Investigation of Longitudinal Cracking Reflected Through Asphaltic Concrete Resurfacing

John E. Boring and Bert Myers,
Materials Department, Iowa State Highway Commission

• THE JOINT at the outside edge of an old portland cement concrete slab that has been widened and then resurfaced with asphaltic concrete frequently produces a reflection crack in the asphaltic concrete resurfacing. In September 1958 the Iowa Highway Commission made a survey of 599 mi of pavement that had been widened and resurfaced in the preceding ten years. This paper reports the incidence of reflection cracking in the 1,198 mi of joint surveyed. An attempt has been made to discover the relative effect of the following factors which appear to be significant in the development of reflection cracks:

1. The use of welded wire fabric reinforcement in the asphaltic concrete resurfacing.
2. Three types of widening, including:
   a. Nine inches of portland cement concrete;
   b. Six inches of rolled stone and five inches of asphaltic concrete;
   c. Ten or eleven inches of asphaltic concrete.
3. The delay between widening and resurfacing.
4. The age of the resurfacing.

The pavements surveyed were of portland cement concrete built originally to a width of either 18 or 20 ft and later widened to 24 ft. In nearly all cases equal widths of widening strip were placed on each side of the original pavement slab. The data included in this report refer only to pavements with equal widths of widening strips on the two sides of the old slab.

The subgrade beneath the widening strips was compacted in its natural state as to moisture content, and there was no subbase beneath the old pavement or the widening strips. The widening strips were not doweled to the old slab.

In all but four cases the resurfacing has consisted of two layers of dense-graded, hot-mix asphaltic concrete, each 1½ in. thick. In all but two of the projects utilizing rolled stone and asphaltic concrete as the base, the rolled stone portion was 6 in. thick. These six cases which deviate from the normal thicknesses are included in Tables 1 and 2 but have been excluded from Tables 2 and 3, Figures 1, 2, and 3, and the analysis.

The collection of data was undertaken using a device consisting of a small wheel towed behind a slow moving automobile and two revolution counters. A cam on the wheel opened and closed a micro-switch activating the counters located inside the automobile. One of these counters ran continuously giving the total number of wheel revolutions in a project. The other counter could be thrown into and out of operation by means of a toggle switch held by the operator. This latter counter yielded the total wheel revolutions of cracking in a project. An in-line switch was used to stop and start both counters simultaneously so that all mileage over bridges, culverts and railroad crossings could be eliminated from the total counts. This wheel was towed as fast as the operator could distinguish the beginning and ending of the cracking, usually at a maximum of about 15 mph.

Table 1 is a summary of all projects by counties and gives the results for each individual project as surveyed in September, 1958. Table 2 gives the same information derived from a similar survey made in March, 1956. Table 3 is a compilation of all projects according to delay time, in years, between widening

TABLE 1

SUMMARY OF PROJECTS

Project	Road	Length (mi)	Type Widening	Year Widened	Year Resurfaced	Delay (yr)	Age of Resurf	Mesh	Cracking
A-1	US 71	11.82	P.C.	1957	1957	0	1	No	8.4
A-2	US 71	4.77	P.C.	1956	1956	0	2	No	27.7
B-1	US 30	2.77	P.C.	1954	1954	0	4	No	0.9
B-2	US 63	7.91	P.C.	1955	1955	0	3	No	63.6
B-3	US 20	4.62	P.C.	1955	1956	1	2	No	5.5
B-4	US 218	13.13	P.C.	1955	56-57	2	1	No	15.3
B-5	US 63	4.98	P.C.	1954	1954	0	4	No	63.4
B-6	Ia 150	10.49	P.C.	1954	1954	0	4	No	10.7
B-7	US 20	7.95	P.C.	1956	1956	0	2	No	45.2
B-8	US 20	13.28	P.C.	1956	56-57	1	1	No	10.4
C-1	US 20	12.12	P.C.	1956	1957	1	1	No	9.6
C-2[a]	US 30	10.13	P.C.	1954	1954	0	4	No	36.4
C-3	US 6	11.27	P.C.	1955	1956	1	2	No	18.8
C-4	US 71	7.29	RS-AC	1957	1957	0	1	No	0.5
C-5	US 65	4.49	RS-AC	1948	49-49	1	9	No	49.4
C-6	US 65	3.11	RS-AC	1948	1948	0	10	No	23.5
C-7	US 65	5.39	P.C.	1954	1956	2	2	No	0.9
C-8	US 18	5.29	RS-AC	1948	1948	0	10	No	43.3
C-9	US 30	9.78	RS-AC	1950	1950	0	8	No	39.0
C-9	US 30	0.45	P.C.	1950	1950	0	8	No	23.6
C-10	US 30	1.96	RS-AC	1950	1950	0	8	No	48.8
C-11	US 30	15.00	RS-AC	49-50	49-50	0	8	No	70.2
D-1	{Ia 141, US 169}	10.6	P.C.	1955	1956	1	2	Yes	0.0[b]
D-2	US 169	9.57	P.C.	1955	1957	2	1	No	4.4
D-3[c]	US 34	7.63	P.C.	1953	1953	0	5	No	5.5
D-4	US 61	7.08	P.C.	1956	1957	1	1	No	0.4
F-1	US 18	1.27	RS-AC	1948	1948	0	10	No	83.2
F-2	US 18	15.07	RS-AC	1948	48-49	1	9	No	61.2
H-1	US 20	10.15	P.C.	1955	1957	2	1	No	2.6
H-2	US 69	10.98	P.C.	1955	1957	2	1	Yes	0.3
H-3	US 65	13.37	P.C.	1956	1957	1	1	Yes	0.6
H-4	US 65	10.49	P.C.	1955	1957	2	1	Yes	0.2
H-5	US 30	15.80	P.C.	1956	1956	0	2	No	0.1
H-6	US 30	9.59	P.C.	1956	1956	0	2	No	10.5
H-7	US 75	12.17	P.C.	1956	1957	1	1	No	0.3
I-1	US 6	3.32	10" AC	1956	1956	0	2	Yes	1.1
I-2	US 6	19.86	P.C.	1955	55-56	1	2	No	1.5
I-2	US 6	0.26	P.C.	1955	55-56	1	2	Yes	0.0
J-1	Ia 163	16.35	P.C.	1956	1957	1	1	Yes	0.0
J-2	US 6	5.58	RS-AC	1950	1950	0	8	No	33.9
J-2	US 6	6.98	P.C.	1950	1950	0	8	No	79.2
J-3	US 6	6.16	11" AC	1950	1950	0	8	No	95.6
J-4	US 6	6.23	P.C.	1955	1956	1	2	Yes	0.0
J-5	US 6	7.90	P.C.	1955	55-56	1	2	No	0.0
L-1	US 61	7.76	P.C.	1951	51-52	1	6	No	44.8
L-2	Ia 2	8.79	10" AC	1957	1957	0	1	No	0.2
L-3	Ia 150	12.97	P.C.	1955	1957	2	1	Yes	0.0
L-4	US 61	7.73	P.C.	1956	1957	1	1	No	5.5
L-5	US 34	8.73	P.C.	1956	1957	1	1	Yes	0.0[d]
M-1	Ia 163	11.33	P.C.	1956	1956	0	2	No	10.4
M-2	US 63	12.25	P.C.	1953	1953	0	5	No	16.0
M-3	Ia 163	1.94	P.C.	1956	1956	0	2	No	20.1
M-4	Ia 60	19.49	P.C.	1956	1957	1	1	Yes	0.0
M-5	Ia 92	15.11	P.C.	1955	1956	1	2	No	0.5
M-6	US 75	10.90	P.C.	1956	1956	0	2	No	0.5
M-7	US 75	14.12	P.C.	1955	1956	1	2	No	0.0[d]
M-8	US 6	16.52	P.C.	1955	1956	1	2	No	0.0[d]
P-1[e]	US 69	7.21	RS-AC	1949	49-56	0 & 7	2	No	8.4
P-1[e]	US 69	1.87	RS-AC	1949	49-56	0 & 7	2	Yes	0.1
P-2	US 69	4.47	P.C.	1949	1949	0	9	No	38.9
P-3	US 6	7.87	RS-AC	1950	1950	0	8	No	92.4
P-3	US 6	0.84	12" RS 5" AC	1950	1950	0	8	No	86.2[e]
P-4	Ia 28	6.41	P.C.	1955	1956	1	2	No	0.3
P-4	Ia 28	5.17	P.C.	1955	1956	1	2	Yes	0.2
S-1	US 6	8.66	P.C.	1955	1956	1	2	No	0.1
S-2	US 6	9.13	P.C.	1955	1956	1	2	No	0.0
S-3	US 69	0.24	P.C.	55-56	1958	2	0	No	0.0
S-3	US 69	5.68	P.C.	55-56	1958	2	0	Yes	0.1
S-4	US 65	13.55	P.C.	1956	1957	1	1	No	23.3
S-5	US 30	5.28	P.C.	1953	1956	3	2	No	1.9
S-6	US 69	6.74	RS-AC	1949	1949	0	9	No	83.3
S-7	US 30	5.06	P.C.	1955	1956	1	2	No	4.3
W-1	US 34	6.33	P.C.	1952	1952	0	6	No	39.8
W-2	Ia 92	10.03	P.C.	1956	1957	1	1	Yes	0.0
W-3	US 20	12.36	P.C.	1956	1957	1	1	No	1.3
W-4	US 75	7.61	P.C.	1955	1956	1	2	No	2.6
W-5	US 75	4.18	P.C.	1955	1956	1	2	No	5.2
W-6[f]	US 75	9.00	P.C.	1954	1954	0	4	No	90.4
W-7	US 65	2.10	P.C.	1954	1956	2	2	No	0.3

[a] Data not included in analysis due to resurfacing of only 1½ in.
[b] Some cracking, but less than 0.05 percent.
[c] Not included in analysis.
[d] Some cracking, but less than 0.05 percent.
[e] Not included in analysis.
[f] This data not included in analysis due to resurfacing of only 2 in.

TABLE 2

SUMMARY OF 1956 SURVEY

Project	Road Number	Length (mi)	Type Widening	Year Widened	Year Resurfaced	Delay (yr)	Age of Resurf.	Mesh	Cracking
B-1	US 30	2.77	P.C.	1954	1954	0	2	No	0
B-2	US 63	7.91	P.C.	1955	1955	0	1	No	41
B-5	US 63	5.07	P.C.	1954	1954	0	2	No	29
B-6	Ia 150	10.54	P.C.	1954	1954	0	2	No	9
C-5	US 65	4.49	RS-AC	1948	48-49	1	7	No	16
C-6	US 65	3.11	RS-AC	1948	1948	0	8	No	16
C-8	US 18	5.29	RS-AC	1948	1948	0	8	No	43
C-9	US 30	10.21	RS-AC	1950	1950	0	6	No	26
C-10	US 30	1.96	RS-AC	1950	1950	0	6	No	37
C-11	US 30	15.00	RS-AC	49-50	49-50	0	6	No	46
F-1	US 18	1.27	RS-AC	1948	1948	0	8	No	63
F-2	US 18	15.87	RS-AC	1948	48-49	1	7	No	41
J-2	US 6	5.58	RS-AC	1950	1950	0	6	No	14
J-2	US 6	6.98	P.C.	1950	1950	0	6	No	64
L-1	US 61	7.59	P.C.	1951	51-52	1	4	No	24
M-2	US 63	12.25	P.C.	1953	1953	0	3	No	10
P-2	US 69	6.55	P.C.	1949	1949	0	7	No	42
P-3	US 6	7.87	RS-AC	1950	1950	0	6	No	78
S-6	US 69	10.95	RS-AC	1949	1949	0	7	No	74
W-1	US 34	6.33	P.C.	1952	1952	0	4	No	23

TABLE 3

TABULATION ACCORDING TO DELAY TIME, AGE OF RESURFACING, AND USE OF STEEL MESH

Delay Years	Age Resurfacing (yr)	Mesh	Length Surveyed (mi)	Total Length Surveyed (%)	No. Projects Included	Cracking (%)
(a) 9 In. Portland Cement Concrete						
0	1	No	19.37	98	2	21.7
0	2	No	95.29	96	12	16.1
0	3	No	20.21	100	2	31.1
0	4	No	23.69	96	4	22.0
0	5	No	11.69	95	1	16.0
0	6	No	13.26	100	2	52.6
0	7	No	6.55	100	1	42.0
0	8	No	6.27	84	2	75.1
1	1	No	72.15	92	7	8.2
1	2	No	121.42	93	13	2.4
1	4	No	7.59	100	1	24.0
1	6	No	7.17	92	1	44.8
2	0	No	0.24	100	1	0.0
2	1	No	27.90	85	3	8.0
2	2	No	6.71	90	2	0.7
3	2	No	5.04	95	1	1.9
1	1	Yes	63.93	94	5	0.1
1	2	Yes	17.87	83	4	0.0[a]
2	0	Yes	6.53	100	1	0.1
2	1	Yes	33.28	97	3	0.1
(b) 6 In. Rolled Stone and 5 In. Asphaltic Concrete						
0	1	No	6.35	—	1	0.5
0	6	No	32.75	100	4	33.8
0	7	No	6.74	100	1	74.0
0	8	No	37.31	75	8	55.8
0	9	No	11.01	98	2	65.4
0	10	No	8.11	84	3	40.6
1	7	No	20.36	100	2	35.5
1	9	No	19.08	98	2	58.4
(c) 10 In. or 11 In. Asphaltic Concrete						
0[b]	1	No	8.42	96	1	0.2
0[b]	2	No	2.63	79	1	1.1
0[c]	8	No	1.53	25	1	95.6

[a] Actual = 0.04 percent.
[b] 10 in. asphaltic concrete and 2 in. limestone screenings.
[c] 11 in. asphaltic concrete.

and resurfacing, the age of the resurfacing and the use of welded wire fabric reinforcing. Figure 1 shows the effect of age of the resurfacing and compares the types of widening; Figure 2, the effect of a delay period between widening and resurfacing; and Figure 3, the effect of welded wire fabric reinforcement as related to the delay period and the age of the resurfacing. Table 4 is a comparison of cracking present at the time of the 1956 and 1958 surveys on the same projects and shows the increase in cracking during that period.

Even with the substantial volume of data available the amount of comparative data is limited. This is because the pavements surveyed were not designed as experimental projects in that no attempt was made to eliminate or minimize the effects of uncontrolled variables in their construction. The effect of this situation is apparent in Table 3 under "No. Projects Included." It will be noted that when the data are separated into categories such that the age of the resurfacing, the delay between widening and resurfacing, the type of pavement in the widening strip, and the presence or absence of steel reinforcement is the same, there are 12 of 31 categories in which only one project can be included and 8 of the 31 categories represent only two projects. Only 5 of 31 categories represent 5 or more projects each. Reinforcement of the resurfacing with welded wire fabric has

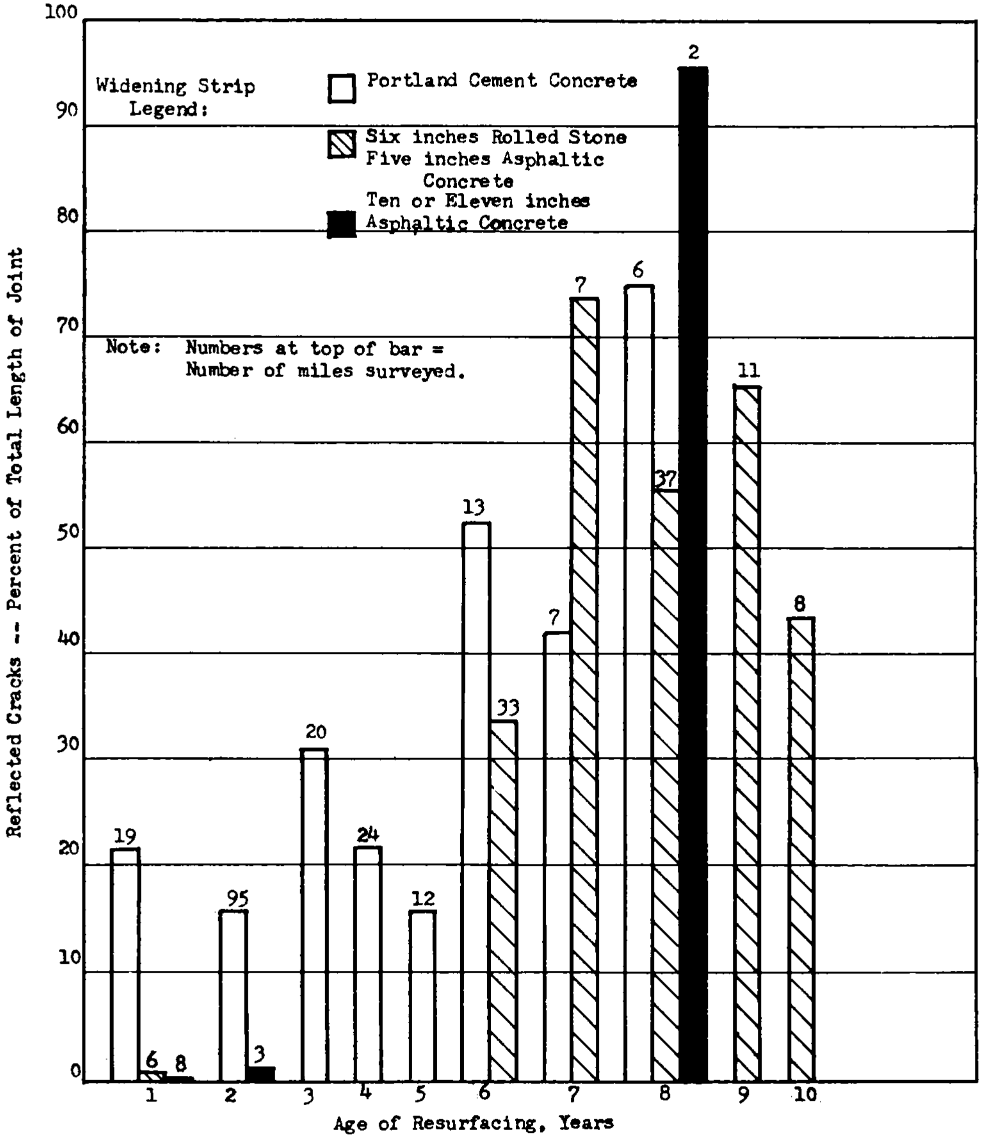

Figure 1. Longitudinal reflection cracking along widening as related to age of resurfacing and type of widening. No reinforcement — no delay time between widening and resurfacing.

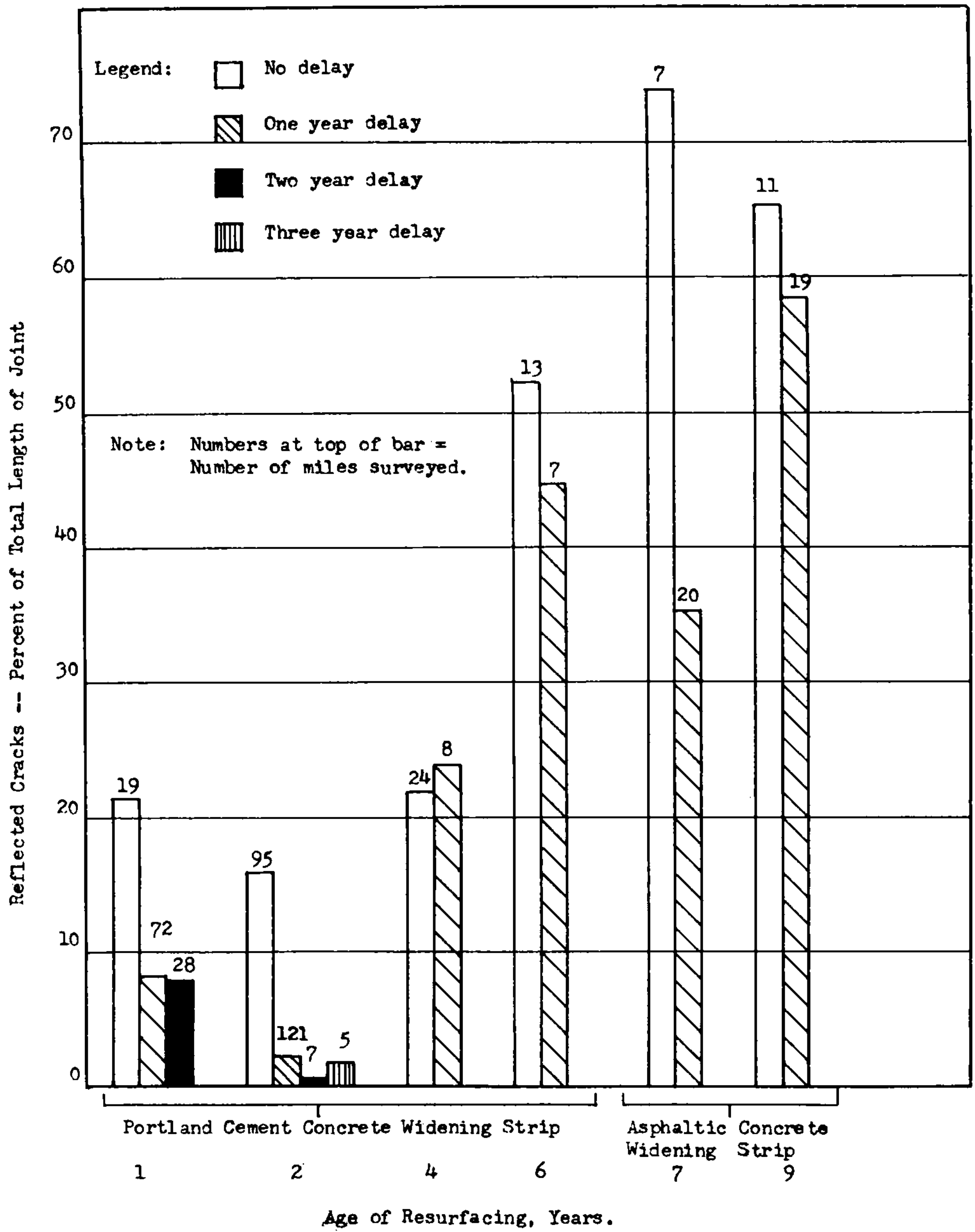

Figure 2. Longitudinal reflection cracking along widening as related to delay in years between widening and resurfacing with respect to age of resurfacing. No reinforcement.

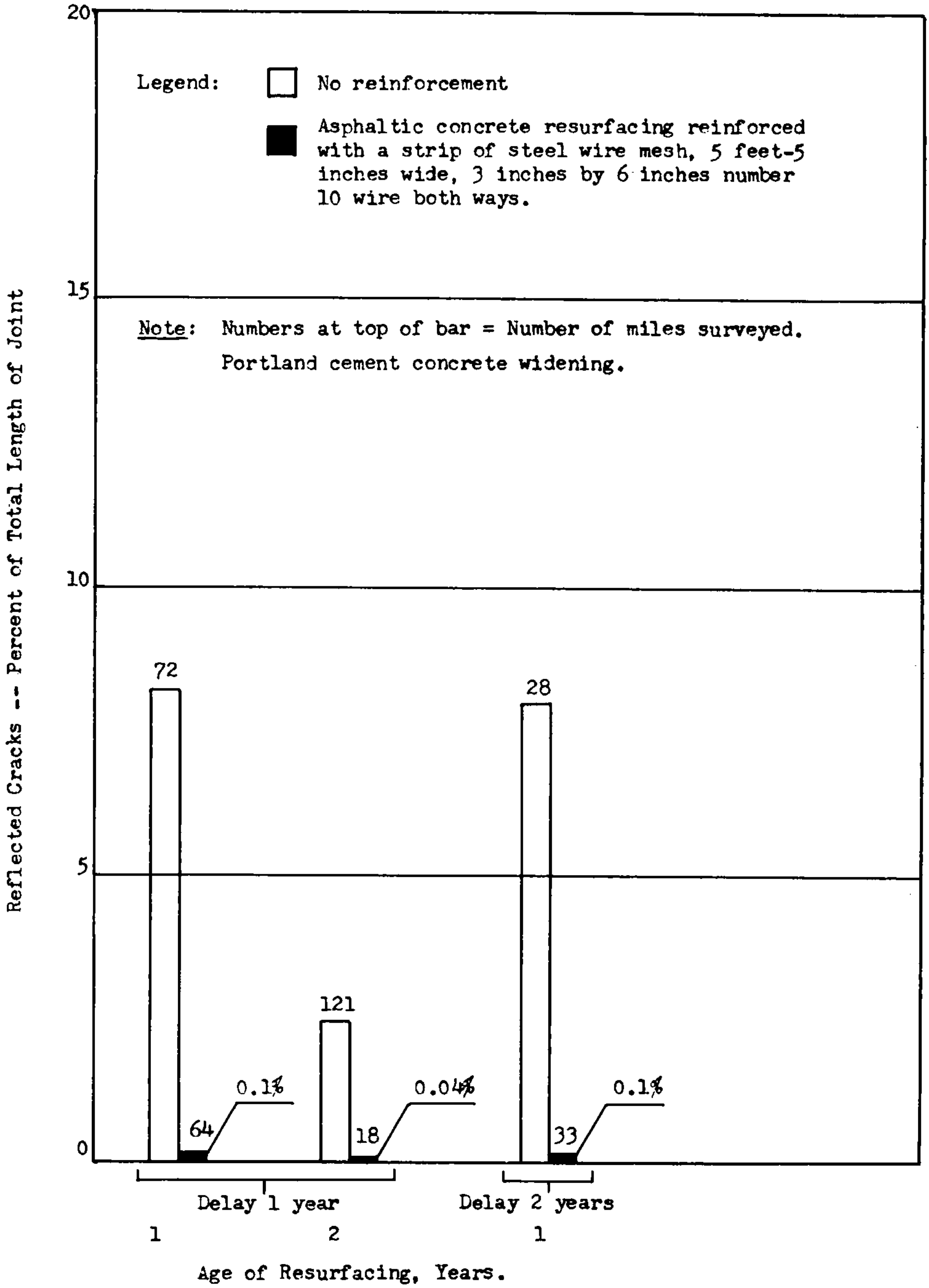

Figure 3. Longitudinal reflection cracking along widening as related to reinforcement of the asphaltic concrete resurfacing with respect to the delay time and age of the resurfacing.

TABLE 4

COMPARISON OF THE 1956 AND 1958 SURVEYS, SHOWING INCREASE IN CRACKING

Project	Type Widening	Delay (yr)	Mesh	Cracking 1956 (%)	Cracking 1958 (%)	Increase (%)
B-1	P.C.	0	No	0	1	1
B-2	P.C.	0	No	41	64	23
B-5	P.C.	0	No	29	63	34
B-6	P.C.	0	No	9	11	2
C-5	RS-AC	1	No	16	49	33
C-6	RS-AC	0	No	16	24	8
C-8	RS-AC	0	No	43	43	0
C-9	RS-AC	0	No	26	39	13
C-10	RS-AC	0	No	37	49	12
C-11	RS-AC	0	No	46	70	24
F-1	RS-AC	0	No	63	83	20
F-2	RS-AC	1	No	41	61	20
J-2	RS-AC	0	No	14	34	20
J-2	P.C.	0	No	64	79	15
L-1	P.C.	1	No	24	45	21
M-2	P.C.	0	No	10	16	6
P-2	P.C.	0	No	42[a]	39	—
P-3	RS-AC	0	No	78	92	14
S-6	RS-AC	0	No	74	83	9
W-1	P.C.	0	No	23	40	17

[a] This project resurfaced in 1956 immediately after the survey was taken.

been done only on projects using portland cement concrete as the widening medium so that a comparison of the use of wire fabric reinforcement on the three different types of widening strips cannot be made. Two years is the maximum age of resurfacing reinforced with welded wire fabric on any project of significant length. The data for the section of pavement only 0.26 of a mile long where the resurfacing was reinforced and which is now three years old have not been included in the analysis. However, the data do seem to provide the following indications:

1. The use of welded wire fabric reinforcement in the asphaltic concrete resurfacing will reduce or delay the development of longitudinal reflection cracking. Up to an age of two years this appears to be about 8 percent. Surveys made in future years should provide data as to the permanence of this apparent improvement. A project or projects designed to segregate the effects of this factor would be desirable.

2. A condition rating of the three types of widening does not indicate clearly the superiority of any one particular type. As in the case of steel reinforcement, more data should be available before a definite conclusion can be reached.

3. A delay of at least one year between widening and resurfacing will have an effect as great or greater than the use of welded wire fabric reinforcement. In one case (comparison of no delay and one year delay at age two years) the percent cracking decreased from 16.1 percent to 2.4 percent on 12 projects (95 mi) and 13 projects (121 mi), respectively, indicating a decrease in reflection cracking due solely to a delay period.

4. Other things being equal, the extent of reflection cracking varies with the age of the asphaltic concrete resurfacing.

Several of the uncontrolled variables have been investigated to determine the degree to which they may have affected the percent of cracking.

Soil maps of the state have been studied with the idea in mind that some soils give more subgrade support than others or are affected less by freeze and thaw and consolidation or swelling in the trench subgrade. No close correlation could be found between subgrade soil type and the incidence in cracking. However, when the percent of cracking by projects is divided into brackets and the subgrade soil type is listed opposite each project it is found that glacial soils occur more frequently in the brackets of low percentages of cracking than opposite the projects in the brackets of high percentage cracking. The opposite is true for loess and bottomland soils.

The specification for weight of the rollers used in trench compaction was changed as of October 2, 1956. The required loading before this time had been 250 lb per lin in. of width of roller. After October 2, 1956, the loading was left to the discretion of the engineer on the job with a minimum of a 3- to 5-ton smoothing roller. This was done to eliminate extra compaction of soils which are easily compacted when dry but which tend to swell considerably when wet. The effect of this change could not be expected to be apparent in the survey made in 1958.

Climatological reports for the state have been studied with the thought that possibly the construction of the widening strip in a relatively dry year followed by a relatively wet one would cause swelling of the trench subgrade—subsequently increasing cracking. No indication is shown that this effect is appreciable.

It is suggested that a continuing study be made of these and any additional projects constructed. In this manner the effect of the uncontrolled variables such as subgrade support, weather, construction practice and traffic will tend to minimize themselves. It is further suggested that an experimental road or roads be established in which the many variables could be isolated for study. Such an experimental road could have the type of widening alternated and the reinforcing welded wire fabric placed intermittently along the full length of the project on both traffic lanes.

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