Early Entry Sawed Portland Cement Concrete Transverse Joint Ends

Final Report
For
MLR-97-05

April 2003

Highway Division

Iowa Department
Of Transportation

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By
Robert Steffes
Assistant to the Research Engineer
515-239-1392
FAX 515-817-6594

And

BJ Siljenberg
Materials Research

Office of Materials
Highway Division
Iowa Department of Transportation
Ames, Iowa 50010

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5. AUTHOR(S)

Robert Steffes
Assistant to the Research Engineer

BJ Siljenberg
Materials Research

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Iowa Department of Transportation
Office of Materials
800 Lincoln Way
Ames, Iowa 50010

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Des Moines Construction
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Office of Materials

Thanks and appreciation go out to the project RCE, Mitch Dillavou, the Contractor representative, Mike Flynn, and to supporters from Materials Research who helped make this research possible.

8. ABSTRACT

Experiments with early entry light sawing of Portland cement concrete (PCC) contraction joints began in Iowa in 1989. Since that time, changes in early sawing equipment have occurred as well as changes in specifications for sawing. The option to use early sawing for transverse contraction joints was specified in 1992. A problem happening occasionally with early sawing was the break out of some of the concrete around the end of the joint as the saw blade approached the edge of the slab. To prevent this, it was proposed that the sawing would terminate approximately ½" to ¾" before the edge of the slab, creating a "short joint". This procedure would also leave a concrete "dam" to prevent the run-out and waste of the hot liquid joint sealant onto the shoulder. It would also eliminate the need for the labor and material for applying a duct tape dam at the open ends of each sawed joint to stop hot liquid sealant run-out.

Agreements were made with the contractor to apply the "short joint" technique for 1 day of paving. The evaluation and results are compared with an adjoining control section.

The research found no negative aspects from sawing the "short joint". Three specific findings were noted. They are the following:

1) No joint end "blow-out" spalls of concrete occurred.
2) The need for the duct tape dam to stop liquid sealant overflow was eliminated.
3) Joint end corner spalls appear to be caused mainly by construction shouldering operations equipment.

The "short joint" sawing technique can be routinely applied to early entry sawed transverse contraction joints with expectations of only positive results.

9. KEY WORDS

Contraction Joint Cracking
Corner Spalls

10. NO. OF PAGES

48

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DISCLAIMER

INTRODUCTION

Experiments with early entry light sawing of PCC contraction joints began in Iowa in 1989. Since that time, changes have been made to the equipment and procedures used in early sawing. The option to use early sawing for transverse contraction joints was first specified in 1992.

The conventional method of early sawing of PCC was cutting a 1 1/8 inch deep joint with the saw blade passing completely out through the edge of the slab. This practice, in "green" concrete, often resulted in an immediate large spall at the joint end or caused hairline cracks which result in corner breaks or spalls later (See Figure 1). A logical cause for this spalling was the saw blade being forced toward the unsupported slab edge. In addition, sawing completely out to the shoulder resulted in weakening of the joint ends leading to potential additional damage or corner spalls from roadway construction and maintenance equipment operating or scraping along the shoulder's edge (See Figure 2).

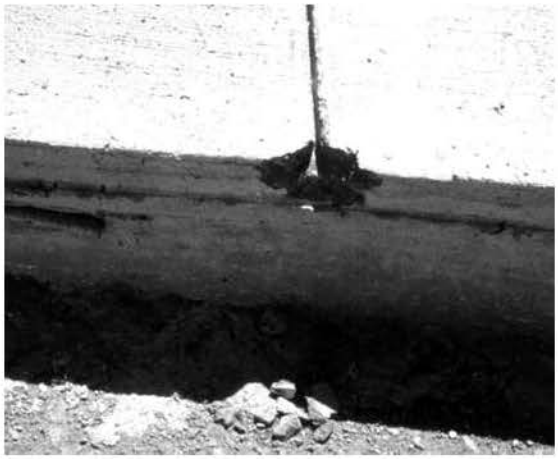


Figure 1
Joint End Corner Spall

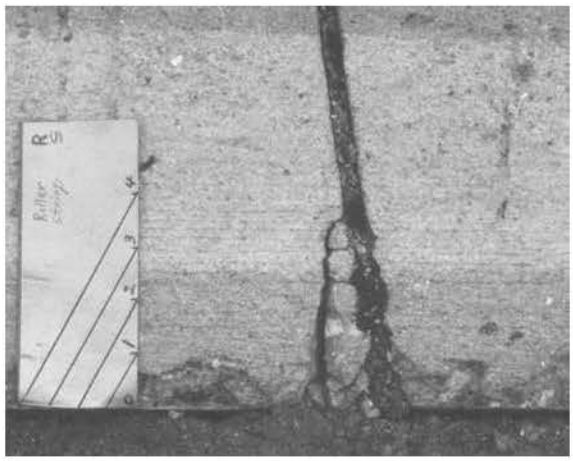


Figure 2
Joint End Corner Spall

OBJECTIVE

Reduction of the joint end spalling is the primary objective of this research (See Appendix A). In order to do this, a southbound lane test section of one day's paving on highway US 65 bypass southeast of Des Moines has been evaluated using non-conventional methods. This procedure involved early sawing of the transverse contraction joints at the conventional depth of 1 1/8 inches up until approximately ½ to ¾ inch before the leading edge of the blade reaches the end of the slab. Stopping the saw at that point created a "short joint". In addition to preventing end spalls, this method will decrease costs of labor by leaving a concrete "dam" to contain hot pour sealant from flowing out over the end of the joint (See Figure 3). Currently, materials and labor are used to create a duct tape dam at the end of each joint. The tape dam has a high rate of adhesion failure due to the curing compound coating on the PCC (See Figure 4).

Figure 3
"Short Cut" creates a sealant dam.

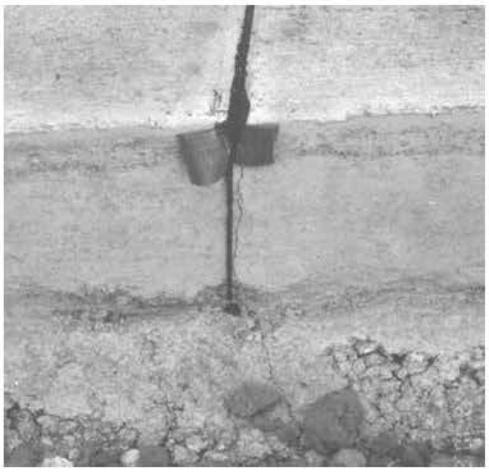


Figure 4
Adhesion failure of duct tape and sealant leakage.

PROJECT LOCATION

The research test section is in Polk and Warren counties new PCC paving project NHS-500-1(96)--19-77. An agreement was made with the contractor to apply the ½" to ¾" short joint technique for 1 day of paving. Construction began on September 3, 1997. Research was conducted on the southbound 2 lanes of highway US 65 bypass, in Warren County. To identify the location of joint ends, the right side of the pavement was called "right of way" (ROW) side, and the left side was called "median" side. Construction of the research section was from station 583+18 to station 615+50. The following two days of paving, from station 615+50 to 642+96, serve as control sections #1 and #2 for the research. The research test section consisted of 162 transverse joints and the two control sections consisted of a total of 138 transverse joints.

JOINT GEOMETRY

The transverse joints were skewed 6:1, and made at 20 ft. spacing. They were early entry sawed in a single pass, with joint dimensions being 1/4" wide and 1 1/8" deep.

SEALING PROCEDURE

The joints were blown clean at sawing time. After 48 hours to 72 hours, the joints were re-blown clean and filled with a hot poured asphaltic sealant up to 1/8" to 1/4" from the top. No backer rod was used. The longitudinal joint was treated in the conventional manner and is not a part of this study.

TESTING PROCEDURE

Measurements to determine corner spall lengths were made (in inches) using a special gauge (See Figure 5). Contraction joint crack width was measured in inches using a crack comparator (See Figure 6).

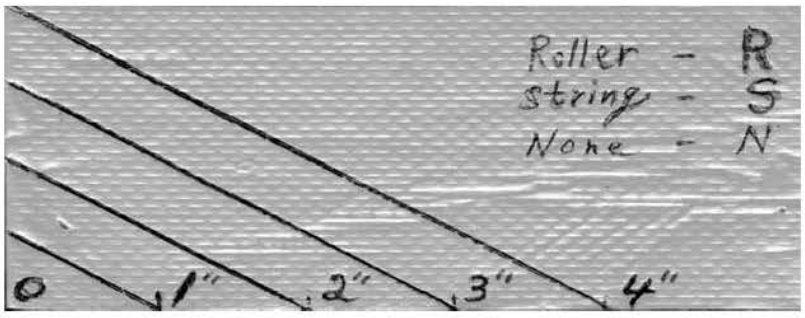


Figure 5
Corner Spall Gauge
(Not to scale)

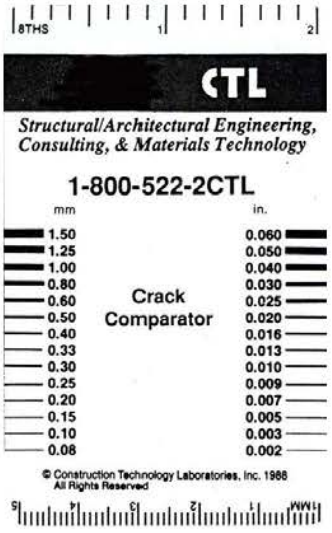


Figure 6
Crack Comparator
(Not to scale)

OBSERVATIONS

The evaluation of the early entry light sawed joint ends performance was done starting on September 7, 1997. Several observations were significant. The first was:

- The saw did not always follow, exactly, the mark left by the contractors' joint marking string. The string marking action on the plastic concrete over the center of the dowel basket, often created a deep groove near the shoulder, simulating a shallow joint (See Figure 7). That groove created a secondary-like joint and provided a path for the hot liquid sealant to escape over the shoulder's edge. It can eliminate the benefit of the dam left by the "short joint".

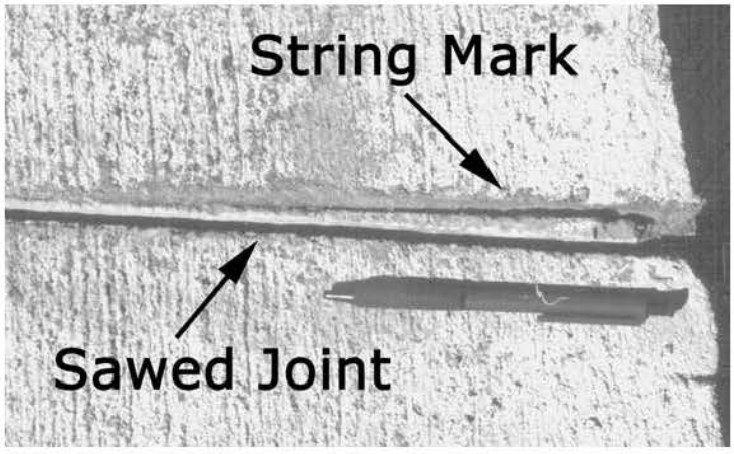


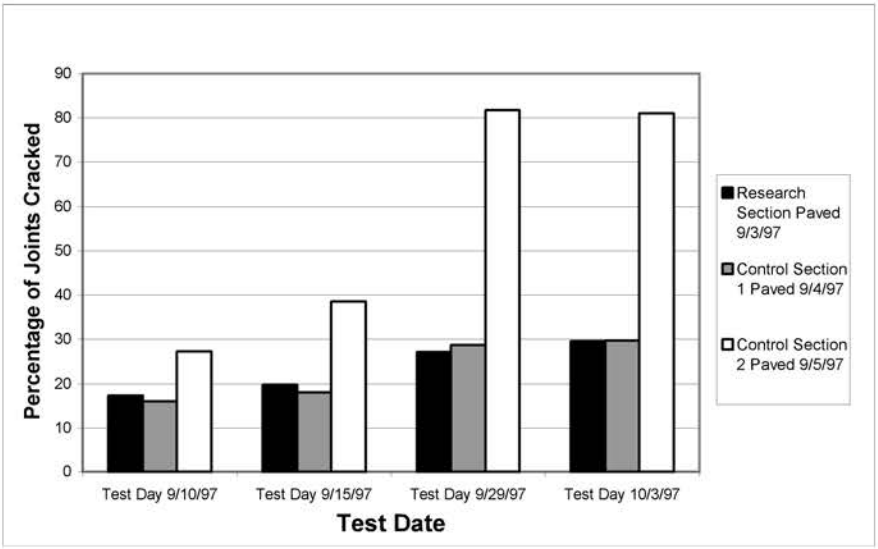
Figure 7
String mark seen beside sawed joint.

- A later observation showed that damage done along the top edge of the slab by shouldering construction equipment was a main cause of joint end corner spalls. As the motor grader blade and compaction roller scrape along the edge of the slab, they can cause extensive chipping and spalling, especially at the location of the joint end. (See Figure 2 and data in Appendix B) The "short joint" sawing technique eliminates the vulnerable weak corners at the end of a joint and provides joint-end/corner support to minimize damage done by shouldering equipment (See Figure 3 and data in Appendix C). The control section, in which joint sawing was done completely out through the edge of the slab, suffered significantly more shouldering construction damage than the "short joint" test section. From the results in Appendix B one could conclude that the shouldering equipment was traveling northbound on the median side and southbound on the ROW side, that equipment was being forced against the edge of the slab and was breaking joint end corners off and was pushing them into the joint reservoir, as shown in Figure 2. It should be noted that the depth of the joint end corner spalls is to the bottom of the sawed joint and is not a full slab depth corner crack. In the "short joint" test section there was, in general, less joint end corner spalls than in the control section.

Contraction Joint Cracking

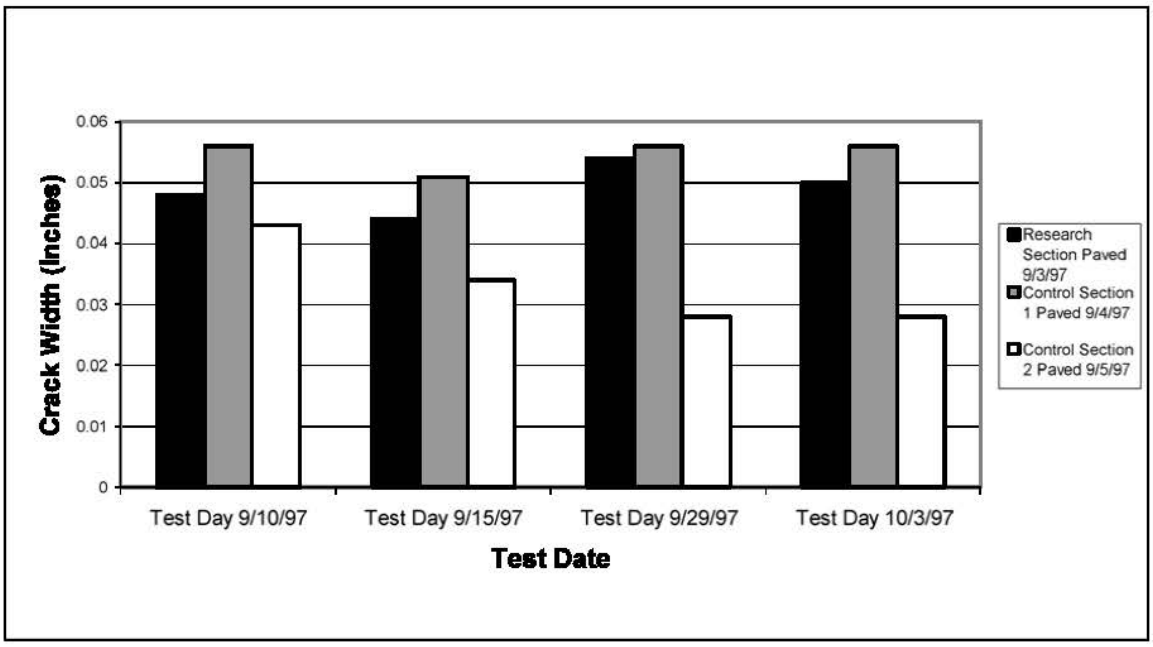
The development of shrinkage cracks below the sawed joints was observed along the shoulder's edge and recorded progressively on 4 different dates before shouldering work covered the edge of the slab. The data is given in Appendix D. It is interesting to note the rate of concrete joint shrinkage crack development over time. The research section and control section #1 each acted in a similar way, but control section #2 had an unusually high rate of joint cracking. Over the 3 sections, the percent of joints cracked at approximately 1 week of age was 17.3, 16.0 and 27.3 respectively and at 4 weeks of age was 29.6, 29.8 and 81.8 respectively (See Graph 1).

Graph 1
Percentages of Contraction Joints Cracked



Analysis of paving and weather data over that time period did not show any significant changes which would influence the high cracking rate for control section #2, as shown in the data on page 20 near the end of Appendix D. It is interesting to note that the number of contraction joint cracks in control section #2 were much higher (82%) than in control section #1 (30%). It is also interesting to note that the crack width for control section #2 was about half as wide (0.028 inches) as control section #1 (0.056 inches) and in the research section (0.050 inches). (See Graph 2) The cause for the difference in joint cracking rate was not determined.

Any joint that showed a shrinkage crack on one shoulder also showed it on the opposite shoulder, indicating that the crack was full length. There were no mid panel or random cracks observed.

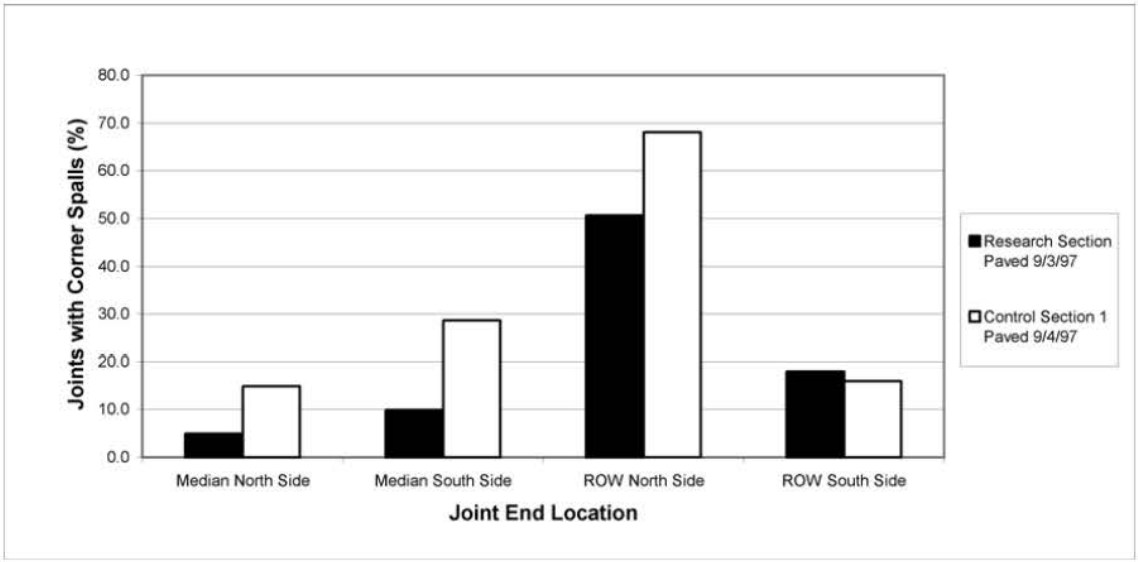


Graph 2
Average Crack Width

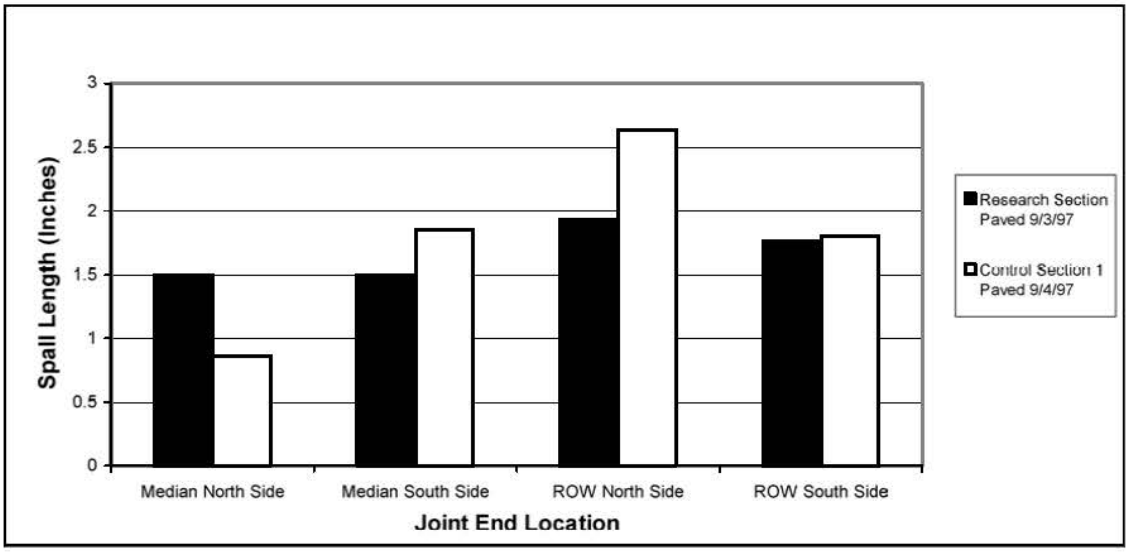
Corner Spalls

In the test section passing lane end of the joint, 10% of the south and 5% of the north joint ends have corner spalls. This is much less than the control section where 35% of south and 13% of north joint ends have corner spalls. Actual sizes of the spalls in the test section are also smaller with an average length of 1.5 inches on both, the north and the south sides. Control section corner spall sizes average 2 inches in length on the south side and 1.6 inches on the north side (See Appendix B).

The test section ROW end of the joint contains even more damage (See Graph 3). The test section shows damage on 17.9% of the joint ends on the south side and 50.6% on the north side. Similarly, control section 1 showed 16.0% of the joint ends damaged on the south side and 68.1% on the north side. Control section 2 showed 9.1% of joints damaged on the south side and 47.7% on the north side (See page 20 in Appendix B). Test section joints have spalls averaging 1.9 inches on the north side and 1.5 inches on the south side (See Graph 4). The control corner spalls average 2.5 inches on the north side of joint ends and 1.7 inches on the south side (See Appendix B).



Graph 3
Joint End Corner Spalls



Graph 4
Average Corner Spall Lengths

In summary, the control sections have more end spalls and longer spalls. This damage can result from sawing a full length joint or from a combination of that sawing and shouldering operations.

CONCLUSIONS/RECOMMENDATION

This test results shows that stopping the joint sawing ½" to ¾" before the shoulder end can reduce spalling at the joint ends. By leaving a small amount of concrete unsawed in the end of the joint, the saw blade does not push through the slab edge and initiate damage. In addition, the concrete dam left from "short joint" sawing serves to maintain strength at the joint end. This maintained strength provides protection to minimize damage when shoulder construction work is performed. The force of shouldering construction equipment against the edge of the pavement appears to be the primary cause of joint corner spalls. Shouldering construction operations can cause significant damage to sawed joint ends. The concrete dam left in the end of the joint will stop the overflow and loss of sealant and will also eliminate the need to install the duct tape barrier. Based upon joint performance from this research, it is recommended that "short joint" sawing practices be implemented in early entry sawing of PCC contraction joints. In addition, it is recommended that the joint marking operation be such that it does not cut into the edge of the pavement.

IMPLEMENTATION

Following the recommendations of this research will result in significantly less joint corner spalls and procure a roadway with a better appearance. The elimination of the need for the duct tape dam at the ends of each joint will bring a construction savings in materials and labor.

APPENDIX A

MATERIALS LABORATORY RESEARCH PROPOSAL

DATE: August 27, 1997

PROJECT: MLR-97-5

PROJECT TITLE: Soff-Cut Sawed PCC Joint Ends

PRINCIPAL INVESTIGATOR: Bob Steffes

OBJECTIVE: The objective of this research is to determine which of two joint sawing procedures provides the more favorable performance to reduce joint end spalls.

DISCUSSION: With the current method of early sawing of transverse PCC joints, using a Soff-Cut saw, the saw blade passes completely out of the end of the joint while cutting at a constant depth. In many cases, a large shoulder spall occurs at the end of the joint from the saw blade force toward the edge of the slab.

PURPOSE: Shoulder spalls should be prevented if joint sawing would stop approximately ½ to ¾ inch before coming out of the edge of the slab. A fringe benefit of labor reduction would also occur as the operation of applying a duct tape dam to prevent the hot pour sealant from flowing out of the end of the sawed joint would not be needed.

PROCEDURE: The procedure for the proposed research would be to saw at standard depth until about ½ to ¾ inch before the leading edge of the blade reaches the end of the slab. At that point, the forward motion of the saw is stopped and the saw blade is raised vertically out of the joint.

This procedure would be done for a test section of approximately 1,000 ft. of paving length or one day of paving.

ANALYSIS: The results of this proposed sawing procedure will be compared with the standard procedure in which the saw blade passes completely out of the edge of the slab.

RESPONSIBILITIES: The Resident Construction Engineer of the Des Moines Construction Residency will coordinate the research with a contractor.

The Materials Research Office will observe, evaluate and compare results from the research.

REPORTING: The Materials Research Office will write a brief construction report followed by a final report at the end of three years.

APPENDIX B

JOINT END CORNER SPALLS - LOCATION AND LENGTH

Location (Joint Number or Station)
Length (Inch)

Joint End Corner Spalls – Location And Length

Joint Number	Station	Median North Side	Median South Side	ROW North Side	ROW South Side
1	583+18	0	0	2	0
2		0	0	1	0
3		0	0	1	0
4		0	0	2	0
5	584+02	0	0	2	0
6		0	0	0	0
7		0	0	1	1
8		0	0	0	0
9		0	0	0	0
10	585+02	0	0	1	0
11		0	0	0	0
12		0	0	0	0
13		0	0	0	0
14		0	0	0	0
15	586+02	0	0	3	3
16		0	0	0	0
17		0	0	0	0
18		0	0	0	0
19		0	0	0	0
20	587+02	0	0	0	0
21		0	0	1	2
22		0	0	0	0
23		0	0	2	2
24		0	0	4	0
25	588+02	1	0	2	0
26		0	0	0	0
27		0	0	0	0
28		0	0	2	0
29		0	0	0	1
30	589+03	0	0	2	2
31		0	0	2	0
32		0	0	3	0
33		0	0	4	2
34		0	0	1	2
35	590+03	0	0	1	2
36		0	0	1	1
37		0	2	1	0
38		0	0	0	0
39		0	0	0	0
40	591+03	0	0	0	0
41		0	0	0	0
42		0	1	3	0
43		0	0	1	0
44		0	0	0	0
45	592+03	0	1	3	0

Joint End Corner Spalls – Location And Length

Joint Number	Station	Median North Side	Median South Side	ROW North Side	ROW South Side
46		0	0	0	0
47		0	0	0	0
48		0	0	0	0
49		0	0	0	0
50	593+03	0	0	0	0
51		0	0	2	0
52		0	0	1	1
53		0	0	1	0
54		0	0	0	0
55	594+03	0	0	0	0
56		0	0	0	0
57		0	0	2	2
58		0	0	2	0
59		0	0	1	1
60	595+02	0	0	0	0
61		0	0	0	0
62		0	0	0	0
63		0	0	0	0
64		0	0	0	0
65	596+03	0	0	0	0
66		0	0	0	0
67		0	0	0	0
68		0	0	2	2
69		0	0	0	0
70	597+04	0	0	0	0
71		0	0	0	0
72		0	0	0	0
73		0	0	1	2
74		0	0	0	0
75	598+03	0	0	0	0
76		0	0	0	0
77		0	0	0	1
78		0	0	1	2
79		0	0	0	0
80	599+03	0	0	0	0
81		0	0	0	0
82		0	0	1	0
83		0	1	0	0
84		0	0	0	0
85	600+04	1	1	1	0
86		2	2	0	0
87		0	0	0	0
88		0	0	0	0
89		0	0	1	1
90	601+03	0	0	1	0

Joint End Corner Spalls – Location And Length

Joint Number	Station	Median North Side	Median South Side	ROW North Side	ROW South Side
91		0	0	0	0
92		0	1	0	0
93		0	0	0	0
94		0	0	0	0
95	602+03	0	0	3	0
96		0	0	0	0
97		0	0	0	0
98		0	0	1	0
99		0	0	1	1
100	603+03	0	0	3	0
101		0	0	0	2
102		0	0	0	0
103		0	0	1	0
104		0	0	0	0
105	604+03	0	0	0	0
106		0	0	0	0
107		0	0	0	0
108		0	0	4	0
109		0	0	0	0
110	605+02	1	2	1	0
111		0	0	3	0
112		0	0	3	0
113		0	0	4	0
114		0	0	0	0
115	606+03	0	0	0	0
116		0	0	0	0
117		0	0	3	0
118		0	0	2	3
119		0	0	2	0
120	607+03	0	0	3	1
121		0	0	1	1
122		0	0	1	0
123		0	0	0	0
124		0	0	0	0
125	608+02	0	0	3	0
126		0	0	1	0
127		0	1	0	0
128		0	1	0	0
129		0	0	2	1
130	609+02	0	0	0	0
131		0	0	2	1
132		0	0	1	1
133		0	0	1	1
134		0	0	0	0
135	610+01	0	0	1	0

Joint End Corner Spalls – Location And Length

Joint Number	Station	Median North Side	Median South Side	ROW North Side	ROW South Side
136		0	3	1	0
137		2	0	2	0
138		0	0	4	0
139		2	0	3	7
140	611+01	0	0	0	0
141		0	0	1	0
142		0	0	2	0
143		0	0	2	2
144		2	2	2	0
145	612+02	0	0	1	0
146		0	0	1	0
147		0	0	1	0
148		0	1	2	0
149		0	0	3	0
150	613+02	0	1	3	0
151		0	0	2	0
152		0	0	1	0
153		0	3	0	0
154		0	0	2	0
155	614+02	0	0	4	0
156		0	0	3	0
157		0	0	0	0
158		1	1	2	0
159		0	0	0	0
160	615+02	0	0	0	0
161	615+20	0	0	3	0
162	615+50	0	0	3	0
Total number of joints		162	162	162	162
Number of joints with corner spalls		8	16	82	29
Total length of corner spalls		12	24	158	51
Average spall length for all joints		0.07	0.15	0.98	0.31
Average spall length for spalled joints		1.50	1.50	1.93	1.76

Joint End Corner Spalls – Location And Length

Joint Number	Station	Median North Side	Median South Side	ROW North Side	ROW South Side
163		0	0	0	0
164		0	2	2	2
165	616+02	0	0	3	0
166		0	0	3	0
167		0	0	1	0
168		0	0	2	1
169		0	0	2	0
170	617+02	1	1	4	0
171		0	0	0	0
172		0	0	2	0
173		0	1	4	3
174		0	0	4	0
175	618+02	0	0	4	0
176		0	0	4	0
177		0	0	1	1
178		0	0	0	0
179		0	0	1	2
180	619+02	0	0	4	0
181		0	0	5	0
182		0	0	2	0
183		0	0	0	0
184		0	0	0	2
185	620+03	0	2	3	0
186		0	0	3	0
187		0	0	0	0
188		0	0	0	0
189		2	3	5	0
190	621+02	1	0	4	0
191		0	0	1	0
192		0	0	0	0
193		1	0	0	0
194		0	0	3	0
195	622+02	0	0	6	0
196		0	1	0	2
197		0	0	0	0
198		0	0	2	0
199		0	0	3	0
200	623+02	0	0	0	1
201		0	0	2	2
202		0	0	3	1
203		0	0	4	0
204		0	0	3	0
205	624+02	0	0	2	2
206		0	0	0	2
207		0	1	0	0

Joint End Corner Spalls – Location And Length

Joint Number	Station	Median North Side	Median South Side	ROW North Side	ROW South Side
208		0	0	2	0
209		0	0	2	0
210	625+02	0	0	4	0
211		0	0	1	0
212		0	0	3	0
213		0	1	0	0
214		0	3	1	0
215	626+02	1	1	2	3
216		2	2	2	0
217		0	0	3	0
218		0	0	4	0
219		1	0	1	0
220	627+00	0	0	3	0
221		0	1	1	0
222		0	0	3	0
223		0	2	0	0
224		2	0	0	0
225	628+01	0	0	0	0
226		2	2	0	0
227		0	1	2	0
228		0	3	3	0
229		0	2	0	0
230	629+01	1	0	1	0
231		0	0	0	0
232		0	0	3	0
233		0	0	0	0
234		2	0	3	0
235	629+99	0	2	1	0
236		0	0	0	0
237		1	1	1	0
238		0	1	4	2
239		0	2	2	0
240	631+01	1	1	4	0
241		0	0	0	0
242		0	0	2	0
243		0	2	2	0
244		0	0	0	0
245	632+02	0	2	0	1
246		1	0	0	0
247		0	0	0	0
248		0	0	2	0
249		0	0	3	0
250	633+02	0	2	4	0
251		0	0	2	0
252		0	4	2	0

Joint End Corner Spalls – Location And Length

Joint Number	Station	Median North Side	Median South Side	ROW North Side	ROW South Side
253		0	0	0	0
254		0	4	2	0
255	633+98	0	0	0	0
256	634+19	0	0	2	0
Total number of joints		94	94	94	94
Number of joints with corner spalls		14	27	64	15
Total length of corner spalls		19	50	169	27
Average spall length for all joints		0.20	0.53	1.80	0.29
Average spall length for spalled joints		1.36	1.85	2.64	1.80

Joint End Corner Spalls – Location And Length

Joint Number	Station	Median North Side	Median South Side	ROW North Side	ROW South Side
257	634+40	0	0	0	0
258		0	0	3	0
259		0	1	0	0
260	635+02	0	0	0	0
261		0	0	1	0
262		0	0	0	2
263		0	0	0	0
264		0	0	2	0
265	635+98	0	2	2	0
266		0	0	1	1
267		0	0	0	0
268		2	4	0	0
269		2	2	1	0
270	636+98	0	2	0	0
271		0	3	2	0
272		0	0	0	0
273		0	3	4	0
274		0	2	0	0
275	637+98	0	2	0	0
276		0	0	0	0
277		0	1	0	0
278		0	0	2	0
279		0	0	1	0
280	638+97	0	4	3	0
281		0	3	2	1
282		0	3	4	2
283		0	2	0	0
284		0	1	2	0
285	639+95	4	2	1	0
286		0	0	0	0
287		0	0	0	0
288		0	0	2	0
289		0	0	1	0
290	640+95	0	0	0	0
291	641+15	0	0	0	0
292		0	0	0	0
293		0	0	0	0
294		0	1	4	0
295		0	2	2	0
296	642+16	0	0	1	0
297		0	1	1	0
298		0	3	0	0
299		0	0	0	0
300		2	2	0	0

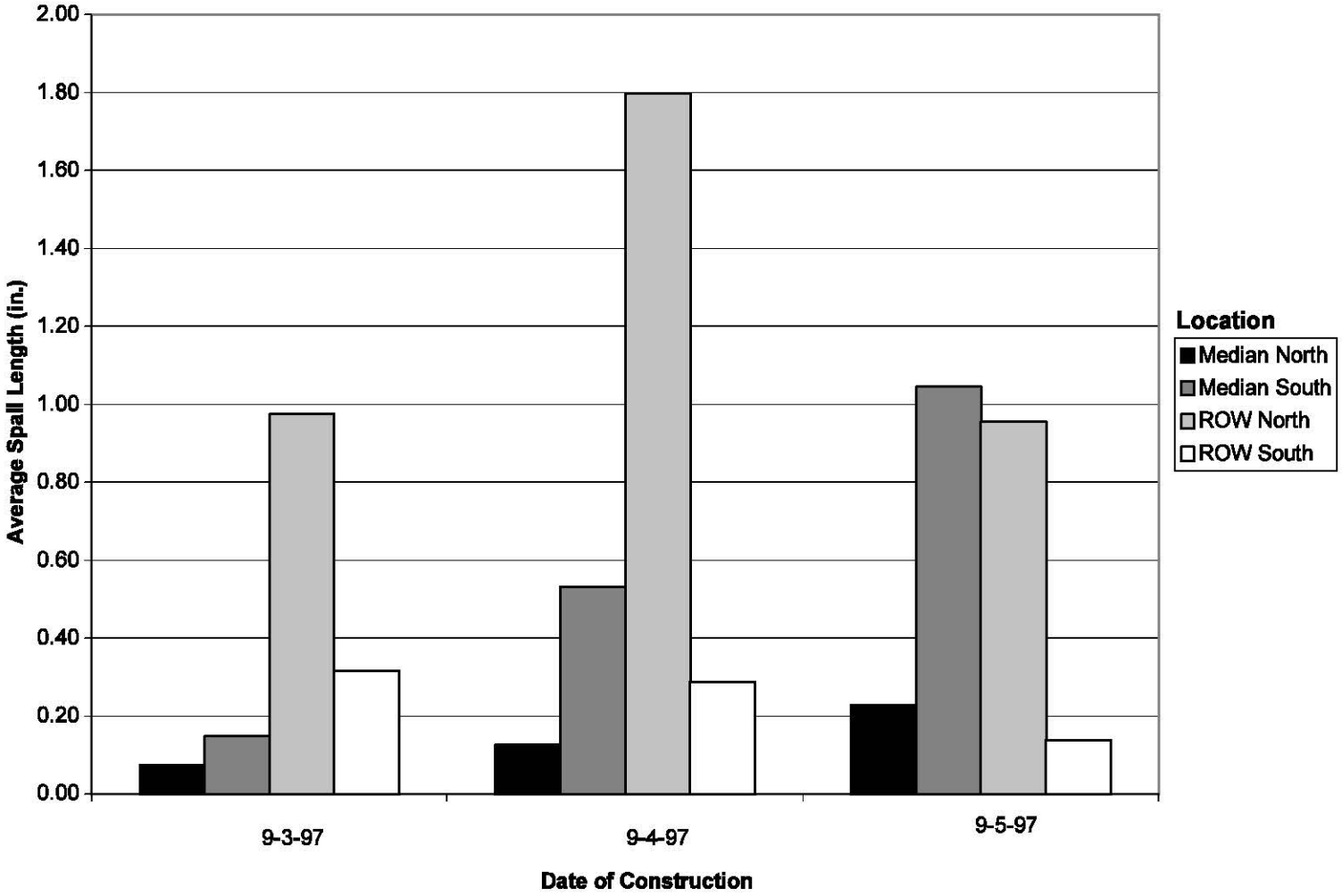
Joint End Corner Spalls – Location And Length

	Median North Side	Median South Side	ROW North Side	ROW South Side
Total number of joints	44	44	44	44
Number of joints with corner spalls	4	21	21	4
Total length of corner spalls	10	46	42	6
Average spall length for all joints	0.23	1.05	0.95	0.14
Average spall length for spalled joints	2.50	2.19	2.00	1.50

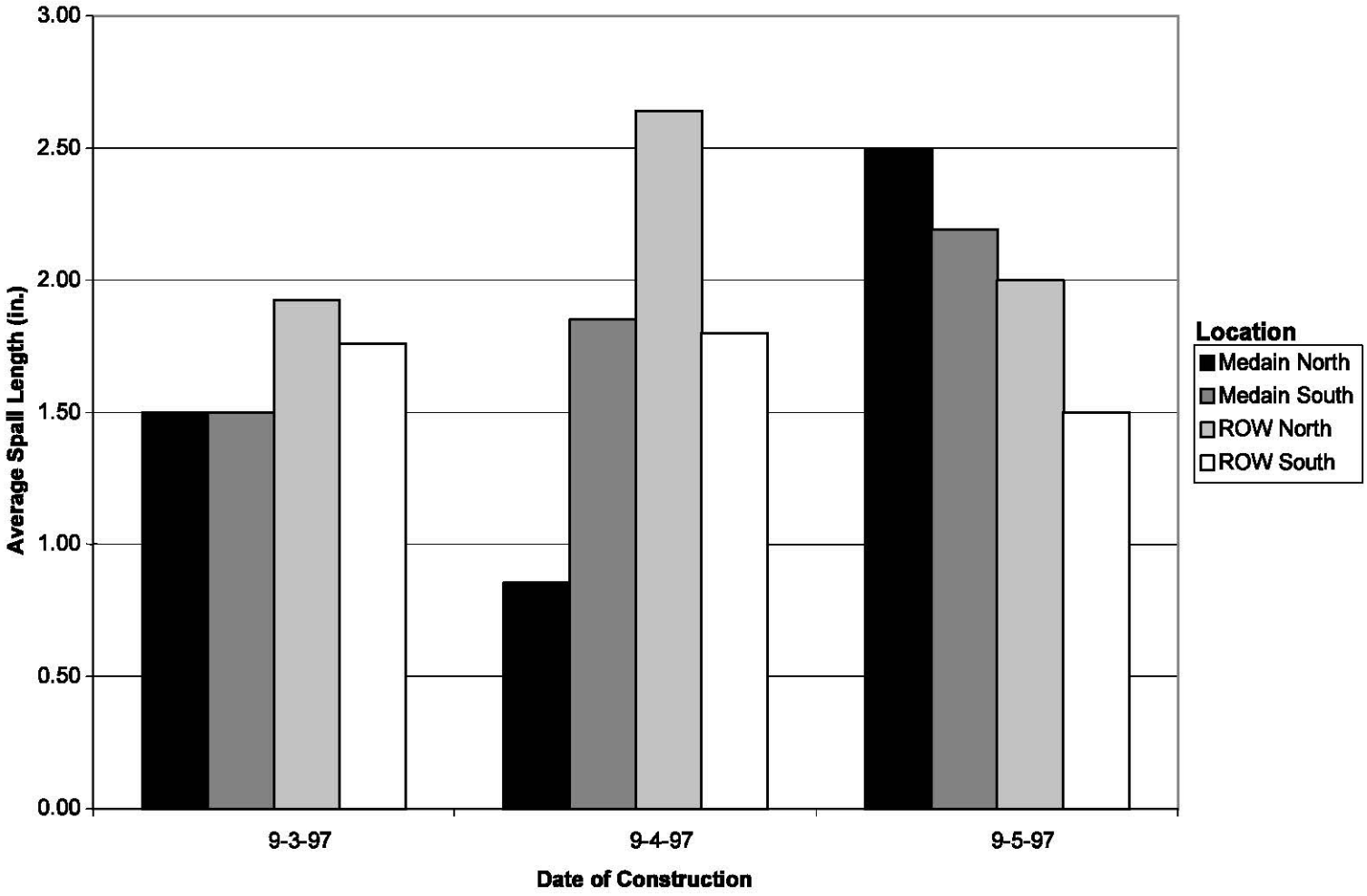
Joint End Corner Spalls – Location And Length

Joint End Spall Data (Appendix B) Summary

Description	Median North Side	Median South Side	ROW North Side	ROW South Side
Research Section Paved 9/3/97				
Total number of joints	162	162	162	162
Number of joints with corner spalls	8	16	82	29
Total length of corner spalls	12	24	158	51
Average spall length for all joints	0.07	0.15	0.98	0.31
Average spall length for spalled joints	1.50	1.50	1.93	1.76
Percent joints spalled	4.9	9.9	50.6	17.9
Control Section 1 Paved 9/4/97				
Total number of joints	94	94	94	94
Number of joints with corner spalls	14	27	64	15
Total length of corner spalls	12	50	169	27
Average spall length for all joints	0.13	0.53	1.80	0.29
Average spall length for spalled joints	0.86	1.85	2.64	1.80
Percent joints spalled	14.9	28.7	68.1	16.0
Control Section 2 Paved 9/5/97				
Total number of joints	44	44	44	44
Number of joints with corner spalls	4	21	21	4
Total length of corner spalls	10	46	42	6
Average spall length for all joints	0.23	1.05	0.95	0.14
Average spall length for spalled joints	2.50	2.19	2.00	1.50
Percent joints spalled	9.1	47.7	47.7	9.1



Graph B-1: Average Joint End Spall Length For All Joints.



Graph B-2: Average Joint End Spall Length For Spalled Joints.

APPENDIX C

JOINT END CORNER SPALLS - CAUSE, NUMBER and LENGTH

Cause (Roller/Grader or Sting)
Number (Spalls)
Length (Inch)

Joint End Corner Spalls – Cause, Number and Length

Joint Number	Station	Median Side		ROW Side	
		Roller/Grader	String	Roller/Grader	String
1	583+18	0	0	1	0
2		1	0	0	0
3		0	0	0	1
4		0	0	1	0
5	584+02	0	0	0	2
6		0	0	1	0
7		0	0	0	1
8		0	0	0	2
9		0	0	1	0
10	585+02	0	0	0	0
11		0	0	2	0
12		0	0	0	0
13		0	0	0	0
14		0	0	0	0
15	586+02	0	0	0	0
16		0	0	3	0
17		0	0	0	0
18		1	0	0	0
19		0	0	0	0
20	587+02	0	0	0	0
21		0	0	0	0
22		1	0	0	0
23		0	0	0	0
24		0	0	0	0
25	588+02	1	0	4	0
26		0	0	1	0
27		0	0	0	0
28		0	0	0	0
29		1	0	2	0
30	589+03	0	0	0	0
31		0	1	2	0
32		0	0	0	0
33		0	0	2	0
34		0	0	3	0
35	590+03	0	0	2	0
36		0	0	2	0
37		0	0	1	0
38		0	0	1	0
39		0	0	0	0
40	591+03	0	0	2	0
41		0	0	0	0
42		0	0	1	0
43		0	0	3	0
44		0	0	1	0
45	592+03	0	0	0	0

Joint End Corner Spalls – Cause, Number and Length

Joint Number	Station	Median Side		ROW Side	
		Roller/Grader	String	Roller/Grader	String
46		0	0	3	0
47		0	0	1	0
48		0	0	0	0
49		0	0	1	0
50	593+03	0	0	2	0
51		0	0	0	0
52		0	0	2	0
53		0	0	1	0
54		0	0	0	0
55	594+03	0	0	1	0
56		0	0	0	0
57		0	0	0	0
58		0	0	2	0
59		0	0	2	0
60	595+02	0	0	1	0
61		1	0	0	0
62		0	0	0	0
63		0	0	0	0
64		0	0	0	0
65	596+03	0	0	0	0
66		0	0	0	0
67		0	0	0	0
68		0	0	0	0
69		0	0	3	0
70	597+04	0	0	1	0
71		0	0	0	0
72		0	0	0	0
73		0	0	0	0
74		0	0	2	0
75	598+03	0	0	0	0
76		0	0	0	0
77		0	0	0	0
78		0	0	1	0
79		1	0	2	0
80	599+03	0	0	0	0
81		0	0	1	0
82		0	0	0	0
83		1	0	1	0
84		0	0	0	0
85	600+04	0	0	0	0
86		1	0	1	0
87		2	0	0	0
88		0	0	0	0
89		0	0	1	0
90	601+03	1	0	1	0

Joint End Corner Spalls – Cause, Number and Length

Joint Number	Station	Median Side		ROW Side	
		Roller/Grader	String	Roller/Grader	String
91		0	0	1	0
92		0	0	1	0
93		1	0	0	0
94		0	0	1	0
95	602+03	1	0	0	0
96		1	0	3	0
97		1	0	0	0
98		0	0	1	0
99		0	0	1	0
100	603+03	0	0	2	0
101		0	0	3	0
102		0	0	2	0
103		0	0	1	0
104		0	0	0	0
105	604+03	1	0	1	0
106		0	0	0	0
107		0	0	0	0
108		0	0	0	0
109		0	0	0	0
110	605+02	0	0	0	0
111		2	0	2	0
112		0	0	3	0
113		0	0	3	0
114		0	0	4	0
115	606+03	0	0	0	0
116		0	0	0	0
117		0	0	0	0
118		0	0	0	0
119		0	0	3	0
120	607+03	0	0	2	0
121		0	0	4	0
122		0	0	1	0
123		0	0	1	0
124		0	0	0	0
125	608+02	0	0	0	0
126		0	0	3	0
127		1	0	1	0
128		1	0	0	0
129		0	0	0	0
130	609+02	0	0	2	0
131		0	0	0	0
132		0	0	2	0
133		0	0	1	0
134		0	0	2	0
135	610+01	0	1	1	0

Joint End Corner Spalls – Cause, Number and Length

Joint Number	Station	Median Side		ROW Side	
		Roller/Grader	String	Roller/Grader	String
136		0	0	1	0
137		3	0	1	0
138		2	0	1	0
139		0	0	3	0
140	611+01	2	0	4	0
141		0	0	0	0
142		0	0	1	0
143		0	0	1	0
144		0	0	2	0
145	612+02	2	0	1	0
146		0	0	0	0
147		0	0	1	0
148		2	0	0	0
149		0	0	2	0
150	613+02	0	0	3	0
151		2	0	3	0
152		1	0	2	0
153		1	0	1	0
154		3	0	0	0
155	614+02	1	0	2	0
156		0	0	4	0
157		0	0	2	0
158		0	0	0	0
159		2	0	2	0
160	615+02	0	0	0	0
161	615+20	2	0	0	0
162	615+50	0	0	3	0
Total number of joints		162	162	162	162
Total number of joints with corner spalls		31	2	87	4
Total length of spalls for corner spalls		44	2	158	6
Average corner spall length for all joints		0.27	0.01	0.98	0.04
Average spall length for corner spalls		1.42	1.00	1.82	1.50

Joint End Corner Spalls – Cause, Number and Length

Joint Number	Station	Median Side		ROW Side	
		Roller/Grader	String	Roller/Grader	String
163		0	0	2	0
164		0	0	0	0
165	616+02	1	0	0	2
166		0	0	2	0
167		0	0	1	0
168		0	0	1	0
169		0	0	2	0
170	617+02	0	0	2	0
171		1	0	3	0
172		0	0	0	0
173		1	0	2	0
174		0	0	1	0
175	618+02	0	0	1	0
176		0	0	2	0
177		1	0	3	0
178		1	0	1	0
179		0	0	2	0
180	619+02	1	0	3	0
181		0	0	4	0
182		0	0	1	0
183		0	0	0	0
184		0	0	2	0
185	620+03	2	0	3	0
186		0	0	4	0
187		0	0	0	0
188		0	0	1	0
189		3	0	3	0
190	621+02	0	0	4	0
191		1	0	1	0
192		0	0	0	0
193		1	0	0	0
194		0	0	0	0
195	622+02	0	0	4	0
196		1	0	3	0
197		0	0	0	0
198		0	0	2	0
199		0	0	3	0
200	623+02	0	0	0	0
201		0	0	2	0
202		0	0	1	0
203		0	0	4	0
204		0	0	2	0
205	624+02	0	0	2	0
206		0	0	2	0
207		1	0	0	0

Joint End Corner Spalls – Cause, Number and Length

Joint Number	Station	Median Side		ROW Side	
		Roller/Grader	String	Roller/Grader	String
208		1	0	2	0
209		0	0	2	0
210	625+02	2	0	4	0
211		1	0	1	0
212		0	0	3	0
213		0	0	1	0
214		4	0	1	0
215	626+02	1	0	2	0
216		2	0	2	0
217		0	0	3	0
218		0	0	4	0
219		1	0	1	0
220	627+00	0	0	1	0
221		2	0	1	0
222		0	0	3	0
223		2	0	1	0
224		2	0	1	0
225	628+01	0	0	0	0
226		3	0	0	0
227		1	0	0	0
228		3	0	2	0
229		2	0	0	0
230	629+01	1	0	1	0
231		0	0	0	0
232		0	0	2	0
233		0	0	1	0
234		2	0	4	0
235	629+99	2	0	1	0
236		1	0	0	0
237		2	0	1	0
238		0	0	4	0
239		2	0	3	0
240	631+01	1	0	4	0
241		0	0	0	0
242		2	0	0	2
243		0	1	2	0
244		0	0	0	0
245	632+02	2	0	1	0
246		1	0	0	0
247		0	0	0	0
248		0	0	1	0
249		0	0	0	3
250	633+02	0	0	4	0
251		1	0	2	0
252		4	0	2	0

Joint End Corner Spalls – Cause, Number and Length

Joint Number	Station	Median Side		ROW Side	
		Roller/Grader	String	Roller/Grader	String
253		1	0	0	0
254		4	0	2	0
255	633+98	1	0	0	1
256	634+19	0	0	0	2
Total number of joints		94	94	94	94
Total number of joints with corner cracks		41	1	68	5
Total length of cracks for corner cracks		69	1	146	10
Average corner crack length for all joints		0.73	0.01	1.55	0.11
Average crack length for corner cracks		1.68	1.00	2.15	2.00

Joint End Corner Spalls – Cause, Number and Length

Joint Number	Station	Median Side		ROW Side	
		Roller/Grader	String	Roller/Grader	String
257	634+40	0	0	0	0
258		0	0	3	0
259		1	0	1	0
260	635+02	0	0	0	0
261		0	0	2	0
262		1	0	0	2
263		0	0	1	0
264		0	0	1	0
265	635+98	2	0	2	0
266		0	0	2	0
267		0	0	1	0
268		4	0	0	0
269		2	0	1	0
270	636+98	3	0	0	0
271		3	0	1	0
272		0	0	0	0
273		2	0	3	0
274		2	0	0	0
275	637+98	2	0	0	0
276		1	0	0	0
277		1	0	1	0
278		0	0	2	0
279		1	0	3	0
280	638+97	4	0	3	0
281		3	0	3	0
282		3	0	4	0
283		3	0	1	0
284		2	0	2	0
285	639+95	3	0	1	0
286		0	0	1	0
287		1	0	0	0
288		0	0	3	0
289		1	0	2	0
290	640+95	0	0	1	0
291	641+15	1	0	0	0
292		1	0	2	0
293		1	0	0	0
294		1	0	4	0
295		2	0	3	0
296	642+16	0	0	1	0
297		2	0	0	0
298		2	0	0	0
299		0	0	0	0
300	642+96	2	0	0	0

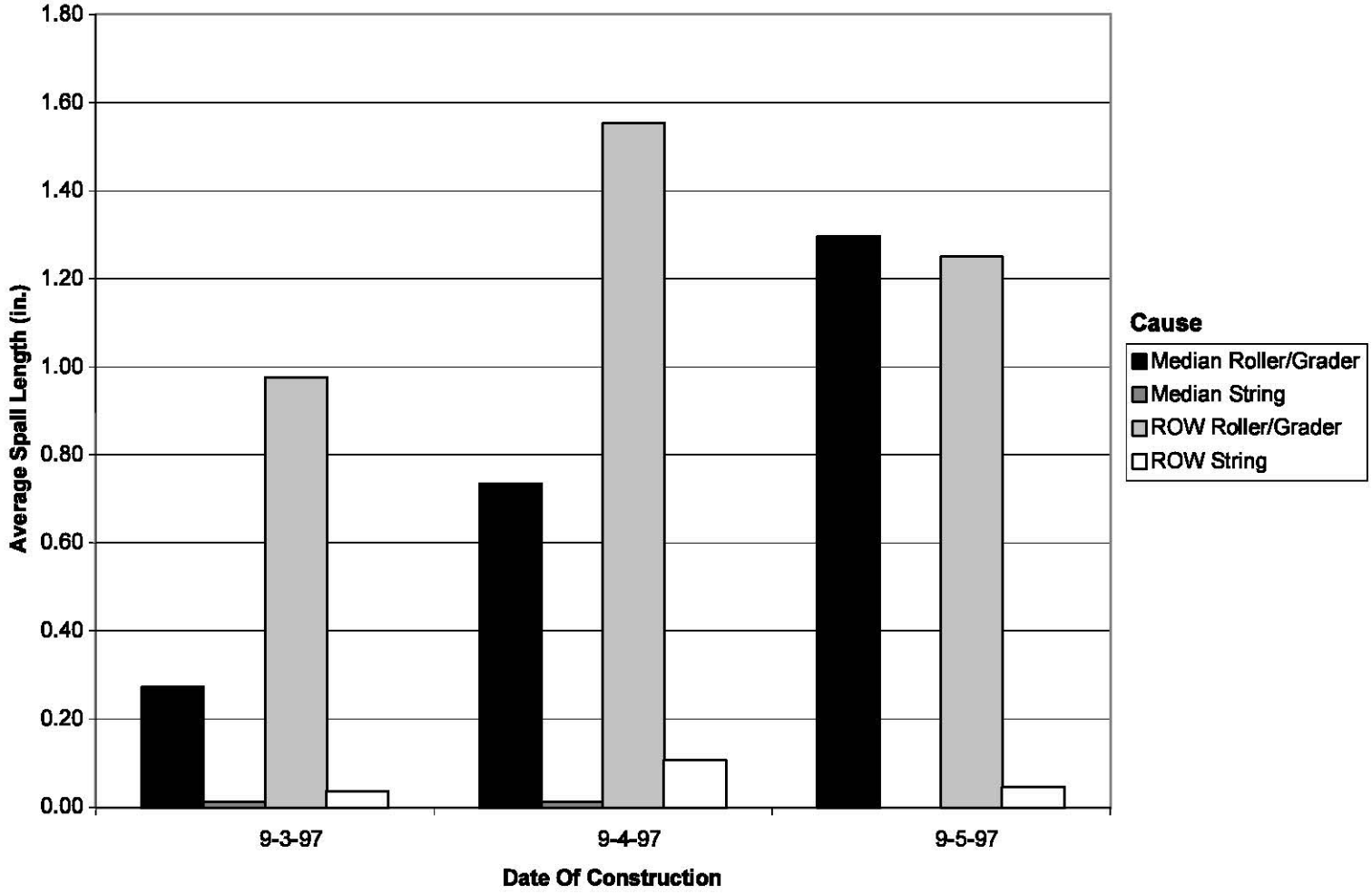
Joint End Corner Spalls – Cause, Number and Length

	Median Side		ROW Side	
	Roller/Grader	String	Roller/Grader	String
Total number of joints	44	44	44	44
Total number of joints with corner spalls	29	0	28	1
Total length of spalls for corner spalls	57	0	55	2
Average corner spall length for all joints	1.30	0.00	1.25	0.05
Average spall length for corner spalls	1.97	0.00	1.96	2.00

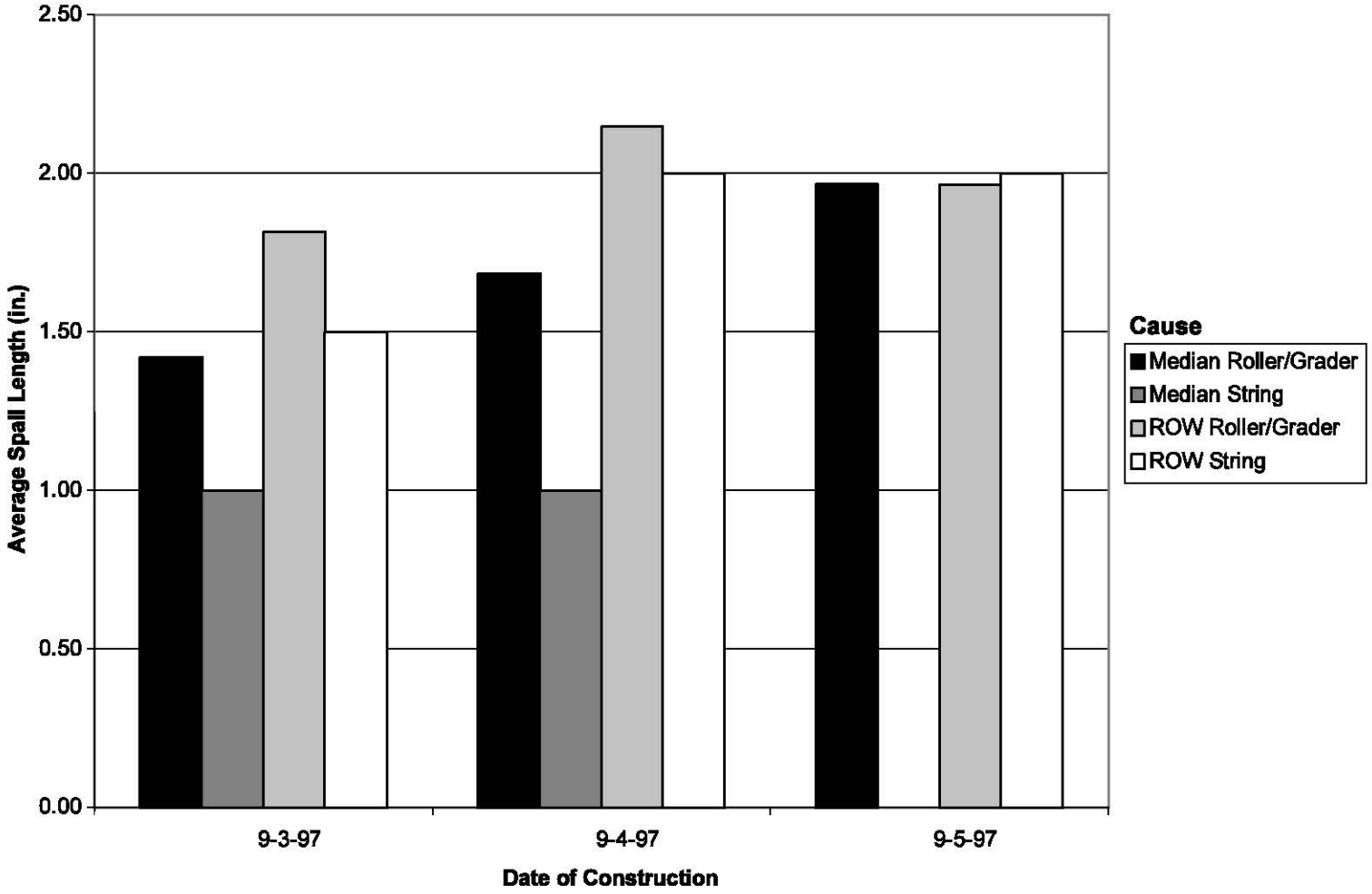
Joint End Corner Spalls – Cause, Number and Length

Joint End Corner Spall Data (Appendix C) Summary

Description	Median Side		ROW Side	
	Roller/Grader	String	Roller/Grader	String
Research Section Paved 9/3/97				
Total number of joints	162	162	162	162
Total number of joints with corner spalls	31	2	87	4
Total length of spalls for corner spalls	44	2	158	6
Average corner spall length for all joints	0.27	0.01	0.98	0.04
Average spall length for corner spalls	1.42	1.00	1.82	1.50
Percent joints spalled	19.1	1.2	53.7	2.5
Control Section 1 Paved 9/4/97				
Total number of joints	94	94	94	94
Total number of joints with corner spalls	41	1	68	5
Total length of spalls for corner spalls	69	1	146	10
Average corner spall length for all joints	0.73	0.01	1.55	0.11
Average spall length for corner spalls	1.68	1.00	2.15	2.00
Percent joints spalled	43.6	1.1	72.3	5.3
Control Section 2 Paved 9/5/97				
Total number of joints	44	44	44	44
Total number of joints with corner spalls	29	0	28	1
Total length of spalls for corner spalls	57	0	55	2
Average corner spall length for all joints	1.30	0.00	1.25	0.05
Average spall length for corner spalls	1.97	0.00	1.96	2.00
Percent joints spalled	65.9	0.0	63.6	2.3



Graph C-1: Average Joint End Spall Length For All Joints.



Graph C-2: Average Joint End Spall Length For Spalled Joints.

APPENDIX D

CONTRACTION JOINT CRACKING – PROGRESSION DATA

Number (Joint Number)
Width (Inch)

Contraction Joint Cracking Progression – Number and Width

Joint Number	Station	9/10/97	9/15/97	9/29/97	10/3/97
1	583+18	0	0	0	0
2		0	0	0	0
3		0	0	0.025	0.025
4		0	0	0	0
5	584+02	0.025	0.025	0.05	0.04
6		0	0	0	0
7		0	0	0	0
8		0	0	0	0
9		0	0	0	0
10	585+02	0.05	0.05	0.07	0.08
11		0	0	0	0
12		0	0	0	0
13		0.025	0.025	0.04	0.045
14		0	0	0	0
15	586+02	0	0	0.03	0.03
16		0	0	0	0
17		0	0	0	0
18		0.06	0.06	0.06	0.045
19		0	0	0	0
20	587+02	0	0	0	0
21		0	0	0.035	0.035
22		0	0	0	0
23		0	0	0	0
24		0.03	0.03	0.06	0.045
25	588+02	0	0	0	0
26		0	0	0	0
27		0	0	0	0
28		0.06	0.06	0.08	0.07
29		0	0	0	0
30	589+03	0	0	0	0
31		0	0	0	0.01
32		0.025	0.025	0.05	0.05
33		0	0	0	0
34		0	0	0	0.01
35	590+03	0.05	0.05	0.05	0.05
36		0	0	0	0
37		0	0	0.03	0.04
38		0	0	0	0
39		0	0	0	0
40	591+03	0.05	0.05	0.06	0.06
41		0	0	0	0
42		0	0	0	0
43		0	0	0.025	0.035
44		0	0	0	0
45	592+03	0.06	0.06	0.06	0.07
*Crack Width Dimensions are in Inches					

Contraction Joint Cracking Progression – Number and Width

Joint Number	Station	9/10/97	9/15/97	9/29/97	10/3/97
46		0	0	0	0
47		0	0	0	0
48		0	0	0	0
49		0	0.025	0.05	0.06
50	593+03	0	0	0	0
51		0	0	0	0
52		0.05	0.05	0.05	0.05
53		0	0	0	0
54		0	0	0	0
55	594+03	0	0	0.03	0.035
56		0	0	0	0
57		0	0	0	0
58		0.065	0.065	0.09	0.09
59		0	0	0	0
60	595+02	0	0	0	0.01
61		0	0	0	0
62		0	0	0	0
63		0.035	0.035	0.05	0.055
64		0	0	0	0
65	596+03	0	0	0	0
66		0	0	0	0
67		0	0	0	0
68		0.065	0.065	0.1	0.1
69		0	0	0	0
70	597+04	0	0	0	0
71		0	0	0	0
72		0.035	0.035	0.075	0.075
73		0	0	0	0
74		0	0	0	0
75	598+03	0	0	0	0
76		0	0	0	0
77		0	0	0	0
78		0.065	0.065	0.075	0.075
79		0	0	0	0
80	599+03	0	0	0	0
81		0	0	0	0
82		0	0	0.045	0.045
83		0	0	0	0
84		0	0	0	0
85	600+04	0	0	0	0
86		0.05	0.05	0.06	0.06
87		0	0	0	0
88		0	0	0.03	0.035
89		0	0	0	0
90	601+03	0	0	0	0
*Crack Width Dimensions are in Inches					

Contraction Joint Cracking Progression – Number and Width

Joint Number	Station	9/10/97	9/15/97	9/29/97	10/3/97
91		0	0	0	0
92		0.065	0.065	0.075	0.07
93		0	0	0	0
94		0	0	0	0
95	602+03	0	0	0.035	0.035
96		0	0	0	0
97		0	0	0	0
98		0	0	0	0
99		0.05	0.05	0.07	0.06
100	603+03	0	0	0	0
101		0	0	0	0
102		0	0	0	0
103		0	0	0	0
104		0.06	0.06	0.07	0.065
105	604+03	0	0	0	0
106		0	0	0	0
107		0	0	0	0
108		0	0.016	0.065	0.06
109		0	0	0	0
110	605+02	0	0	0	0
111		0	0	0	0
112		0	0	0	0
113		0.06	0.06	0.075	0.07
114		0	0	0	0
115	606+03	0	0	0	0
116		0	0	0	0
117		0	0	0	0
118		0.04	0.04	0.065	0.07
119		0	0	0	0
120	607+03	0	0	0	0
121		0	0	0	0
122		0	0	0.025	0.03
123		0	0	0	0
124		0	0	0	0
125	608+02	0.07	0.07	0.07	0.065
126		0	0	0	0
127		0	0	0	0
128		0	0	0	0
129		0	0	0	0
130	609+02	0	0	0	0
131		0	0.02	0.07	0.06
132		0	0	0	0
133		0	0	0	0
134		0	0	0	0.01
135	610+01	0	0	0	0
*Crack Width Dimensions are in Inches					

Contraction Joint Cracking Progression – Number and Width

Joint Number	Station	9/10/97	9/15/97	9/29/97	10/3/97
136		0.06	0.06	0.06	0.04
137		0	0	0.02	0.025
138		0	0	0	0
139		0	0	0	0
140	611+01	0	0	0	0
141		0	0	0	0
142		0	0	0.01	0.015
143		0.03	0.03	0.06	0.05
144		0	0	0	0
145	612+02	0	0	0	0
146		0	0	0	0
147		0.045	0.045	0.06	0.055
148		0	0	0	0
149		0	0	0	0
150	613+02	0	0	0	0
151		0.016	0.016	0.05	0.055
152		0	0	0	0
153		0	0	0	0
154		0	0	0	0
155	614+02	0.04	0.04	0.06	0.06
156		0	0	0	0
157		0	0	0	0
158		0	0	0	0
159		0	0	0	0
160	615+02	0	0.016	0.06	0.055
161	615+20	0	0	0	0
162	615+50	0	0	0	0
Total number of joints		162	162	162	162
Total number of cracked joints		28	32	44	48
Total width for all cracks		1.34	1.41	2.38	2.38
Average crack width for all joints		0.008	0.009	0.015	0.015
Average crack width for cracked joints		0.048	0.044	0.054	0.050
*Crack Width Dimensions are in Inches					

Contraction Joint Cracking Progression – Number and Width

Joint Number	Station	9/10/97	9/15/97	9/29/97	10/3/97
163		0	0	0	0
164		0.1	0.1	0.12	0.12
165	616+02	0	0	0	0
166		0	0	0	0
167		0	0	0	0
168		0	0	0	0
169		0	0	0.05	0.05
170	617+02	0	0	0	0
171		0	0	0	0
172		0.05	0.05	0.06	0.06
173		0	0	0	0
174		0	0	0.035	0.035
175	618+02	0	0	0	0
176		0	0	0	0
177		0.1	0.1	0.1	0.1
178		0	0	0	0
179		0	0	0	0
180	619+02	0	0	0	0
181		0	0	0.05	0.05
182		0	0	0	0
183		0	0	0	0
184		0	0	0	0
185	620+03	0.04	0.04	0.08	0.08
186		0	0	0	0
187		0	0	0	0
188		0	0	0	0
189		0	0	0	0
190	621+02	0.08	0.08	0.09	0.1
191		0	0	0	0
192		0	0	0	0
193		0	0	0	0
194		0	0	0.025	0.025
195	622+02	0.035	0.035	0.05	0.05
196		0	0	0	0
197		0	0	0	0.01
198		0	0	0	0
199		0.025	0.025	0.06	0.06
200	623+02	0	0	0	0
201		0	0	0.03	0.03
202		0	0	0	0
203		0	0	0	0
204		0	0	0	0
*Crack Width Dimensions are in Inches					

Contraction Joint Cracking Progression – Number and Width

Joint Number	Station	9/10/97	9/15/97	9/29/97	10/3/97
205	624+02	0.08	0.08	0.09	0.09
206		0	0	0	0
207		0	0	0	0
208		0	0	0.02	0.02
209		0	0	0	0
210	625+02	0	0.016	0.04	0.04
211		0	0	0	0
212		0	0	0	0
213		0.05	0.05	0.07	0.07
214		0	0	0	0
215	626+02	0	0	0	0
216		0	0	0	0
217		0	0	0.04	0.045
218		0	0	0	0
219		0	0	0	0
220	627+00	0	0	0	0
221		0.055	0.055	0.075	0.075
222		0	0	0	0
223		0	0	0	0
224		0	0	0.03	0.035
225	628+01	0	0	0	0
226		0	0	0	0
227		0	0	0	0
228		0.04	0.04	0.065	0.07
229		0	0	0	0
230	629+01	0	0	0	0
231		0	0	0.03	0.03
232		0	0	0	0
233		0	0	0	0
234		0.06	0.06	0.08	0.08
235	629+99	0	0	0	0
236		0	0	0	0
237		0	0	0	0
238		0	0	0.025	0.03
239		0	0.016	0.04	0.045
240	631+01	0	0	0	0
241		0	0	0	0
242		0.04	0.04	0.04	0.04
243		0	0	0	0
244		0	0	0	0
245	632+02	0	0	0	0
246		0	0	0	0
247		0.05	0.05	0.05	0.05
248		0	0	0	0
249		0	0	0	0
*Crack Width Dimensions are in Inches					

Contraction Joint Cracking Progression – Number and Width

Joint Number	Station	9/10/97	9/15/97	9/29/97	10/3/97
250	633+02	0	0	0	0
251		0	0	0	0
252		0.035	0.035	0.07	0.07
253		0	0	0	0
254		0	0	0	0
255	633+98	0	0	0	0
256	634+19	0	0	0	0
Total number of joints		94	94	94	94
Total number of cracked joints		15	17	27	28
Total width for all cracks		0.84	0.87	1.52	1.56
Average crack width for all joints		0.009	0.009	0.016	0.017
Average crack width for cracked joints		0.056	0.051	0.056	0.056
*Crack Width Dimensions are in Inches					

Contraction Joint Cracking Progression – Number and Width

Joint Number	Station	9/10/97	9/15/97	9/29/97	10/3/97
257	634+40	0	0.016	0.045	0.045
258		0.03	0.03	0.045	0.045
259		0	0	0.01	0.015
260	635+02	0.06	0.06	0.07	0.07
261		0	0	0.01	0.01
262		0	0	0.015	0.015
263		0	0	0.01	0.01
264		0.03	0.03	0.04	0.04
265	635+98	0	0.002	0.015	0.025
266		0.002	0.002	0.01	0.01
267		0	0	0.01	0.015
268		0.06	0.06	0.06	0.06
269		0	0	0.01	0.01
270	636+98	0	0	0.01	0.01
271		0	0	0.01	0.01
272		0.045	0.045	0.06	0.06
273		0	0	0.015	0.01
274		0	0.002	0.02	0.02
275	637+98	0	0.002	0.015	0.02
276		0.035	0.035	0.03	0.035
277		0	0	0.01	0.01
278		0	0	0.01	0.01
279		0	0	0.01	0.01
280	638+97	0.06	0.06	0.06	0.06
281		0	0	0.01	0.01
282		0	0.016	0.035	0.035
283		0	0	0	0
284		0	0	0	0
285	639+95	0.04	0.04	0.05	0.05
286		0	0	0.015	0.015
287		0	0	0.015	0.015
288		0	0	0.01	0.01
289		0.065	0.065	0.075	0.075
290	640+95	0	0	0	0
291	641+15	0	0	0	0
292		0.03	0.035	0.05	0.05
293		0	0	0	0
294		0	0	0.015	0.015
295		0	0	0	0
296	642+16	0	0	0.025	0.025
297		0	0	0	0
298		0.065	0.075	0.08	0.08
299		0	0	0	0
300		0	0	0.01	0.015
*Crack Width Dimensions are in Inches					

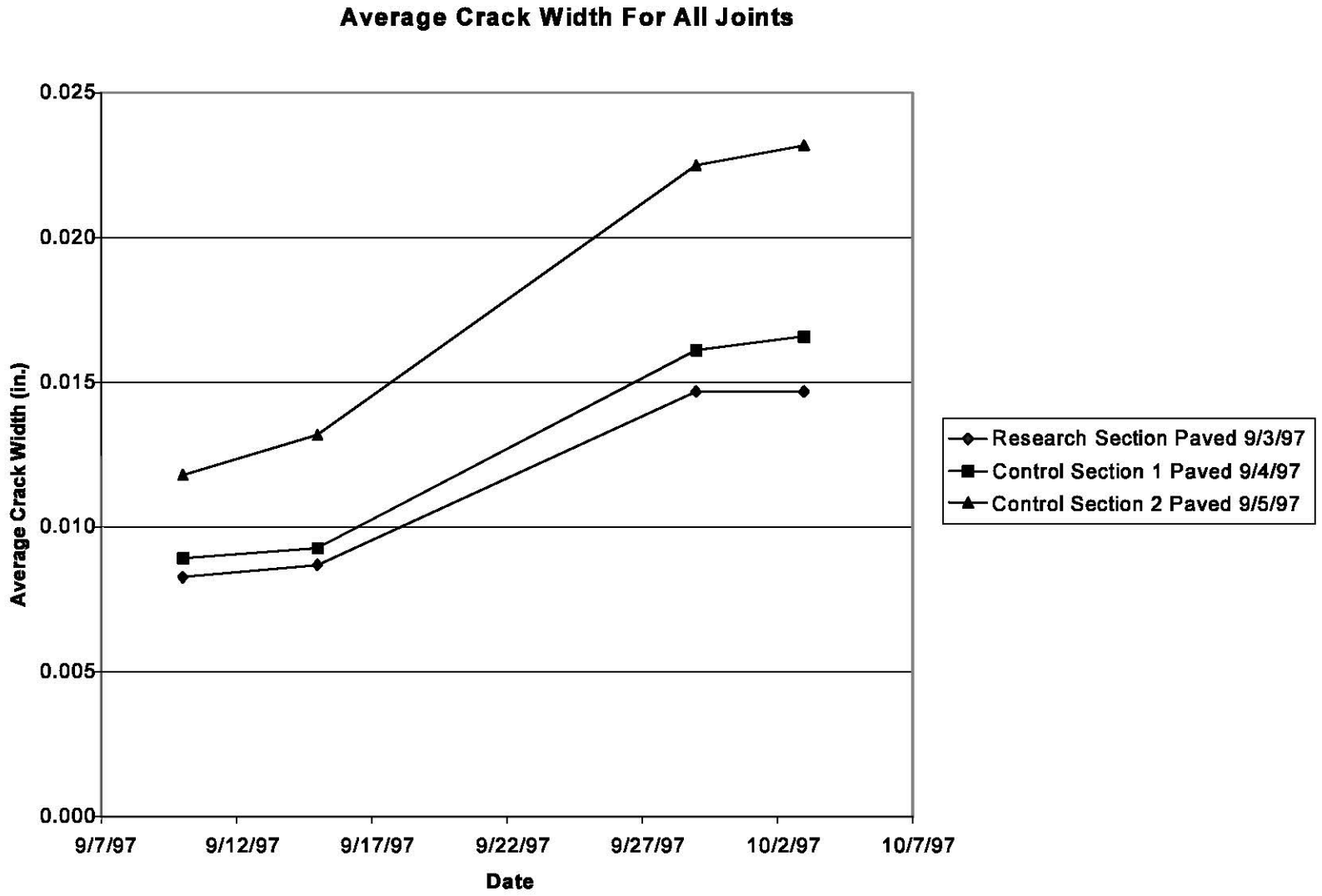
Contraction Joint Cracking Progression – Number and Width

	9/10/97	9/15/97	9/29/97	10/3/97
Total number of joints	44	44	44	44
Total number of cracked joints	12	17	36	36
Total width for all cracks	0.52	0.58	0.99	1.02
Average crack width for all joints	0.012	0.013	0.023	0.023
Average crack width for cracked joints	0.044	0.034	0.028	0.028
Average crack width for cracked joints	0.044	0.034	0.028	0.028
Average crack width for cracked joints	0.044	0.034	0.028	0.028
*Crack Width Dimensions are in Inches				

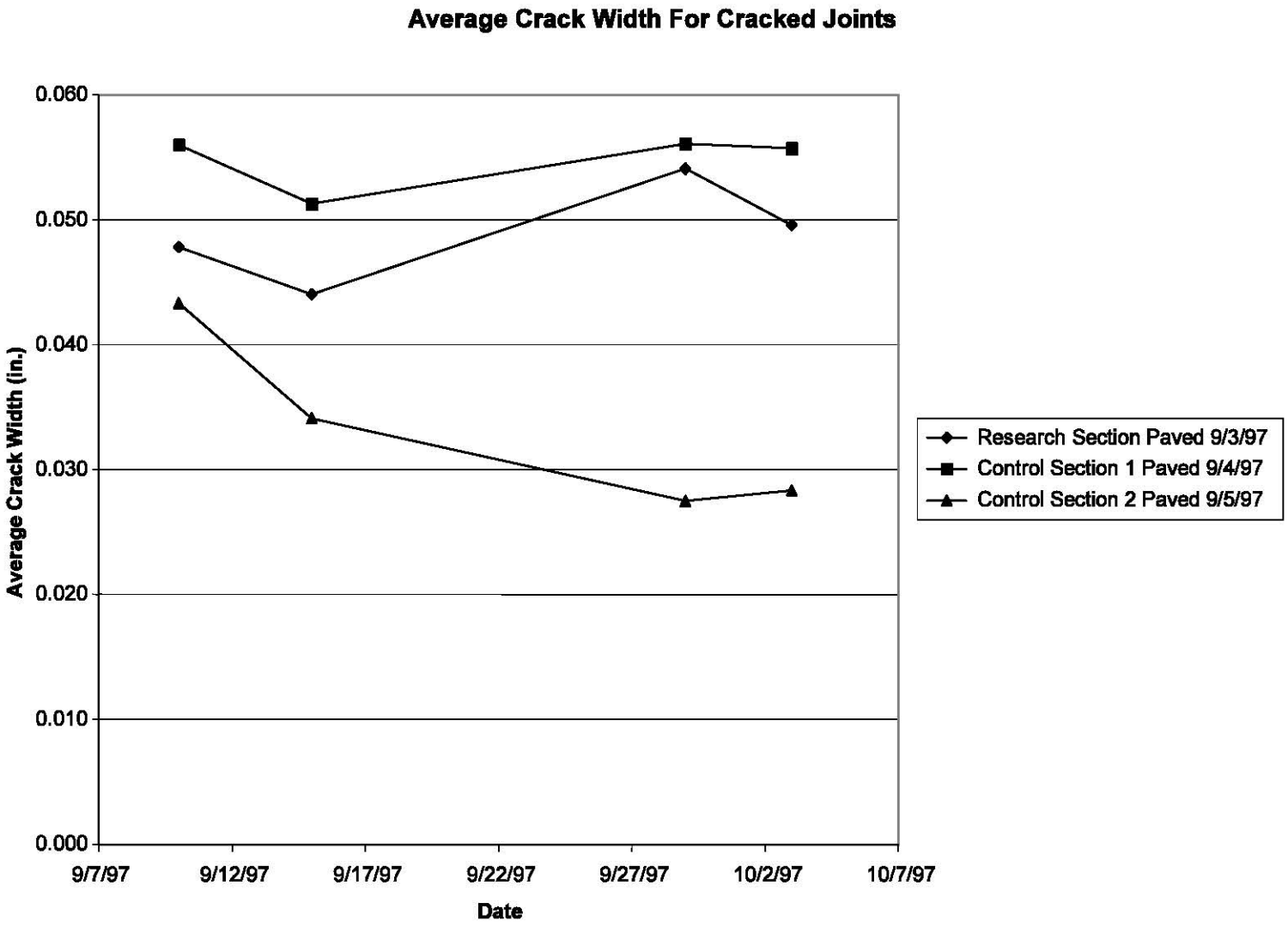
Contraction Joint Cracking Progression – Number and Width

Contraction Joint Cracking Progression Data (Appendix D) Summary

Description	9/10/97	9/15/97	9/29/97	10/3/97
Research Section Paved 9/3/97				
Total number of joints	162	162	162	162
Total number of cracked joints	28	32	44	48
Total width for all cracks	1.34	1.41	2.38	2.38
Average crack width for all joints	0.008	0.009	0.015	0.015
Average crack width for cracked joints	0.048	0.044	0.054	0.050
Percent joints cracked	17.3	19.8	27.2	29.6
Control Section 1 Paved 9/4/97				
Total number of joints	94	94	94	94
Total number of cracked joints	15	17	27	28
Total width for all cracks	0.84	0.87	1.52	1.56
Average crack width for all joints	0.009	0.009	0.016	0.017
Average crack width for cracked joints	0.056	0.051	0.056	0.056
Percent joints cracked	16.0	18.1	28.7	29.8
Control Section 2 Paved 9/5/97				
Total number of joints	44	44	44	44
Total number of cracked joints	12	17	36	36
Total width for all cracks	0.52	0.58	0.99	1.02
Average crack width for all joints	0.012	0.013	0.023	0.023
Average crack width for cracked joints	0.043	0.034	0.028	0.028
Percent joints cracked	27.3	38.6	81.8	81.8
*Crack Width Dimensions are in Inches				



Graph D-1: Average Crack Width For All Joints.



Graph D-2: Average Crack Width For Cracked Joint