VIBRATORY EFFECTS IN REINFORCED PORTLAND CEMENT CONCRETE PAVEMENT

Final Report
For
Project MLR-97-2

May 1997

Project Development Division

Iowa Department of Transportation

VIBRATORY EFFECTS
IN REINFORCED
PORTLAND CEMENT CONCRETE PAVEMENT

Final Report
for
MLR-97-2

By
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TECHNICAL REPORT TITLE PAGE

1. REPORT NO.

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2. REPORT DATE

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3. TITLE AND SUBTITLE

Vibratory Effects in
Reinforced PCC Pavement

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5. AUTHOR(S)

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7. ACKNOWLEDGEMENT OF COOPERATING ORGANIZATIONS

8. ABSTRACT

A double mat of reinforcement steel consisting of No. 5 bars was placed in the longitudinal and transverse directions in a 26′ wide, 10" thick pavement. The bars were placed on 12" centers with 2" of cover from the top and bottom surfaces. The special reinforcement is to provide additional strength in the pavement over an area of old coal mine tunnels. Auxiliary and standard paver vibrators were used to consolidate the concrete. There was concern that over-vibration could be occurring in some areas and also that a lack of consolidation may be occurring under the steel bars in some areas.

A core evaluation study of the pavement was developed. The results showed that the consolidation and the air contents were satisfactory. Additional paving with reinforcement in the same area should use the same or similar method and amount of vibration as was used in the area evaluated in this study.

9. KEY WORDS

Portland cement concrete
Reinforced PCC
Special reinforcement
Consolidation
Auxiliary vibrator

10. NO. OF PAGES

27

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DISCLAIMER

INTRODUCTION

This project is a result of a request in February 1997 from the Construction Office to the Materials Office, Research Section, to evaluate the concrete consolidation and air content in a 563' section of special reinforced concrete pavement. The section contains a double mat of No. 5 uncoated steel bars placed on 12" centers running in the longitudinal and transverse directions. This section of pavement passes over an area of old (prior to 1950) coal mine tunnels (see Appendix A). There was concern about the amount of vibration needed for proper consolidation of the concrete around the steel bars. Two auxiliary handheld vibrators were used in addition to the standard paver vibrators for this section of pavement.

An answer was needed, before the start of the 1997 construction season, on the quality of concrete consolidation and on air content of the 1996 pavement in this area. A Materials Laboratory Research (MLR) 97-02 was initiated to provide the guidelines for the project (see Appendix B).

PROJECT LOCATION

The project is on relocated IA 163 in Mahaska County, project No. NHS-163-4(11)--19-62, near the city of Oskaloosa. The initial paving in 1996 was a 563' section in the northbound lane from Station 384+31 to Station 389+94. Many additional similar sections within this project are scheduled for construction in 1997 (see Appendix C).

CORE SAMPLING

The coring plan had a target to hit the intersection of steel in some cases and to avoid the steel in other cases. Due to the tight pattern of steel, a 3" core bit was used to avoid steel and a 4" bit was used when coring the intersection of the longitudinal and transverse steel bars. A total of 12 cores were taken over the area to be evaluated. A Pachometer steel locator was used to determine the location of the steel reinforcing bars.

OBSERVATIONS

From visual observations of the cores, the consolidation of the concrete around the steel bars appeared satisfactory. Only in one case, in Core No. 12, was there evidence of void areas around the bars. In that case, the lower steel mat was found abnormally low, being only 1" off of the base instead of the 2" as specified in the plans.

There is a visual appearance of longitudinal ridges on the surface of the pavement which appear to correspond to the location of the top longitudinal steel bars within the concrete. As there was no obvious transverse ridges from the top steel, it should be determined whether the longitudinal ridges are actually ridges in the concrete from steel or they are apparent ridges made by the uniformly spaced nozzles from the spray bar applying curing compound.

If concrete ridges do exist in this section, these ridges could cause a rough ride or abnormal noise. The paver used in this section was a smaller paver than the contractor is planning to use for 1997 paving. For future paving on this project, a "super smoother" would be attached to the paver which is likely to remove surface effects caused by the top steel bars in the concrete.

AIR CONTENT OF HARDENED CONCRETE

The cores were prepared and tested according to the "Method of Test for Determination of Air Content of Portland Cement Concrete Cores Using a High Pressure Air Meter," Test Method No. Iowa 407-B (see Appendix D).

A full length slice was first taken from each core and kept for any future evaluation. The main part of the core was then cut at half length to give a top half and bottom half for testing. For the cores which contained steel, a calculation was done to eliminate the effect of the steel. The results of the tests for hard air content are given in Appendix E.

RESULTS

The visual results of the study indicate that the concrete consolidation using the standard paver vibrators plus two auxiliary vibrators did a satisfactory job.

The air content test results on the hardened concrete show an average of 5.4% air based on 23 tests. The air content was 5.3% in the top halves of the cores and 5.5% in the bottom halves (see Appendix E). There was only one core that exhibited significant voids around a bar and in that case, the steel bar was only 1" off of the base making it abnormally difficult for the concrete to flow under the bar.

DISCUSSION

To get the results of this study as quickly as possible to the Iowa DOT and the contractor, a preliminary presentation was made in draft form at the project preconstruction meeting on March 27, 1997.

The results given in this report confirm and elaborate on the preliminary results given previously.

An appendix for Auxiliary Vibrator Use giving a variety of options for vibrator dip (emersion) time and area covered was prepared and is presented only as a guideline for use with the auxiliary vibrators (see Appendix F).

RECOMMENDATIONS

Based upon the visual evaluation of the cores and on the percent air values found, it is recommended that a similar or equivalent amount of vibration effort be applied in paving the remaining special reinforced sections in this paving project.

A proposed guideline is that the auxiliary vibrators be inserted into the concrete such that each insertion does not go beyond approximately 3 seconds time within the plastic concrete and that each insertion covers an area of 2' x 2' (see Appendix F).

CONCLUSIONS

Placement of reinforcing bars within 1" of the base can prevent concrete from flowing completely under the bar.

Concrete consolidation efforts and methods used in this section gave satisfactory results.

ACKNOWLEDGEMENTS

Appreciation is expressed to the Southeast Iowa Transportation Center for their support of this study, to the Central Materials Special Investigations for their assistance to obtain cores and to the Cement & Concrete Section for their support in core analysis. Special thanks goes to Ed Engle for his many hours of core preparation, testing and data organization and to Kathy Davis for her secretarial support.

APPENDICES

Appendix A
Project Request

Post-It™ brand fax transmittal memo 7671 | # of pages ▸ 1

To Pete Tollenaere | From Mark Bortle

1/2

Jim Grove
Bob Steffes
John Lane
John Smythe

Post-It™ brand fax transmittal memo | To Jim Webb | Co.

Post-It™ brand fax transmittal memo | To Ed Kasper | Co.

re: Hardened Air Content on US 63 bypass of Ottumwa and Iowa 137 (Ottumwa to Eddyville)
NHS-163-4(11)--19-62, Sta 384+31 to Sta 389+94

Both of these projects include either double-reinforced pavement sections or CRC pavement over old ~~coal~~ coal mine areas to allow for adequate pavement life.

Last year on the section of the Ottumwa bypass that was paved to allow for traffic staging south of town, the Ottumwa RCE Office required Fred Carlson Company to use additional hand vibration in the areas of double-reinforced pavement.

The field staff (Ottumwa RCE, TCCE and TCME) are concerned about the possible deliterious affects on the entrained air system in this pavement. They propose that a few cores be taken on a statistically valid system to determine the inplace hardended air content.

Jim, could you and Bob Steffes come up with a statistically valid sampling schedule so we can confirm that no deliterious ~~affects~~ to the air entrainment system have ocurred with last Fall's paving?

Let me know your sampling schedule, so cores can be taken and analysed so we know how to proceed with this years paving.

Mark Bartle

cc: Pete Tollenaere, TCCE
Jim Webb, TCME
Ed Kasper, RCE

Appendix B
MLR-97-2

DATE: March 5, 1997

PROJECT NO.: MLR-97-2

PROJECT TITLE: Vibratory Effects in Construction of Special Reinforced PCC Pavement

PRINCIPAL INVESTIGATOR: Bob Steffes

OBJECTIVE: The objective of this research is to evaluate the consolidation and air system of a PCC roadway which has special reinforcement.

DISCUSSION:

The special reinforced pavement is over an area of old underground coal mining activity in Mahaska County on relocated IA 163 south of Oskaloosa. The project No. is NHS-163-4(11)--19-62. The area for testing is from Sta. 384+31 to Sta. 389+94 in the westbound lane.

PURPOSE:

The purpose of the research is to determine if auxiliary vibrators are required to achieve sufficient consolidation of PCC concrete around reinforcing bars. The research will also determine if auxiliary vibration causes an excessive loss of entrained air. The results are needed to determine construction procedures for other similar areas, not yet paved, within this project.

PROCEDURE:

Cores will be taken from locations where: 1) reinforcing bars intersect in the lower mat (2 each, 4" diameter); 2) reinforcing bars intersect in the upper mat (2 each, 4" diameter); 3) a 6"x6" square area exists with no reinforcing bars passing through it (8 each, 3" diameter).

The cores will be removed from two different sections of the currently constructed project.

CORE ANALYSIS:

Cores will be evaluated by:

1. Visual inspection.
2. High pressure hardened air analysis.

REPORTING:

Results of the research will be reported as soon as they are summarized so they can be incorporated into paving procedures for the ongoing construction of this project during the 1997 construction season.

RESPONSIBILITIES:

SEITC - RCE will provide information and authorization for core sampling.

Materials - Research and Special Investigations will select core sites, do coring and perform visual core inspections.

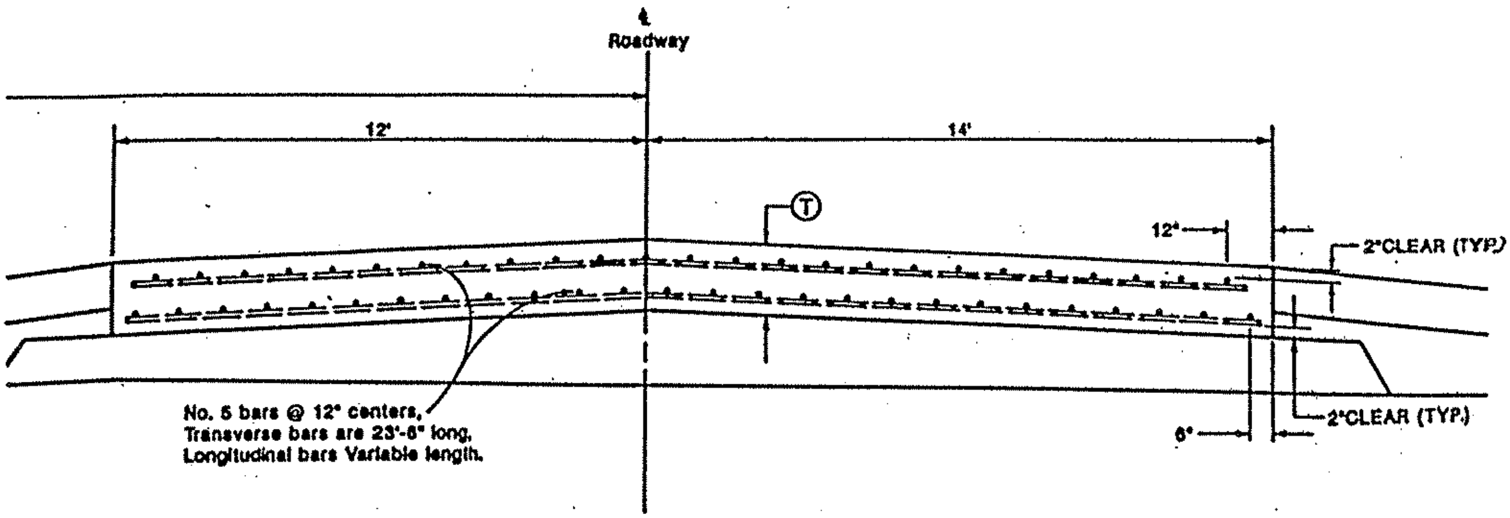
The Cement and Concrete laboratory will perform the high pressure hardened air analysis.

The Materials - Research principal investigator will prepare and present the final report.

RESEARCH PERIOD:

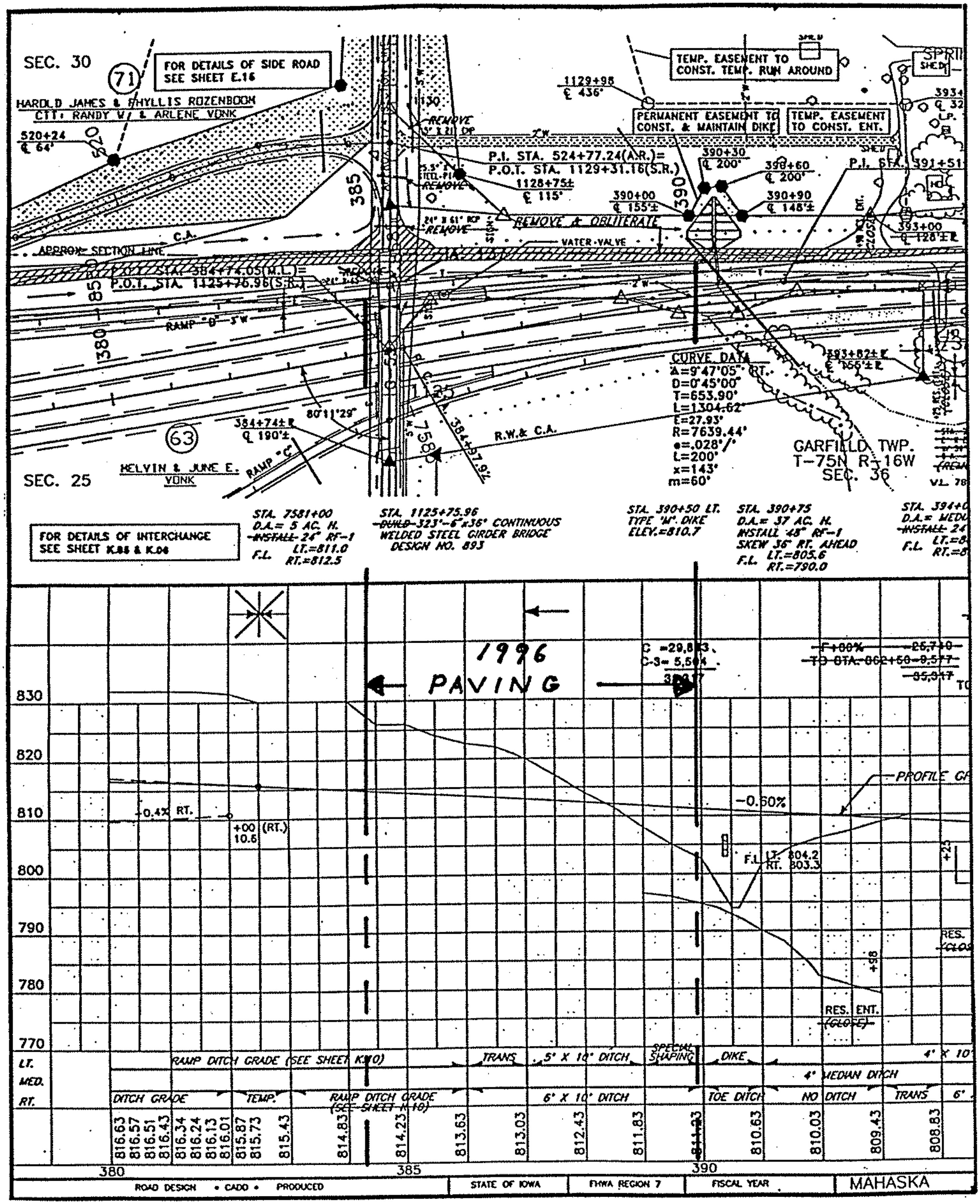
Research work can begin as soon as this MLR is approved. Coring can be done in mid-March and laboratory work will follow as soon as possible, thereafter. Priorities will be given to present the final report before the start-up of the 1997 paving on this project.

Appendix C
Project Plan (Partial)



TYPICAL SECTION

MAHASKA CO. NHS-163-4(11)--19-62 AREAS REQUIRING REINFORCED P.C.C. PAVEMENT FOR DETAIL, SEE SHEET U.08				
STATION	STATION	LANE	S.Y.	REMARKS
1513+60	1517+50	Ramp "A" Iowa 92	693	
		interchange		
213+60	217+50	WBL	1127	
213+60	217+50	EBL	1127	
4513+60	4517+50	Ramp "D" Iowa 92	693	
		interchange		
49+80	54+00	West Access Rd.	1120	Single Reinf.
233+50	237+00	WBL	1011	
233+50	237+00	EBL	1011	
72+75	77+00	West Access Rd	1133	Single Reinf.
5550+00	5558+75	Ramp "A" Iowa 137	1556	
		interchange		
344+00	358+50	WBL & Ramp "A"	4189	
		taper	800	
344+00	358+50	EBL & Ramp "B"	4189	
		taper	800	
6551+00	6558+00	Ramp "B" G-55	1244	
		interchange		
6560+50	6568+50	Ramp "B" G-55	1422	
		interchange		
365+75	389+25	WBL & part of Ramp	6789	
		"D" taper	533	
365+75	389+25	EBL & part of Ramp	6789	
		"C" taper		
7578+00	7589+25	Ramp "C" G-55	2000	
		interchange		
11+25	17+00	East Access Rd.	1533	Single Reinf.


SEC. 30
FOR DETAILS OF SIDE ROAD SEE SHEET E.16
HAROLD JAMES & PHYLLIS ROZENBOOM
CTT: RANDY W. & ARLENE VONK
520+24
℄ 64'
TEMP. EASEMENT TO CONST. TEMP. RUN AROUND
1129+98
℄ 436'
PERMANENT EASEMENT TO CONST. & MAINTAIN DIKE
TEMP. EASEMENT TO CONST. ENT.
P.I. STA. 524+77.24(A.R.)=
P.O.T. STA. 1129+31.16(S.R.)
1128+75±
℄ 115'
390+30
℄ 200'
390+60
℄ 200'
390+00
℄ 155'±
390+90
℄ 148'±
REMOVE & OBLITERATE
393+00
℄ 128'±R
APPROX. SECTION LINE
C.A.
WATER VALVE
P.O.T. STA. 1125+76.96(S.R.)
RAMP "B"
CURVE DATA
Δ=9°47'05" RT.
D=0°45'00"
T=653.90'
L=1304.62'
E=27.93'
R=7639.44'
e=.028'/'
L=200'
x=143'
m=60'
393+82±R
℄ 155'±R
80°11'29"
384+74±R
℄ 190'±
R.W.& C.A.
GARFIELD TWP.
T-75N R-16W
SEC. 36
HELVIN & JUNE E. VONK
RAMP "C"
SEC. 25
FOR DETAILS OF INTERCHANGE SEE SHEET K.05 & K.06
STA. 7581+00
D.A.= 5 AC. H.
INSTALL 24" RF-1
F.L. LT.=811.0
RT.=812.5
STA. 1125+75.96
BUILD 323'-6"x36" CONTINUOUS WELDED STEEL GIRDER BRIDGE
DESIGN NO. 893
STA. 390+50 LT.
TYPE "M" DIKE
ELEV.=810.7
STA. 390+75
D.A.= 37 AC. H.
INSTALL 48" RF-1
SKEW 36° RT. AHEAD
F.L. LT.=805.6
RT.=790.0
1996
PAVING
830
820
810
800
790
780
770
0.4% RT.
+00 (RT.)
10.6
-0.60%
PROFILE GR
F.L. LT. 804.2
RT. 803.3
RES. ENT.
LT.
MED.
RT.
RAMP DITCH GRADE (SEE SHEET K.10)
TRANS
5' X 10' DITCH
SPECIAL SHAPING
DIKE
4' MEDIAN DITCH
DITCH GRADE
TEMP.
RAMP DITCH GRADE (SEE SHEET K.10)
6' X 10' DITCH
TOE DITCH
NO DITCH
TRANS
816.63
816.57
816.51
816.43
816.34
816.24
816.13
816.01
815.87
815.73
815.43
814.83
814.23
813.63
813.03
812.43
811.83
811.23
810.63
810.03
809.43
808.83
380
385
390
ROAD DESIGN • CADD • PRODUCED
STATE OF IOWA
FHWA REGION 7
FISCAL YEAR
MAHASKA

Appendix D
Test Method No. Iowa 407-B
(Air content of hardened PCC)

IOWA DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION

Office of Materials

METHOD OF TEST FOR DETERMINATION OF AIR CONTENT OF PORTLAND CEMENT CONCRETE CORES USING A HIGH PRESSURE AIR METER

PART I, AIR CONTENT OF CONCRETE CORES

Scope

The amount of air in portland cement concrete is a factor that can result in longer life, greater versatility, and better economy. The proper amount of air content will greatly improve the quality, appearance, and placeability of concrete. The air content of cores drilled from pavement, pavement widening, bridges, etc., is determined by a high pressure air meter. In addition, water absorption in paste by volume of the core can also be determined.

A. Apparatus and Materials

1. High pressure air meter (Fig. 1 and 2).
2. Specimen stirrup for lowering the specimen into the compression chamber.
3. Core soaking container.
4. Liquid solution of 20 grams sodium borate, 5 gram sodium chromate, and one gallon water.
5. Oven (300^{o} F.).
6. Scale (capacity = 7,000 grams, accuracy = 0.5 gram).

B. Test Record Forms

1. Data and calculation sheet (Fig. 3).
2. "P.C.C. core strength - air - absorption" coding sheet.
3. Strength and air field book with columns of core number, dry weight, absorbed weight, weight in water, zero reading, and observed dial reading.

C. Test Procedure

1. Dry the core specimen in an oven at 300^{o}F. for a period of 72 hours.
2. Cool the specimen at room temperature for a period of approximately 3 hrs.
3. Weigh the specimen in air.
4. Soak the specimen in the soaking container for a period of 48 hours.
5. Weigh the specimen in water.
6. Wipe the excess water off the specimen using an absorbent cloth.
7. Weigh the specimen in air (absorbed weight).
8. Using the stirrup, lower the specimen into the compression chamber.
9. Close the elliptical lid tightly, such that one-quarter to one-half inch of liquid remains on the top.
10. Remove the trapped air as follows: with a small head pressure, let the liquid flow into the chamber at the low side valve and out of the chamber at the high side valve. Be sure that all the trapped air is removed by checking for air bubbles in the beaker which is used as a receiver of the liquid from the high side valve.
11. When all the trapped air is out of the compression chamber, close both valves tightly.
12. Turn the transmission switch to the (D) down position. The cylinder piston will begin to move downward, the distance of which is indicated by the dial reading. When there is no further visual movement of the dial, note the pressure gauge, and use a correction of 0.05 divisions of the dial for every 100 psi. differential from 5,000 psi. Thus, if the dial reading is 4.81 revolutions and the pressure gauge reads 4,900 psi., the recorded dial reading should be 4.86 revolutions. If the pressure gauge reads 5,060 psi., the recorded reading would be 4.78 revolutions.
13. Loosen the lid screw a half-turn to prevent it from locking up.

14. Turn the transmission switch to the (U) up position. When the pressure has dropped below 1000 psi., open the high side valve and remove the elliptical lid. Make sure that the dial has returned to the zero position.

15. Remove the specimen from the compression chamber by lifting the stirrup.

16. Before and after each series of cores that are tested, a dial reading should be recorded with nothing but the stirrup in the compression chamber. This is the zero reading and is recorded for each core in the field book.

D. Calculations

1. Computer Calculating

a. Computer calculating of the resulting air content can be gained by transferring the relevant data from the field book to the coding sheet labeled "P.C.C. Core Strength - Air - Absorption" Form 909. The coding sheet is then sent to the data processing center for computation.

2. Hand Calculating

a. The calculation sheet shown in Fig. 3 can be used to calculate the air content when the computation is carried out by laboratory personnel.

3. Computer Terminal Calculating

a. The Materials Laboratory computer terminal will calculate the air content when the program login (dpctl, dp01), load (air) is supplied with the requested core data.

E. Reporting the Results

1. The computer print-out and the calculation sheet both present the air content as a percent by volume of the concrete core specimen. The water absorption in paste by volume of a core is determined by the same computer program as air content. All aggregate and mix data should be included on the coding sheet. The water absorption in paste is specified on the print-out.

F. Note

The high pressure air meter is similar to an original design by the Illinois Division of Highways (Highway Research Board Proceedings Vol. 35, "Illinois Develops High Pressure Air Meter For Determining Air Content of Hardened Concrete", pp. 424-435). See also ISHC R-168.

PART II, CALIBRATION

Scope

It is recommended that at least once-a-year the high pressure air meter be calibrated to determine the effects of wear on its performance. These effects are reflected by the two air meters constants which are used in calculating the air content of concrete specimens. The first constant determined is the solid slope-factor which is a correction for the expansión of the equipment and compressibilities of the liquid. The second constant is the volume of air displaced by liquid per dial revolution.

A. Apparatus and Materials

1. High pressure air meter.

2. Liquid solution of 20 grams sodium borate, 5 grams sodium chromate and one gallon water.

3. Two standardized steel volume specimens marked "565 cc" and "1180 cc" along with a threaded rod used to transport the specimens.

4. Complete set of steel air displacement specimens that include:

a. Two steel cylinders marked "50 cc".

b. One steel cylinder marked "100 cc".

c. One cylindrical cup with lid marked "240 cc steel - 250 cc air".

B. Test Report Form

1. Data and calculation sheet labeled "Large High Pressure Air Meter Calibration" (Fig. 4).

C. Calibration Procedure

1. Fill the compression chamber with the liquid solution and close the elliptical lid tightly such that one-quarter to one-half inch of liquid remains on the top.

2. Remove the trapped air as described in item number 10 under the test procedure of Part I, Air Content of Concrete Cores.

3. Close both valves tightly.

4. Turn the transmission switch to the (D) down position and record the 5000 psi. corrected dial reading.

5. Loosen the lid screw a half-turn.

6. Turn the transmission swith to the (U) up position. When the pressure has dropped below 1000 psi. open the high side valve, remove the elliptical lid, and make sure the dial has returned to the zero position.

7. The remainder of the calibration procedure requires that dial readings be recorded for various amounts of steel and air within the compression chamber. These amounts are specified on the data sheet, and can all be gained by using different combinations of the steel specimens and the air measuring cup. Thus, steps 1 through 6 are repeated for the various combinations until the twenty-four corrected dial readings have been recorded on the data sheet.

D. Calculations and Reporting of Results

1. The calculations are made directly on the data sheet under the format presented. The results (solid-slope-factor and cubic centimeters per dial revolution) are recorded on the first page of the high pressure air meter file R-168. A comparison of previous results will indicate the nature of the air meter wear, and will serve as a basis for any repairs.

PART III, AGGREGATE AIR CORRECTION

Scope

Before the air content of a concrete specimen can be computed, a correction for the air within the coarse aggregate must be determined. Since the amount of air within the coarse aggregate is not included in the final results, it is subtracted from the observed air content of the concrete core.

A. Apparatus and Materials

1. High pressure air meter.

2. Soaking container.

3. 500 cc beaker.

4. Specimen stirrup for lowering beaker into the compression chamber.

5. Liquid solution of 20 grams sodium borate, 5 grams sodium chromate and one gallon water.

6. Scale (capacity = 1000 gm., accuracy = 0.2 gm.).

B. Test Record Form

1. Data and calculation sheet labeled "Aggregate Air Correction Using the High Pressure Air Meter" (Fig. 5).

C. Aggregate Correction Procedure

1. Soak a representative aggregate sample of approximately 1000 grams at room temperature for 48 hours.

2. Wipe the excess water of the aggregate using an absorbent cloth (saturated-surface-dry-condition).

3. Weigh a sample having a weight that is equivalent to 100 times the specified gravity in grams.

4. Place the weighed sample in the 500 cc beaker and lower it (by the stirrup) into the compression chamber.

5. Close the elliptical lid tightly, such that one-quarter to one-half inch of liquid remains on the top.

6. Remove the entrapped air as described in item number 10 under the test procedure of Part I, Air Content of Concrete Cores.

7. Close both valves tightly.

8. Turn the transmission to the (D) down position and record the 5000 psi. corrected dial reading.

9. Loosen the lid screw a half-turn.

10. Turn the transmission switch to the (U) up position. When the pressure has dropped to below 1000 psi., open the high side valve, remove the elliptical lid, and make sure the dial has returned to the zero position.

11. Record a zero reading (stirrup, beaker and water in chamber) for each sample.

12. Repeat items 3 through 11 until 3 samples of a given aggregate have been tested and reported.

D. Calculations and Reporting of Results

1. The calculations are made directly on the aggregate correction data sheet (Fig. 5). The results (avg. percent air in aggregate and cc air in standard specimen) are recorded in Table II, "Aggregate Characteristics", which is a listing of air content, specific gravity, and absorbed weight of all aggregates previously tested. Any additions or corrections to Table II should be made available to the data processing center so that future computer calculations can be kept up-to-date.

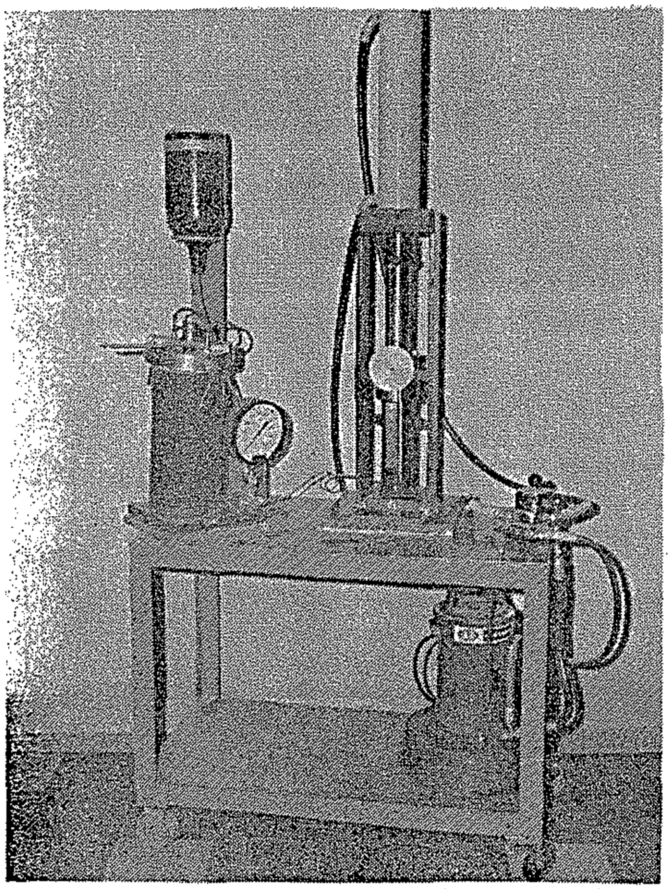


Figure 1
High Pressure Air Meter

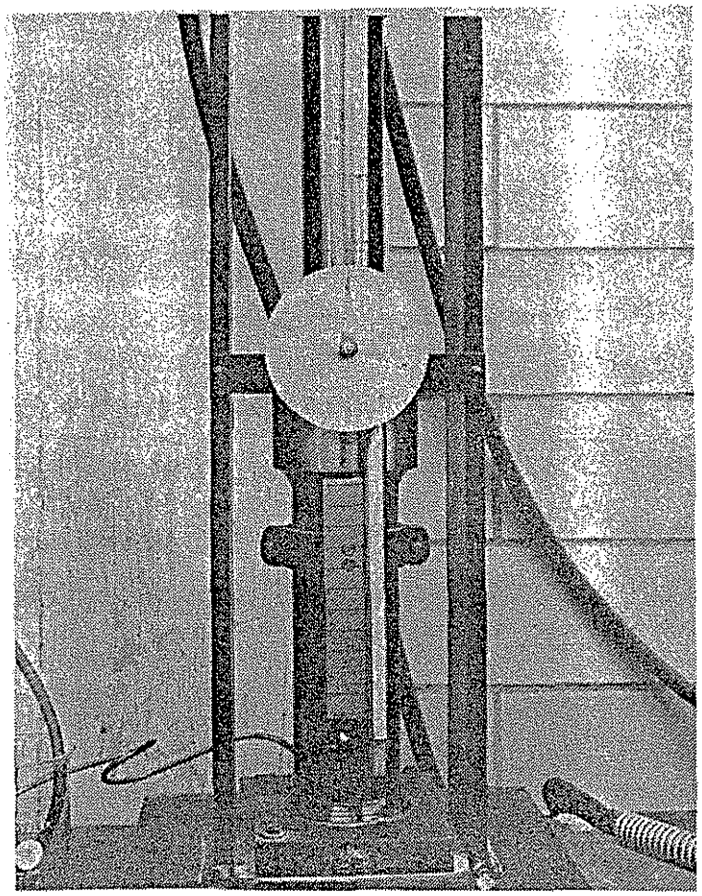


Figure 2
Close-Up of Dial on High Pressure Air Meter

FIGURE 3

ENTRAINED AIR DETERMINATION OF CORE SPECIMENS USING THE HIGH PRESSURE AIR METER-DATA AND CALCULATION SHEET

Project No. 5-1105(6)-50-39 County GUTHRIE

Date 3/23/71 By S. CAREY

Core No. 6991 Lab. No. 3127

Location STA. 101+00

Coarse Aggregate HALLET, GILMORE CITY HUMBOLDT COUNTY Mix B-4

Air Meter Characteristics (Most Recent):

A) Solid Slope Factor, K = 0.00041

B) Volume of Air Per Dial Revolution, V = 36.88

C) Use Pressure Correction of 0.05 Revolutions Per 100 PSI Differential from 5,000 PSI.

Specimen Reference	1					
1. Dry Weight of Specimen, gm. (72 hr. in oven)	2300					
2. Absorbed Wt. of Specimen, gm. (48 hr. soak)	2478					
3. Weight in Water, gm.	1394					
4. Volume of Specimen, Cm^3=(2-3)	1084					
5. Zero Dial Reading (Water & Stirrup)	2.40					
6. Volume Absorbed Water = (2-1)	178					
7. Volume Solids + Air = (4-6)	906					
8. Observed Dial Reading	4.06					
9. Adj. Zero Reading = [5-(Kx7)]	2.03					
10. Net Revolutions = (8-9)	2.03					
11. Observed Vol. Air = (10)(V)	74.87					
12. % Vol. Coarse Agg. (Table I)	34.51					
13. Vol. Coarse Agg. = $\frac{(4)(12)}{100}$	374.09					
14. % Vol. Air in Agg. (Table II)	0.3					
15. Agg. Correction = $\frac{(13)(14)}{100}$	1.12					
16. Vol. Entrained Air = (11-15)	73.75					
17. % Air = (16/4)	6.8%					

IOWA DEPARTMENT OF TRANSPORTATION - MATERIALS LABORATORY

LARGE HIGH PRESSURE AIR METER CALIBRATION

DATA AND CALCULATION SHEET

DATE TESTED: 3-18-87

TESTED BY: M. Coles

VOLUME OF STEEL IN TEST SPECIMEN -CUBIC CENTIMETERS	VOLUME OF AIR IN CONTAINER -CUBIC CENTIMETERS	DIAL READING №	DIAL READING AT 5000 PSI -REVOLUTIONS (SEE NOTE 1)
0	0	1	2.39
565	0	2	2.14
1180	0	3	1.87
1745	0	4	1.65
440	50 1	5	3.54
1005	50 2	6	3.34
1620	50 3	7	3.09
2185	50 4	8	2.84
390	100 1	9	4.95
955	100 2	10	4.72
1570	100 3	11	4.48
2135	100 4	12	4.32
340	150 1	13	6.46
905	150 2	14	6.20
1520	150 3	15	5.94
2085	150 4	16	5.79
290	200 1	17	7.92
855	200 2	18	7.70
1470	200 3	19	7.49
2035	200 4	20	7.31
240	250 1	21	9.07
805	250 2	22	8.68
1420	250 3	23	8.66
1985	250 4	24	8.41

SOLID SLOPE FACTOR (K)

$$K = \frac{\text{DIAL READING Nº1} - \text{DIAL READING Nº4}}{1745}$$

$$K = \frac{2.39 - 1.65}{1745} = \frac{.74}{1745}$$

$$K = 0.000424$$

CALCULATIONS TO DETERMINE AIR DISPLACEMENT PER DIAL REVOLUTION

NOTE: D.R.$_2$ = DIAL READING AT DIAL READING № 2

REVOLUTION CHANGE EQUAL TO STEEL AT O VOLUME OF AIR (Z)	A	B	C	D	E	F
Z_1 = (440)(K) Z_1 = .187	$A_1 = Z_1 + DR_8$ A_1 = 3.03	$B_1 = A_1 - DR_4$ B_1 = 1.38	$C_1 = 50/B_1$ C_1 = 36.23	$D_1 = Z_1 + DR_7$ D_1 = 3.28	$E_1 = D_1 - DR_3$ E_1 = 1.41	$F_1 = 50/E_1$ F_1 = 35.54
Z_2 = (390)(K) Z_2 = .165	$A_2 = Z_2 + DR_{12}$ A_2 = 4.48	$B_2 = A_2 - DR_4$ B_2 = 2.83	$C_2 = 100/B_2$ C_2 = 35.34	$D_2 = Z_2 + DR_{11}$ D_2 = 4.65	$E_2 = D_2 - DR_3$ E_2 = 2.78	$F_2 = 100/E_2$ F_2 = 36.04
Z_3 = (340)(K) Z_3 = .144	$A_3 = Z_3 + DR_{16}$ A_3 = 5.93	$B_3 = A_3 - DR_4$ B_3 = 4.28	$C_3 = 150/B_3$ C_3 = 35.05	$D_3 = Z_3 + DR_{15}$ D_3 = 6.08	$E_3 = D_3 - DR_3$ E_3 = 4.21	$F_3 = 150/E_3$ F_3 = 35.60
Z_4 = (290)(K) Z_4 = .123	$A_4 = Z_4 + DR_{20}$ A_4 = 7.43	$B_4 = A_4 - DR_4$ B_4 = 5.78	$C_4 = 200/B_4$ C_4 = 34.60	$D_4 = Z_4 + DR_{19}$ D_4 = 7.61	$E_4 = D_4 - DR_3$ E_4 = 5.74	$F_4 = 200/E_4$ F_4 = 34.83
Z_5 = (240)(K) Z_5 = .102	$A_5 = Z_5 + DR_{24}$ A_5 = 8.51	$B_5 = A_5 - DR_4$ B_5 = 6.86	$C_5 = 250/B_5$ C_5 = 36.44	$D_5 = Z_5 + DR_{23}$ D_5 = 8.76	$E_5 = D_5 - DR_3$ E_5 = 6.89	$F_5 = 250/E_5$ F_5 = 36.27
			TOTAL C = 177.66 AVERAGE C = 35.53			TOTAL F = 178.28 AVERAGE F = 35.66

G	H	I	J	K	L
$G_1 = Z_1 + DR_6$ G_1 = 3.53	$H_1 = G_1 - DR_2$ H_1 = 1.39	$I_1 = 50/H_1$ I_1 = 36.05	$J_1 = Z_1 + DR_5$ J_1 = 3.73	$K_1 = J_1 - DR_1$ K_1 = 1.34	$L_1 = 50/K_1$ L_1 = 37.40
$G_2 = Z_2 + DR_{10}$ G_2 = 4.89	$H_2 = G_2 - DR_2$ H_2 = 2.75	$I_2 = 100/H_2$ I_2 = 36.43	$J_2 = Z_2 + DR_9$ J_2 = 5.12	$K_2 = J_2 - DR_1$ K_2 = 2.73	$L_2 = 100/K_2$ L_2 = 36.70
$G_3 = Z_3 + DR_{14}$ G_3 = 6.34	$H_3 = G_3 - DR_2$ H_3 = 4.20	$I_3 = 150/H_3$ I_3 = 35.68	$J_3 = Z_3 + DR_{13}$ J_3 = 6.60	$K_3 = J_3 - DR_1$ K_3 = 4.21	$L_3 = 150/K_3$ L_3 = 35.60
$G_4 = Z_4 + DR_{18}$ G_4 = 7.82	$H_4 = G_4 - DR_2$ H_4 = 5.68	$I_4 = 200/H_4$ I_4 = 35.19	$J_4 = Z_4 + DR_{17}$ J_4 = 8.04	$K_4 = J_4 - DR_1$ K_4 = 5.65	$L_4 = 200/K_4$ L_4 = 35.38
$G_5 = Z_5 + DR_{22}$ G_5 = 8.98	$H_5 = G_5 - DR_2$ H_5 = 6.84	$I_5 = 250/H_5$ I_5 = 36.54	$J_5 = Z_5 + DR_{21}$ J_5 = 9.17	$K_5 = J_5 - DR_1$ K_5 = 6.78	$L_5 = 250/K_5$ L_5 = 36.86
		TOTAL I = 179.89 AVERAGE I = 35.98			TOTAL L = 181.94 AVERAGE L = 36.39

AVERAGE DISPLACEMENT PER DIAL REVOLUTION	
AVERAGE C	35.53
AVERAGE F	35.66
AVERAGE I	35.98
AVERAGE L	36.39
TOTAL AVERAGE	143.56
FINAL AVERAGE = $\frac{\text{TOTAL AVE}}{4}$ =	35.89

NOTES:

1. USE PRESSURE CORRECTION OF 0.05 REVOLUTIONS FOR EVERY 100 PSI DIFFERENCE FROM 5000 PSI AS READ ON THE PRESSURE GAUGE.
2. STIRRUP SHOULD BE IN AIR METER WHENEVER POSSIBLE BEFORE RECORDING A DIAL READING.

RESULTS:

SOLID SLOPE FACTOR 0.000424

CUBIC CENTIMETERS PER DIAL REVOLUTION ______

FIGURE 5

AGGREGATE AIR CORRECTION USING THE HIGH PRESSURE AIR METER-DATA AND CALCULATION SHEET

Project No. AAC9-464 County BLACK HAWK

Date 12/12/69 By DEWEES POTTHOFF

Aggregate RAYMOND QUARRY LIMESTONE Location SE 1/4 36-89-12

Specific Gravity 2.674

Air Meter Characteristics:

A) Solid Slope Factor, K = 0.00042

B) Volume of Air Per Dial Revolution, V = 34.3

C) Use Pressure Correction of 0.05 Revolutions Per 100 PSI Differential from 5,000 PSI.

1) Specimen Reference →	1	2	3		
2) Sat. Surface Dry Wt. (100 x S. Gr.) gms. →	267	267	267		
3) Total Volume, cm^3 →	100	100	100	100	100
4) Dial Reading (Stirrup, Beaker, Liquid) →	2.32	2.32	2.32		
5) Observed Dial Reading →	2.31	2.30	2.30		
6) Adjusted Zero Reading = [4 - (K)(3)] →	2.28	2.28	2.28		
7) Net Revolutions = (5 - 6) →	0.03	0.02	0.02		
8) Observed CC Air = (7)(V) →	1.03	0.69	0.69		
9) % Air in Agg. = 8 as % →	1.03%	.69%	.69%		
10) Average Percent Air in Agg. (Use for Hand Calculating Entrained Air) →	→	0.80%	←		
11) CC Air in Standard Specimen = $\frac{(10)(470)}{100}$ → (Use for Computer Calculating Entrained Air)	→	3.8	←		

NOTE: Items 10 and 11 are to be added to Table II.

Appendix E
Core Description and
High Pressure Air Meter Results

MLR-97-2 Vibratory Effects in Construction of Special Reinforced PCC Pavement
Mahaska County, NHS-163-4(11)- - 19-62, WBL
Station 384+31 to station 389+94, Special Reinforcement

Sample Number	Diameter (inches)	Length (inches)	Station	Distance from E. Edge	Core Target	%Air
1B	4	10.75	385+20	5'3"	Hit top bars intersection	6.7
1T*	4	10.75	385+20	5'3"	"	***
2B	3	10.75	385+30	5'5"	Avoid both mats	6.0
2T	3	10.75	385+30	5'5"	"	5.4
3B	3	10.50	385+40	6'3"	"	5.8
3T	3	10.50	385+40	6'3"	"	5.4
4B	3	10.00	385+50	6'8"	"	5.4
4T	3	10.00	385+50	6'8"	"	5.0
5B	3	10.75	385+60	7'1"	"	5.3
5T	3	10.75	385+60	7'1"	"	5.1
6B*	4	10.25	385+70	7'10"	Hit bottom bars intersection	5.2
6T	4	10.25	385+70	7'10"	"	4.8
7B	4	10.00	387+20	10'1"	Hit top bars intersection	6.3
7T*	4	10.00	387+20	10'1"	"	5.0
8B	3	10.25	387+30	10'11"	Avoid both mats	6.0
8T	3	10.25	387+30	10'11"	"	5.7
9B	3	10.75	387+40	12'0"	"	5.2
9T	3	10.75	387+40	12'0"	"	6.2
10B	3	10.50	387+50	13'0"	"	4.8
10T	3	10.50	387+50	13'0"	"	5.2
11B	3	10.75	387+60	13'11"	"	4.2
11T	3	10.75	387+60	13'11"	"	4.9
12B**	4	10.50	387+70	17'8"	Hit bottom bars intersection	5.4
12T	4	10.50	387+70	17'8"	"	5.4
					Average	5.4

* Calculation accounts for steel
** Steel not in core
***Invalid test results

<u>% Air Averages</u>

Total for Cores 1 - 12	5.4
Total for Top	5.3
Total for Bottom	5.5
Total Cores 1 - 6	5.5
Total Cores 7 - 12	5.3
Total for Top 1 - 6	5.1
Total for Bottom 1 - 6	5.7
Total for Top 7 - 12	5.4
Total for Bottom 7 - 12	5.3

Problem Considerations
1. Improve positioning of steel mat
2. No significant change to vibration
3. To reduce surface mat pattern:
- Use paver super-smoother
- Increase slump
- Cause auxiliary vibrators to systematically touch steel bars

Appendix F
Auxiliary Vibrator Use

AUXILIARY VIBRATOR USE

PAVER SPEED FT/MIN	PAVER WIDTH FT	AREA PAVED FT^2	FT^2 COVERED /VIBRATOR INSERTION 2' X 2'/3' X 3')	INSERTIONS/MIN	SECONDS/INSERTION
4	26	104	4/9	26/12	2.3/5
6	26	156	4/9	39/17	1.5/4
8	26	208	4/9	52/23	1.2/3
10	26	260	4/9	65/29	1/2