Technical Report Documentation Page

1. REPORT No.
FHWA-CA-TL-78-29

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE
Performance of Experimental PCC Pavement Sections

5. REPORT DATE
September 1978

6. PERFORMING ORGANIZATION

7. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT No.
19303-635180

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Office of Transportation Laboratory
California Department of Transportation
Sacramento, California 95819

10. WORK UNIT No.

11. CONTRACT OR GRANT No.
D-5-31

12. SPONSORING AGENCY NAME AND ADDRESS
California Department of Transportation
Sacramento, California 95807

13. TYPE OF REPORT & PERIOD COVERED
Final 1971-1978

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
This project was performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

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The performance of experimental PCC pavement sections is described. Construction details were described in a previous report (June 1973). The predominant experimental feature was continuously reinforced concrete with three different types of reinforcement. Other sections included unreinforced pavement with (1) weakened plane joints at about one-half the normal intervals, (2) higher cement content, (3) over designed thickness, and (4) concrete base in lieu of cement treated base under the pavement. Because of relatively light traffic to date, conclusions are very limited.

17. KEYWORDS
Bases, cement content, concrete pavements, continuously reinforced pavements, joints, pavement performance, pavement thickness

18. No. OF PAGES:
17

19. DRI WEBSITE LINK
http://www.dot.ca.gov/hq/research/researchreports/1978-1980/78-29.pdf

20. FILE NAME
78-29.pdf

REPORT NO. FHWA-CA-TL-78-29

PERFORMANCE OF EXPERIMENTAL PCC PAVEMENT SECTIONS

FINAL REPORT

SEPT., 1978

Caltrans

CALIFORNIA DEPARTMENT OF TRANSPORTATION

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TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. FHWA-CA-TL-78-29	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO
4. TITLE AND SUBTITLE PERFORMANCE OF EXPERIMENTAL PCC PAVEMENT SECTIONS		5. REPORT DATE September 1978 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) J. H. Woodstrom; B. F. Neal		8. PERFORMING ORGANIZATION REPORT NO. 19303-635180
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Transportation Laboratory California Department of Transportation Sacramento, California 95819		10. WORK UNIT NO 11. CONTRACT OR GRANT NO. D-5-31
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17. KEY WORDS Bases, cement content, concrete pavements, continuously reinforced pavements, joints, pavement performance, pavement thickness	18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. SECURITY CLASSIF. (OF THIS REPORT)	20. SECURITY CLASSIF. (OF THIS PAGE)	21. NO. OF PAGES	22. PRICE
	Unclassified	17	

DS-TL-1242 (Rev.6/76)

September, 1978

Fox River Road

Corridor

[illegible] have ... sections of desirable [illegible] ... result (Diversity) [illegible] ... reinforce [illegible] ... weakened ... (3) [illegible] ... light construction [illegible] ... and (4) [illegible] ... Because [illegible] ... argument [illegible]

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

September 1978

FHWA No. D-5-31
TL No. 635180

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information, this final research project report titled:

PERFORMANCE OF EXPERIMENTAL PCC
PAVEMENT SECTIONS

Study made by . . . . Roadbed & Concrete

Under the Supervision of . . . . . D. L. Spellman

Principal Investigator . . . . J. H. Woodstrom

Co-Investigator . . . . B. F. Neal

Report Prepared by . . . . B. F. Neal
and
J. H. Woodstrom

Very truly yours,

Neal Andersen

NEAL ANDERSEN
Chief, Office of Transportation Laboratory

Attachment
BFN:cj

Fox River [illegible]

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PERFORMANCE OF EXPERIMENTAL PCC PAVEMENT SECTIONS

BACKGROUND

A large percentage of the more heavily traveled pavements in California are constructed of portland cement concrete (PCC). Typically, these pavements are jointed, unreinforced, and placed over cement treated base. This is referred to as the "standard design". Most performance problems have been associated with the transverse joints. Uneven volume changes result in warped or curled slabs. Faulting or step-off at the joints also occurs and creates roughness. These defects can lead to cracking of the slabs and structural failure. Also, blowups may occur when the slab ends become overstressed due to concrete expansion and filling of the joints with incompressible material.

The steel reinforcing industry has long promoted continuously reinforced concrete pavement (CRCP) to provide better serviceability. In 1971, an experimental project was constructed with CRCP as the predominant variable. In addition to control sections of standard design, four other experimental features were included in the project as possible alternates to steel reinforcement for improving pavement performance.

The experimental project is located in San Joaquin County, east of the town of Tracy. It consists of two lanes in each direction built to freeway standards and is a part of Interstate 5. The experimental sections are in the middle 9.4 miles (15.1 km) of the 14.2 mile (22.9 km) project (See Figure 1).

(1) Control Section
Standard Spaced
Transverse Joints

(1-A) Longitudinal Bars Only
CRCP

(1-B) Longitudinal & Transverse Bars
CRCP

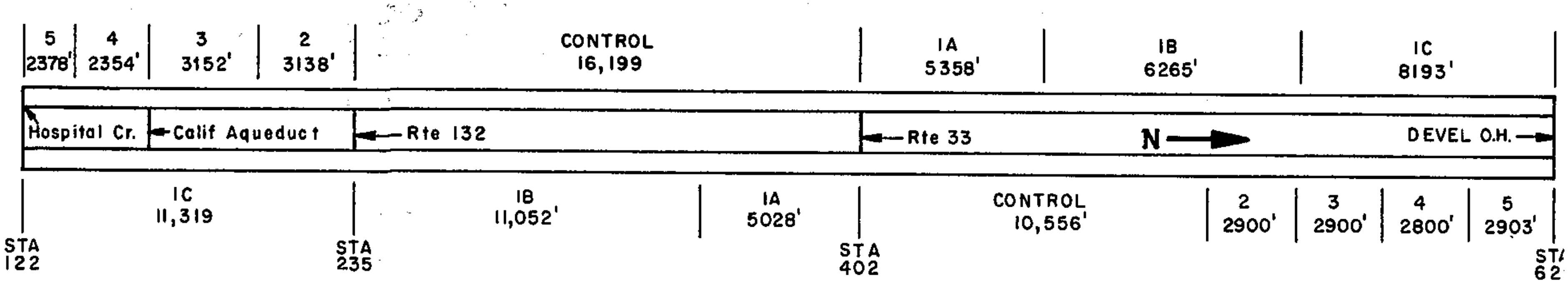
(1-C) Welded Wire Fabric
CRCP

(2) Short Joint Spacing
Transverse Joints at
8', 11', 7', 5', and
Repeat

(3) Higher Cement Content
Increase Cement to 7.5
Sks./C.Y. from 5.5 Sks.

(4) Extra Thickness
From 0.70' to 0.95'

(5) Lean Concrete Base



Note: 1 foot = 0.3048 m

LAYOUT OF TEST SECTIONS

Figure 1

Three different types of reinforcement were used, but all contained longitudinal steel in the amount of 0.56% of the theoretical cross-sectional area. The three types were:

1-A Longitudinal bars only
1-B Longitudinal and transverse bars
1-C Welded wire fabric

The other experimental sections with no reinforcement were:

2 Short joint spacing (Approx. 1/2 normal)

3 Higher cement content (7.5 sks/cy vs. 5.5 sks) (418 kg/m^3 vs. 307 kg/m^3)

4 Extra pavement thickness (0.95 ft vs. 0.70 ft) (290 mm vs. 213 mm)

5 Lean concrete as a base (4 sks/cy) (223 kg/m^3)

Design and construction details, a comparison of construction costs, and early performance characteristics are covered in a California Materials and Research Department report, "Recent Experimental PCC Pavements in California", dated June 1973.

CONCLUSIONS

Because of the limited traffic over this project, general conclusions on relative performance of individual experimental sections are not considered warranted. However, the slower rate of increase in faulting of the sections with short slabs is deemed worthy of mention. If the causes of faulting cannot be eliminated, it might be possible to spread the step-off to twice the number of joints and significantly increase the service life before corrective measures for faulting are needed.

MONITORING OF EXPERIMENTAL SECTIONS

Since completion of the experimental project, selected portions of each feature, plus control sections have been periodically monitored. This has included crack counts and measurements of roughness, faulting and joint openings.

CRCP Cracking

During early ages, cracks in the CRCP were mapped as frequently as time permitted. In addition, typical 1,000 ft (305 m) sections were selected for periodic study. In these sections, cracks in the outer lane were counted and average slab lengths computed. During the last survey, at age 66 months, cracks in the outer lane for the full length of each section were counted. (Earlier mapping indicated that while cracking patterns were not identical, average slab lengths in the passing lane were not significantly different from those in the outer lane.) Average slab lengths of the various CRCP sections are shown in Table 1.

Except for one section, the cracking frequency was about as anticipated. In the southbound lanes, the section with only longitudinal reinforcement shows a significantly larger crack interval. This may be due to improper steel placement. In this section (which was placed first), problems were encountered in adjusting the tubes through which the bars were placed in the fresh concrete, and resulted in a considerable length of the reinforcement being located below the center of the slab.

TABLE 1

CRACKING vs. TIME
CRCP SLAB LENGTHS IN FEET*

Age	Longitudinal Only		Longitudinal With Transverse		Welded Wire Fabric	
	S.B.	N.B.	S.B.	N.B.	S.B.	N.B.
Days						
1	1000	---	1000	---	1000	---
2	---	---	29	---	1000	80
3	24	30	20	---	---	---
4	20	---	19	13	100	---
5	14.7	---	17	---	56	12
6	14.5	---	---	9.8	---	---
7	---	15	---	9.7	---	10
14	14.1	---	10	---	---	---
20	---	---	---	---	9.1	---
Months						
1	---	8.7	---	8.2	---	8.7
2	13.5	---	9.1	---	6.4	---
5	11.1	5.7	5.1	3.8	3.5	5.6
15	8.0	4.5	4.0	3.7	3.3	4.1
42	5.0	4.0	3.5	3.1	2.5	3.3
54	5.0	4.0	3.3	2.8	2.5	2.9
66	4.9	4.0	3.3	2.8	2.3	2.9

*Typical 1000-foot sections in outer lane only.

Average slab length based on full length of outer lane

66 Months	5.3	3.3	3.2	2.8	2.3	2.6

NOTE: 1 foot = 0.3048 meter

Roughness

Table 2 shows the results of roughness measurements obtained at periodic intervals. The profile index is determined by use of the California Profilograph which has a 25-ft (7.6 m) wheelbase. Present Serviceability Index (PSI) is determined by use of the Roadmeter. Only the southbound lanes were profiled during the last survey.

From profile data obtained in the southbound lanes, it appears that all the experimental sections are smoother than the control sections though none would be considered rough riding based on the profile index. The PSI numbers are rather widely scattered, but the lower numbers indicate some significant roughness. This apparent discrepancy is attributed in part to the differences in the two rating systems. While the profiles show individual deviations from a "straightedge", a vehicle's response is dynamic and the effect of a single "bump" or even a series of smaller uniformly spaced irregularities can affect the Roadmeter response in various ways depending on the speed, suspension system, and other factors. Even irregularities of the profile that are "blanked out" for Profile Index determination might influence the ride. A single large depression caused by a fill settlement might also induce dynamic reaction in a vehicle that would extend well past the bump itself. While the two measures of smoothness are related, there is reason not to expect perfect agreement between them. Some of the fill settlements are being corrected by maintenance activity and future roughness measurements may show some improvement in riding quality.

Faulting

Figures 2 and 3 show average faulting per joint of the various non-reinforced sections about 5 years after construction. These averages were calculated from periodic measurements of the same 25 consecutive joints in each of the test sections. The sections with 1/2 length slabs and those with concrete base show the least increase in average faulting. The improved faulting performance of short slabs can only be attained if practically all transverse weakened plane joints are made to crack. This requires applying a load to the pavement while the concrete still has relatively low strength. It might be pointed out that total faulting per given length of pavement will probably be approximately that of normally spaced joints. Concrete base or lean concrete base (LCB) is presently being promoted in California as a means of helping the faulting problem. However, it is also considered necessary to eliminate untreated shoulder material adjacent to the pavement which was not done on this project.

Transverse Joint Movement

Tables 3 and 4 show the movement taking place at joints in the sections with short spacing and normal spacing respectively. The average joint opening of the short slabs is roughly half that of the longer slabs, but total opening over a given length would probably be about the same. Changes due to temperature variations can be seen in the average figures, but individual readings show there is a wide variation in the movements taking place at each joint. The readings are undoubtedly also affected by movement of the adjacent slabs where joint measurements were not made.

TABLE 2

ROUGHNESS OF EXPERIMENTAL SECTIONS

Section		Profile Index Inches/Mile			PSI From Roadmeter			
		Age			Age			
		6 Mos.	16 Mos.	6 Yrs.	6 Mos.	16 Mos.	3 Yrs.	6 Yrs.
Control	SB	7	8	13	4.60	4.30	3.80	3.45
	NB	5	10	-	4.50	4.10	3.75	3.50
1A Longitudinal Bars only	SB	6	6	10	4.15	3.75	3.55	3.35
	NB	3	2	-	4.60	4.35	4.05	4.05
1B Longitudinal and Transverse Bars	SB	3	2	5	4.65	4.50	4.05	4.10
	NB	2	2	-	4.65	4.40	4.10	3.85
1C Welded Wire Fabric	SB	4	4	9	4.55	4.30	4.00	3.95
	NB	6	7	-	4.45	4.30	3.85	3.55
2 Short Slabs	SB	5	6	8	4.55	4.20	4.15	3.45
	NB	2	5	-	4.60	4.30	4.10	4.00
3 Higher Cement Content	SB	6	9	10	4.55	4.00	3.75	3.45
	NB	3	8	-	4.60	4.20	4.00	3.85
4 Extra Thickness Pavement	SB	7	6	10	4.55	4.05	3.90	3.60
	NB	4	6	-	4.60	4.30	4.05	3.90
5 Std. Pavement, Concrete Base	SB	6	6	5	4.55	4.40	4.35	4.15
	NB	5	6	-	4.60	3.95	3.95	3.85

NOTE: 1 inch = 25.4 mm
1 mile = 1.6 km

PAVEMENT JOINT FAULTING

10 SJ 5

E. TRACY (SB)

PAVED 1971

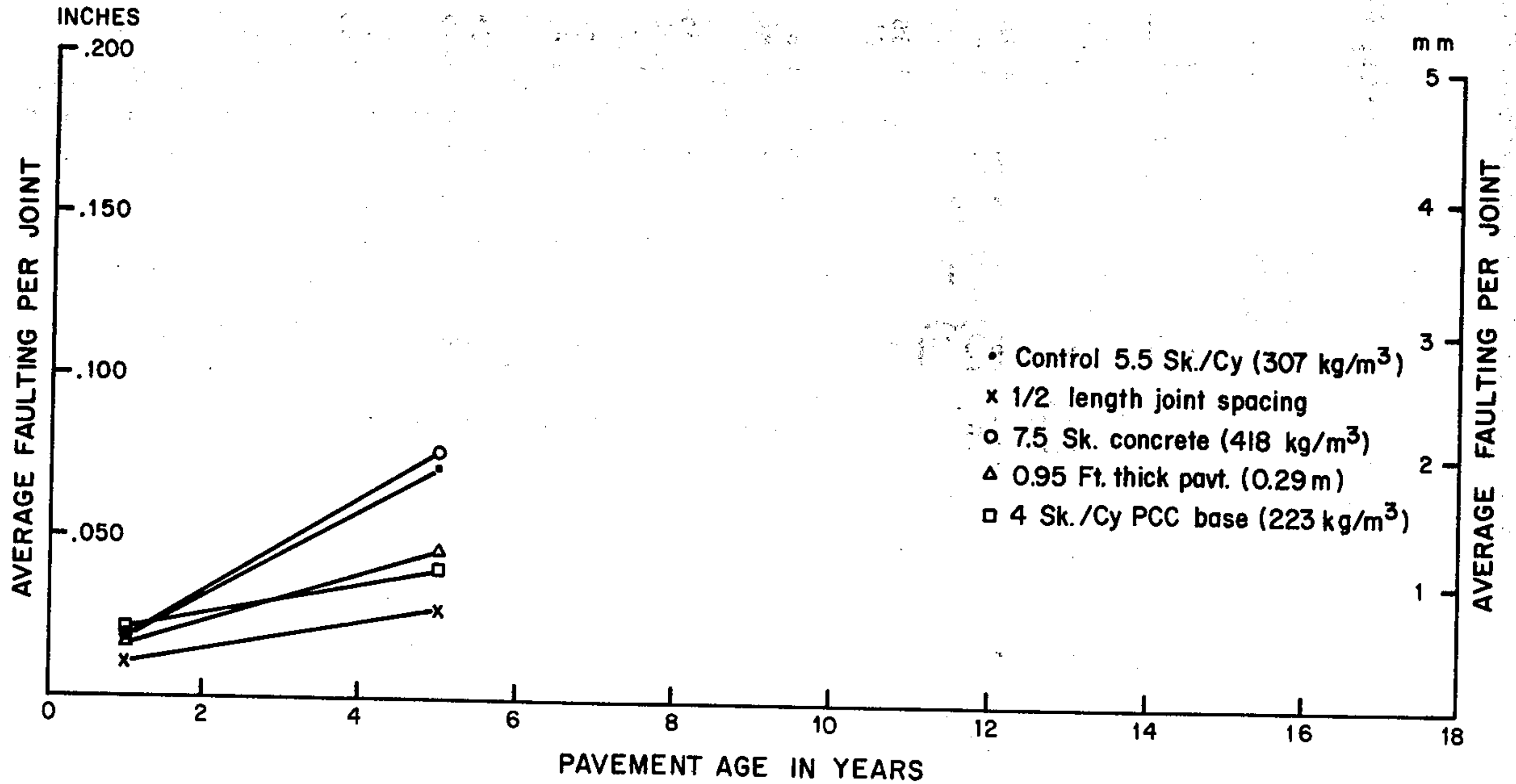


Figure 2

PAVEMENT JOINT FAULTING
10 SJ 5
E. TRACY (NB)

PAVED 1971
CT BASE

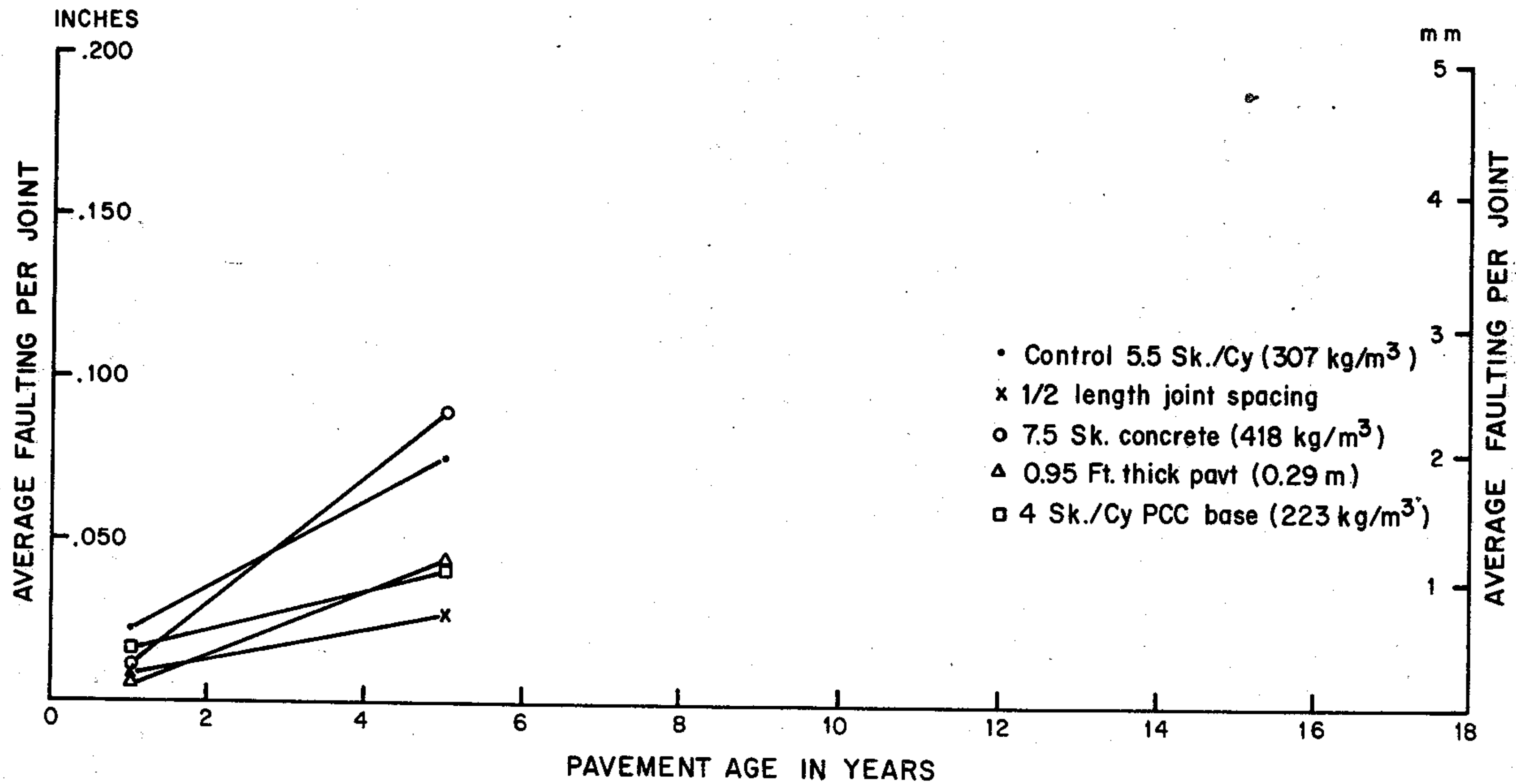


Figure 3

Traffic

Since Interstate 5 has not been completed to the north of this project, traffic has been relatively light to date. A recent traffic count indicated a 2-way ADT of about 5,000 vehicles with approximately 17% trucks. As the experimental sections were constructed to more effectively withstand heavy traffic, it is too early to evaluate the relative performance of the various sections.

Maintenance

The only maintenance on this project has been of isolated locations where fill settlements at culverts and bridge approaches has required slab-jacking to restore pavement slabs to grade. The repairs made during construction at the 57 locations of lap failure in the welded wire fabric sections are performing well. An additional 12 locations of apparent lap failure have been found but, to date, no maintenance has been performed.

TABLE 3

TRANSVERSE JOINT MOVEMENT
(Unreinforced, Short Spacing)

Change in Width from Original, 0.001-inch

Joint Spacing, Feet: 8 5 7 11 8 5 7 11 8 5 7

Gauge Loc. No.	1	2	3	4	5	6	7	8	9	10	Avg.	Air Temp. Deg. F
Placed 7-7-71												
Date												
7-9-71	0	0	2	3	0	-1	3	2	0	6	1	76
7-19-71	-1	-1	18	18	0	0	23	13	-2	27	9	72
7-19-71	0	-1	2	-1	0	0	2	-1	1	7	1	90
11-22-71	-1	8	37		23		39	28	-3	90	38	50
9-21-72	1	34	43	47	57	2	58	57	4	77	38	67
9-21-72	-3	24	27	12	41	-3	35	24	0	41	20	83
12-13-72	-1	27	46	37	36	-2	27	30	-4	98	29	44
1-11-74	1	39	33	12	41	-3	29	22	16	75	27	47
12-17-74	-4	34	28	13	36	9	35	35	24	61	27	53
1-6-76	3	39	9	20	35	78	26	32	33	61	34	60
1-6-77	0	33	9	36	33	77	21	27	33	52	32	49

NOTE: 1 inch = 25.4 mm
1 foot = 0.3048 m
Deg. F = 1.8°C + 32

TABLE 4

TRANSVERSE JOINT MOVEMENT
(Unreinforced, Standard Spacing)

Change in Width from Original, 0.001-inch

Joint Spacing, Feet	13	12	18	19	13	12	18	19	13	12	18		
Gauge Loc. No.	1	2	3	4	5	6	7	8	9	10	Avg.	Air Temp. Deg. F
Placed 7-7-71												
Date												
7-9-71	1	0	29	1	1	10	0	40	1	10	10	76
7-19-71	4	25	42	32	1	47	26	45	1	28	25	72
7-19-71	0	6	6	10	-1	14	8	10	-1	5	6	90
11-22-71	44	45	78		17	46	66	85	27	27	50	50
9-21-72	69	68	90	96	42	68	87	73	49	55	70	67
9-21-72	51	51	60	64	38	55	60	40	39	37	50	83
12-13-72	76	43	72	103	41	53	77	60	41	30	62	44
1-11-74	100	54	68	115	42	48	81	69	45	32	65	47
12-17-74	81	35	49	103	40	47	73	53	39	22	54	53
1-6-76	83	45	49	103	41	44	73	83	37	16	57	60
1-6-77	77	45	45	109	39	44	72	68	34	12	55	49

NOTE: 1 inch = 25.4 mm
1 foot = 0.3048 m
Deg. F = 1.8°C + 32