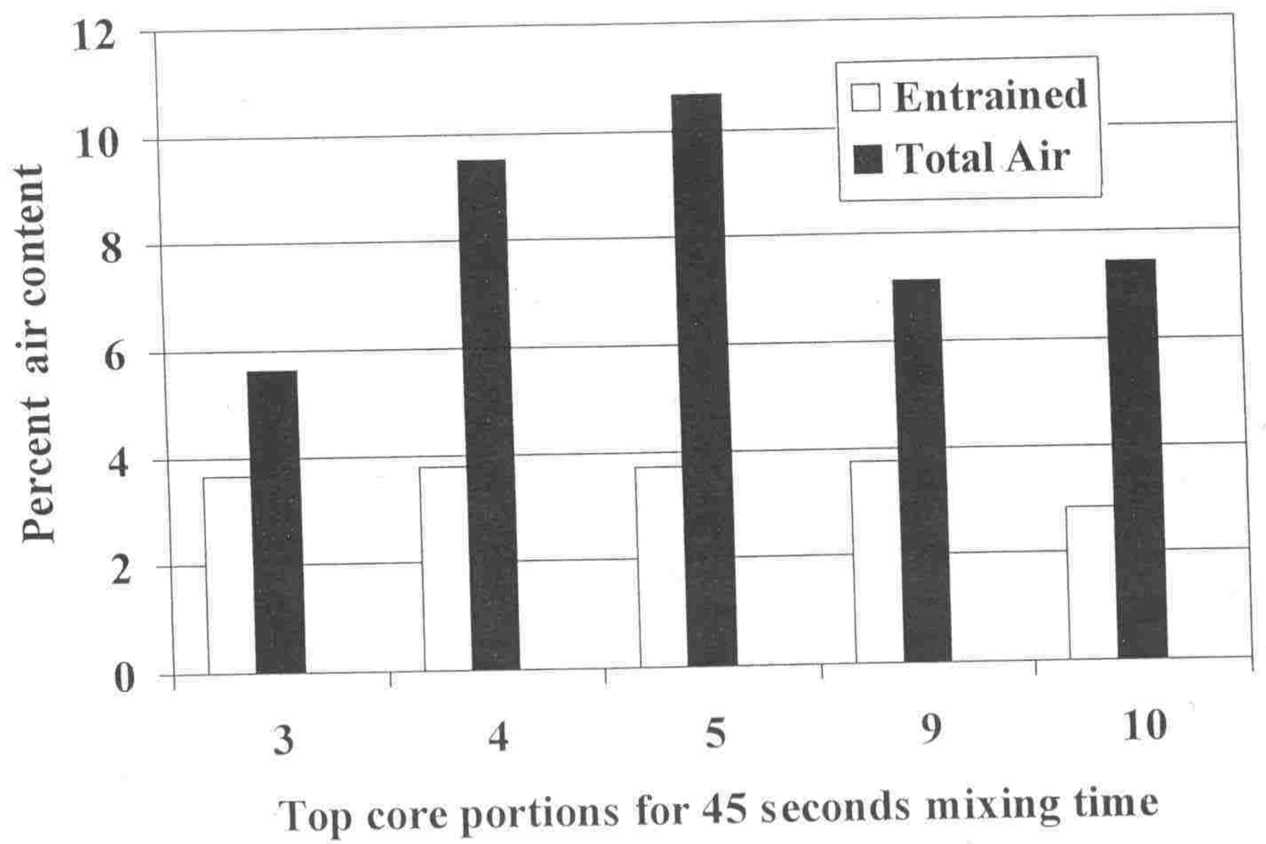
Table 3. Averages of Entrained Air Content by Percent for Vibrator Locations and Short or Regular Mixer Times

Mixer Time	Top Vib	Top Bet	Middle Vib	Middle Bet	Bottom Vib	Bottom Bet
Short Averages	3.6	3.9	4.0	4.0	4.4	4.2
Std.Dev.	0.7	0.8	0.7	0.7	0.6	0.6
Regular Averages	3.8	3.3	3.7	3.7	3.7	4.7
Std.Dev.	0.7	0.6	0.5	0.4	0.5	0.7

Vib = on the vibrator location
Bet = between vibrator locations

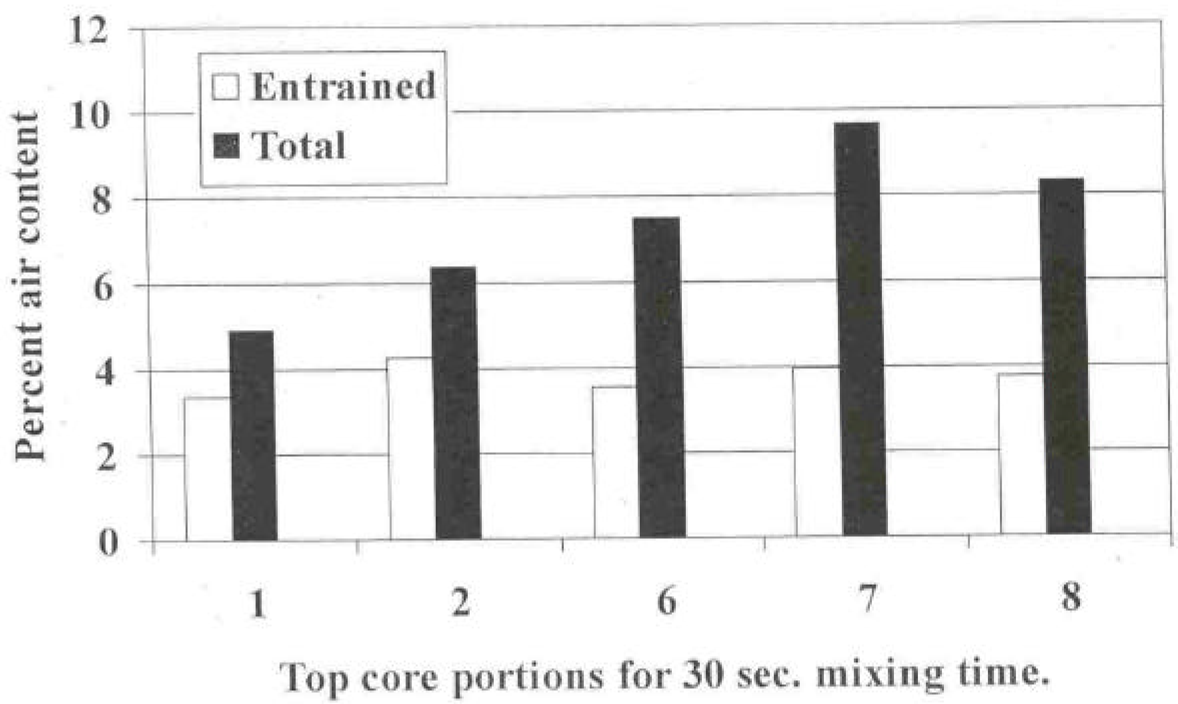
Averages = average of the core portions of all sites for that mixer time

FIGURE 1A: Percent Air Content of 45 seconds mixer times are shown as entrained and total air contents by sites in the top portions of the cores.



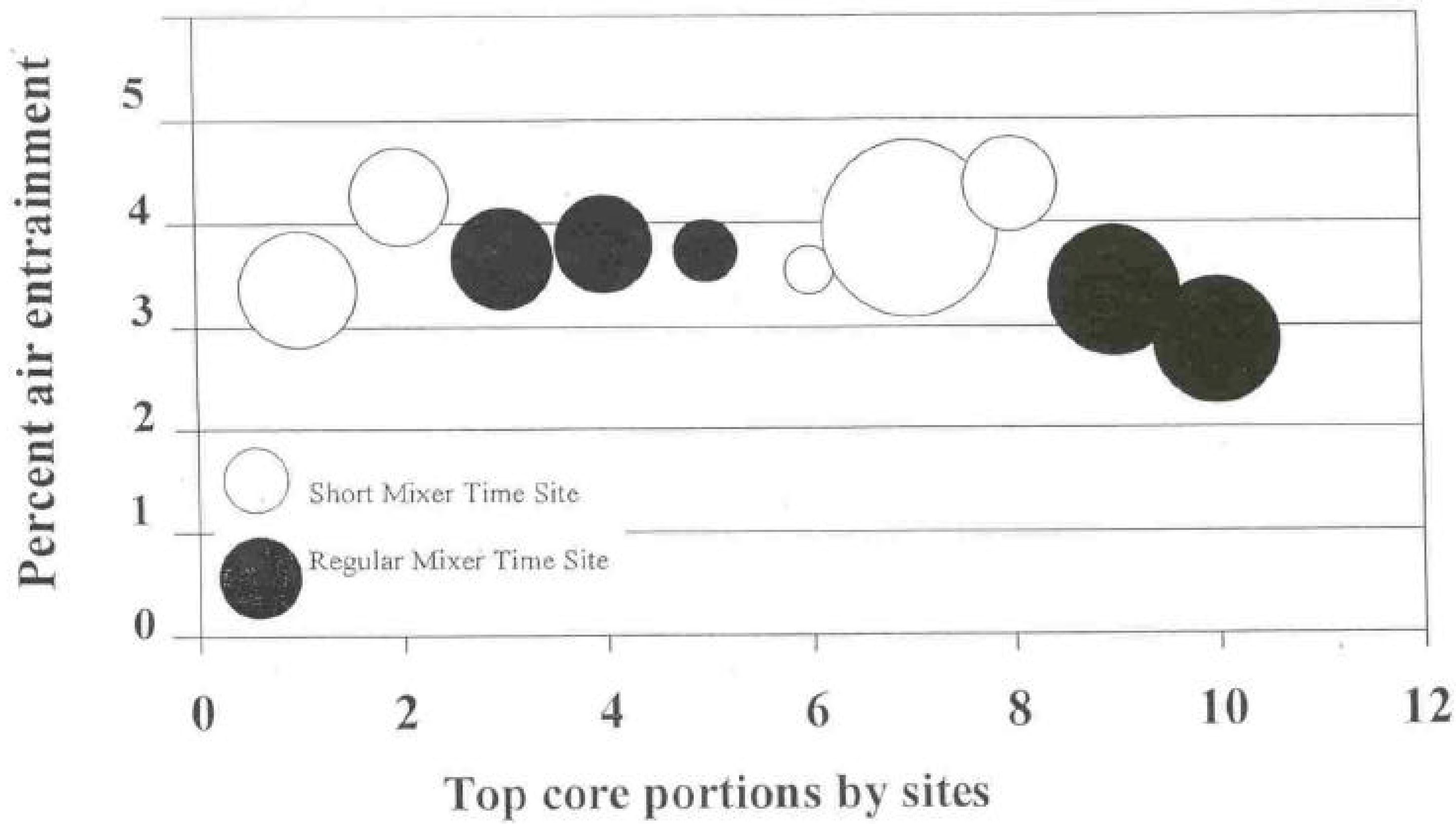
Entrained air is subminimal, below 4 percent. Total is also shown as the total of entrained and entrapped air. Only one site is near the usual expectation of 2 percent entrapped air. The remaining sites have excessive entrapped air.

FIGURE 1B: Percent Air Content of 30 seconds mixer times are shown as entrained and total air contents by sites in the top portions of the cores.



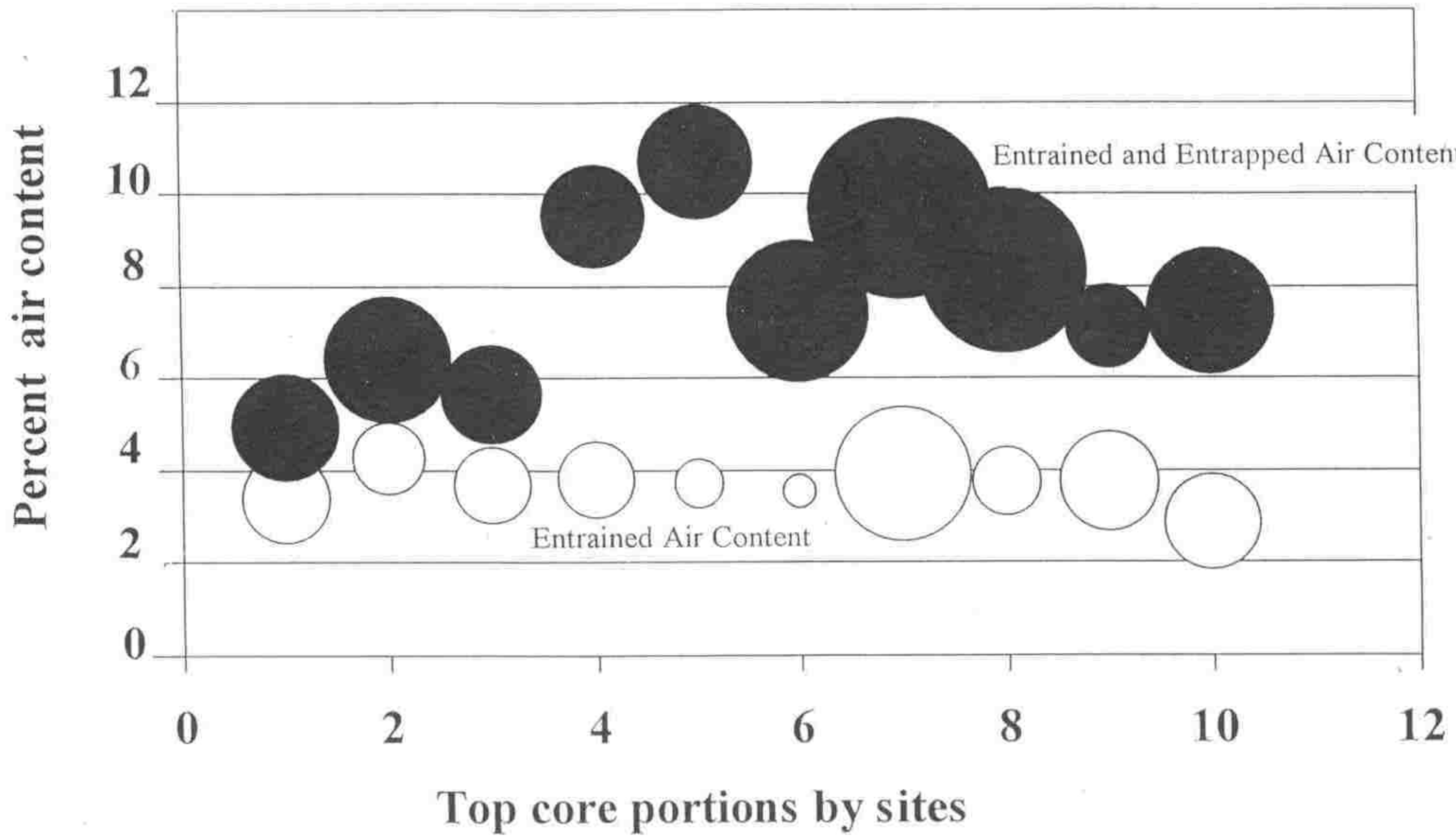
Entrained air content is subminimal. Entrapped air is excessive at most sites.

FIGURE 2: Average entrained air contents of top portions of cores for all sites are shown with the standard deviations shown with the standard deviations shown by the size of the circle.



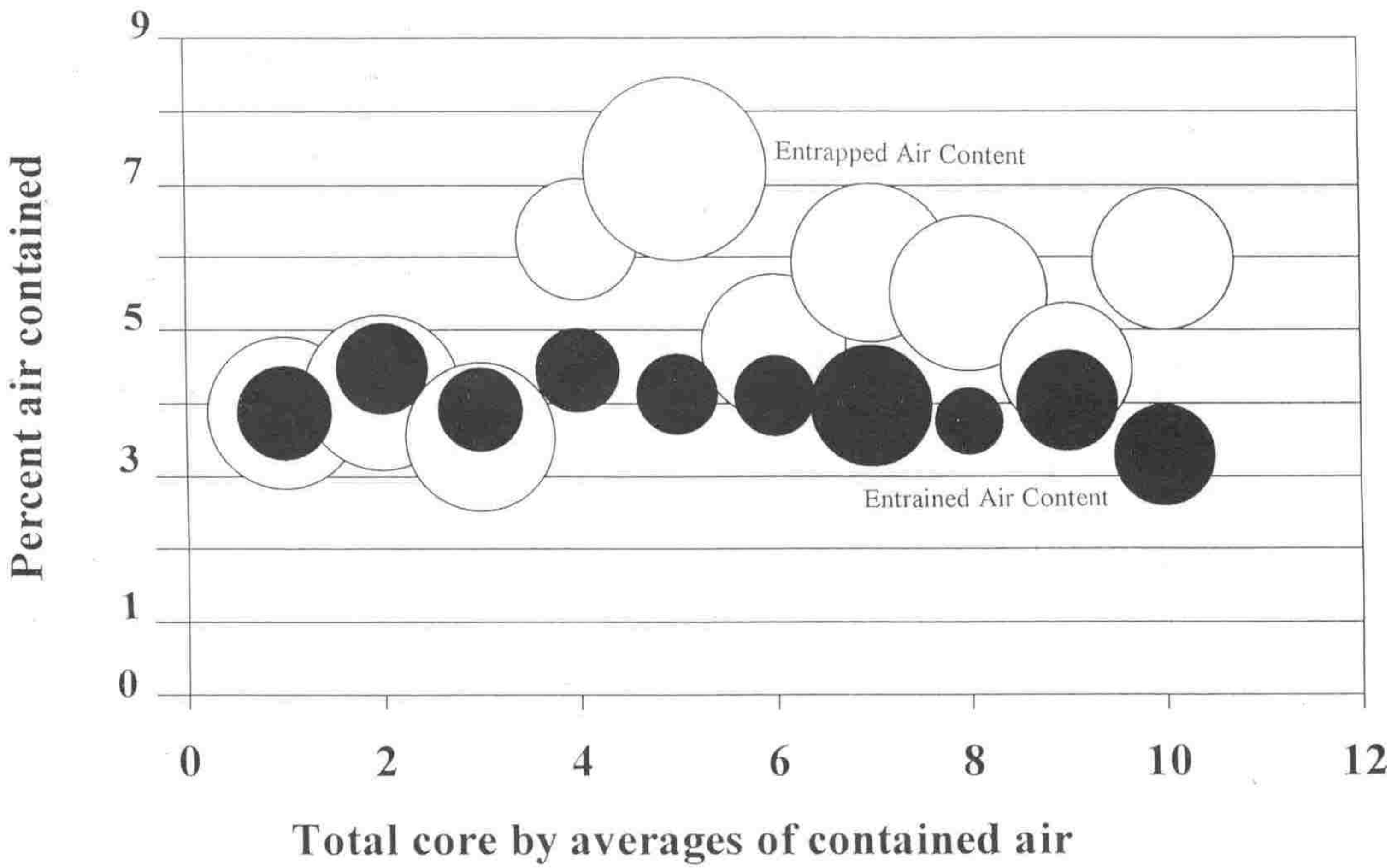
The light circles indicate the shorter mixing time of 30 seconds with darker circles indicating longer mix times of 45 seconds.

FIGURE 3: Average entrained versus total air contents of top portions of cores are shown for all sites with standard deviations shown by the size of the circles.



Shorter mixing times are found at Sites 1, 2, 6, 7, 8, and longer mixing times at Sites 3, 4, 5, 9 and 10.

FIGURE 4: Percent entrained versus entrapped air contents are shown as averages of the top, middle and bottom portions of the cores by sites with the standard deviation shown by the size of the circles.



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