SOIL-AGGREGATE CUSHIONS FOR PREVENTION OF REFLECTION CRACKING OF RESURFACED PAVEMENTS
Third Progress Report

F. Copple

Research Laboratory Division
Office of Testing and Research
Research Project 62 F-70
Research Report No. R-599 (Rev.)

State of Michigan
Department of State Highways
Lansing, October 1966

INFORMATION RETRIEVAL DATA

REFERENCE: Copple, F. "Soil-Aggregate Cushions for Prevention of Reflection Cracking of Resurfaced Pavements: Third Progress Report." Michigan Department of State Highways Research Report No. R-599. September 1966. Research Project 62 F-70.

ABSTRACT: This progress report describes the condition, after almost four years service, of a rigid pavement resurfaced with bituminous concrete, using a soil-aggregate cushion between old and new surfaces. The cushions have significantly reduced cracking of the bituminous overlay. Of the cushion materials, asphalt-stabilized soil-aggregate appears to be more effective in reducing reflection cracking and in preventing map cracking at the pavement edge than the 22A-23A gravel.

KEY WORDS: reflection cracking, resurfacing, surface cracking, crack propagation, cracking (fracturing), cracks, bituminous overlay.

SOIL-AGGREGATE CUSHIONS FOR PREVENSION OF REFLECTION CRACKING OF RESURFACED PAVEMENTS
Third Progress Report

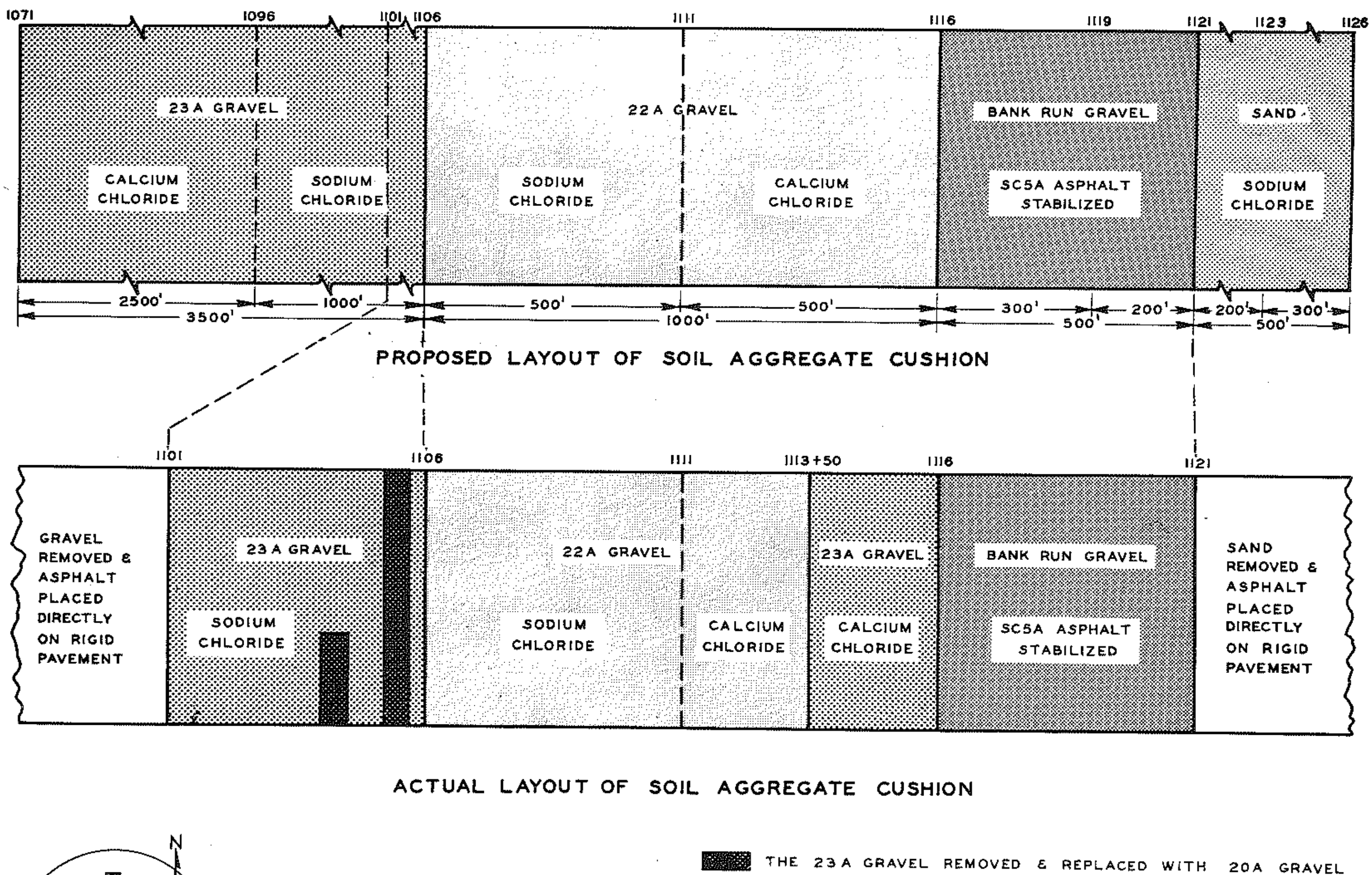
This report describes the condition, after almost four years service, of a rigid pavement resurfaced with bituminous concrete and using a soil-aggregate cushion between the old and new surfaces. Construction of this project was described in detail in Research Report No. R-423 "Soil Aggregate Cushions for Prevention of Reflection Cracking of Resurfaced Pavements" (May 1963). Performance of the pavement after two years of service was discussed in Research Report No. R-470, the second progress report. Final layout of the soil-aggregate cushion, constructed to a thickness of 4 in. and 2000 ft in length, is diagrammed in Figure 1, which shows the five different materials used for the cushion:

23A gravel with sodium chloride admixture
22A gravel with sodium chloride admixture
22A gravel with calcium chloride admixture
23A gravel with calcium chloride admixture
"Bank run" gravel with SC-5A asphalt admixture

Pavement condition surveys were conducted over the old rigid pavement, and again over the resurfaced pavement after each of four winters of use. Results of these surveys are tabulated in Tables 1, 2, and 3, which summarize transverse and longitudinal cracking reflected through the bituminous surface.

Table 1 provides details of transverse reflection cracking in the 22A-23A gravel cushion areas. Although there appears to be some difference in performance between the two gravels and the admixtures, their test sections were too short to provide reliable conclusions, and therefore the 22A-23A results were combined for further discussion.

Table 2 summarizes the effectiveness of the cushions in reducing transverse reflection cracking. The old rigid pavement averaged about five transverse cracks per 100-ft slab. The table shows that after four winters about 51 percent of the transverse cracks had reflected through the bituminous surface where no cushion was used, about 20 percent through the 22A-23A gravel cushion area, and about 11 percent in the "bank run" SC-5A asphalt-stabilized gravel cushion areas. Statistically,



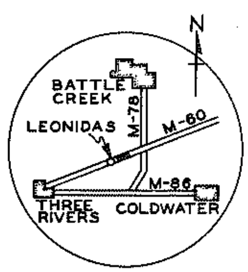


Figure 1. M 60 test site for soil aggregate cushions.

the proportion of transverse reflection cracks reflected through the bituminous surface in the cushioned and non-cushioned areas differs significantly. However, although there appears to be a sizeable difference between the 22A-23A and the "bank run" gravel cushion areas, these are not very significant when tested statistically. Appendix A describes the statistical tests used for these conclusions. Figure 2 shows transverse reflection cracking with respect to time. It is interesting to note that most reflection cracking occurred during the first year of service.

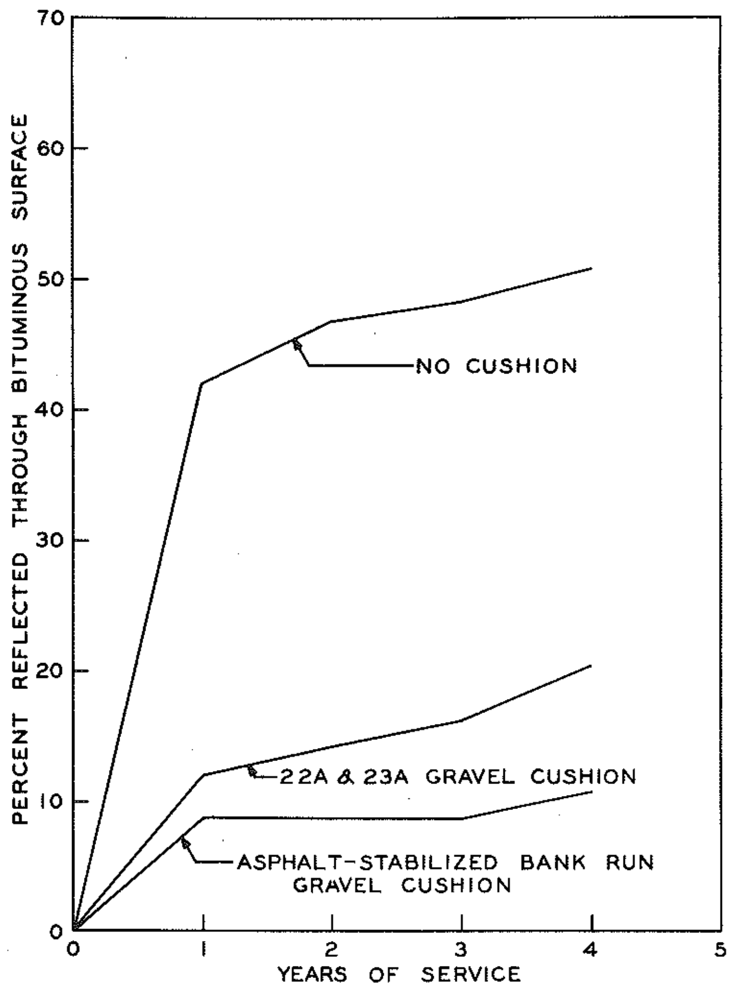


Figure 2. Transverse reflection cracking with respect to time.

Table 3 indicates no longitudinal reflection cracking in the areas where the asphalt-stabilized cushion was used. No longitudinal cracking had been noted in the 22A-23A gravel cushion for the first three winters, but after the fourth about 10 percent of the length of widening strip had reflected through the pavement. Statistical tests of the data, given in Appendix B, indicate that the effect of the gravel cushions in reducing longitudinal reflection cracks was highly significant. Further, the tests indicated the asphalt-stabilized cushion to be significantly better than the 22A-23A in reducing longitudinal reflection cracks.

No joint blowups were apparent in any of the test areas. Map cracking extended about 8 in. in from the edge of the pavement in the 22A-23A gravel cushion areas. None was observed in the asphalt stabilized gravel cushion area.

Summary

After nearly four years of service, the soil aggregate cushions used in these tests have been of significant value in reducing reflection cracking of the bituminous overlay. Of the cushion materials, asphalt-stabilized soil-aggregate appears to be more effective in reducing reflection cracking and in preventing map cracking at the edge of the pavement than the 22A-23A gravel.

TABLE 1

TRANSVERSE CRACKING OF 22A-23A GRAVEL CUSHION SECTIONS

Treatment	Location by Station	Original Pavement		After One Winter		After Two Winters		After Three Winters		After Four Winters	
		Number of Cracks	Cracks per Slab	Number of Cracks	Percent Reflected Through Overlay	Number of Cracks	Percent Reflected Through Overlay	Number of Cracks	Percent Reflected Through Overlay	Number of Cracks	Percent Reflected Through Overlay
23A Gravel with Sodium Chloride Admixture	1101+00 to 1106+00	29	5.8	2	6.9	3.5	12.1	4	13.8	6.0	20.7
22A Gravel with Sodium Chloride Admixture	1106+00 to 1111+00	23	4.6	4	17.4	4.25	18.4	5	21.7	5.5	23.9
22A Gravel with Calcium Chloride Admixture	1111+00 to 1113+50	7	2.8	3	42.9	3.0	42.9	3	42.8	3.5	50.0
23A Gravel with Calcium Chloride Admixture	1113+50 to 1116+00	15	6.0	0	0	0	0	0	0	0	0
Complete 22A-23A Gravel Section	1101+00 to 1116+00	74	4.9	9	12.1	10.75	14.5	12	16.2	15.0	20.3

TABLE 2

TRANSVERSE REFLECTION CRACKING OF BITUMINOUS OVERLAY

Treatment	Location by Station	Total Transverse Cracks and Joints in Original Pavement	After One Winter		After Two Winters		After Three Winters		After Four Winters	
			Number of Cracks	Percent Reflected Through Overlay	Number of Cracks	Percent Reflected Through Overlay	Number of Cracks	Percent Reflected Through Overlay	Number of Cracks	Percent Reflected Through Overlay
Asphalt Surface Directly on Old Rigid Pavement	1022+00 to 1101+00	370	155	42	174	47	182.5	49	191.5	52
22A-23A Gravel with Chlorides	1101+00 to 1116+00	74	9	12	10.75	15	12.0	16	15.0	20
SC-5A Asphalt-Stabilized Bank Run Gravel	1116+00 to 1121+00	23	2	9	2	9	2.0	9	2.5	11
Asphalt Surface Directly on Old Rigid Pavement	1121+00 to 1183+00	329	137	42	151	46	155.5	47	162.5	49

TABLE 3
LONGITUDINAL REFLECTION CRACKING OF BITUMINOUS OVERLAY

Treatment	Location by Station	Original Rigid Pavement			After One Winter		After Two Winters		After Three Winters		After Four Winters	
		Longitudinal Cracking, ft	Length of Widening Strip, ft	Total Length of all Longitudinal Discontinuities, ft	Length, ft	Percent of Original Length	Length, ft	Percent	Length ft.	Percent	Length ft.	Percent
Asphalt Surface Directly on Old Rigid Pavement	1022+00 to 1101+00	838	7900	8738	54	0.6	488	5.6	1699	19.4	2777	31.8
22A-23A Gravel with Chlorides	1101+00 to 1116+00	56	1500	1556	0	0	0	0	0	0	158	10.2
SC-5A Asphalt Stabilized Bank Run Gravel	1116+00 to 1121+00	40	500	540	0	0	0	0	0	0	0	0
Asphalt Surface Directly on Old Rigid Pavement	1121+00 to 1183+00	646	6200	6846	30	0.4	1216	17.8	2150	31.4	3591	52.5

Appendix A
Test for Significant Effects of Soil Aggregate Cushions In Reducing Transverse Reflection Cracking After Four Winters of Service

Data Taken from Table 2:

P_1 = proportion of transverse cracks reflected through pavement in 22A-23A gravel cushion area = 20.3 percent

P_2 = proportion of transverse cracks reflected through pavement in asphalt-stabilized gravel cushion areas = 10.9 percent

P_3 = proportion of transverse cracks reflected through pavement where bituminous surface was placed directly on concrete = 50.7 percent

Null hypothesis: no significant difference in transverse reflection cracking exists between the cushioned and non-cushioned areas; i.e. $P_1 = P_2 = P_3$.

First, the null hypothesis will be tested between P_1 and P_3. Proportion P_1 and P_3 was pooled to obtain a better estimate to be used in determining a standard deviation.

$$P = \frac{N_1 P_1 + N_3 P_3}{N_1 + N_3} = \frac{15 + 354}{74 + 699} = \frac{369}{773} = 0.477$$

where

N_1 = number of transverse cracks in original rigid pavement in 22A-23A gravel cushion areas.

N_3 = number of transverse cracks in original rigid pavement in non-cushioned test area.

$$\sigma_{P_3-P_1} = \sqrt{P\ (1-P)\left(\frac{1}{N_1} + \frac{1}{N_3}\right)} = \sqrt{0.477 \times 0.523\left(\frac{1}{74} + \frac{1}{699}\right)}$$

$$= \sqrt{0.249\ (0.0135 + 0.0014)} = \sqrt{0.249 \times 0.0149} = \sqrt{0.00371}$$

$$\sigma_{P_3-P_1} = 0.061$$

$$Z^* = \frac{P_3-P_1}{\sigma_{P_3-P_1}} = \frac{0.507-0.203}{0.061} = \frac{0.304}{0.061} = 4.98$$

Thus, the difference between P_1 and P_3 is highly significant.

Test for difference between P_1 and P_2

$$\text{Pooled } P = \frac{N_1P_1 + N_2P_2}{N_1 + N_2} = \frac{15 + 2.5}{74 + 23} = \frac{17.5}{97} = 0.18$$

where

N_2 = number of transverse cracks in original rigid pavement in asphalt-stabilized gravel cushion areas.

$$\sigma_{P_1-P_2} = \sqrt{0.18 \times 0.82\left(\frac{1}{74} + \frac{1}{23}\right)} = \sqrt{0.1475\ (0.0135 + 0.0434)}$$

$$= \sqrt{0.1475 \times 0.0569} = \sqrt{0.0084} = 0.092$$

$$Z = \frac{P_1-P_2}{\sigma_{P_1-P_2}} = \frac{0.203-0.109}{0.092} = \frac{0.094}{0.092} = 1.02$$

Thus, the difference between P_1 and P_2 is not significant.

---

*When the value of Z, the standard variable, equals or exceeds 2, the probability is only about 5 percent or less that the null hypothesis is true. Thus, at this level, there is considered to be a significant difference between the two variables being compared. When the value of Z equals or exceeds 3, the probability is only about 0.3 percent or less that the null hypothesis is true. Thus, at this level, there is considered to be a highly significant difference between the two variables being compared.

Appendix B

Test for Significant Effects of Soil Aggregate Cushions In Reducing Longitudinal Reflection Cracking After Four Winters of Service

Data taken from Table 3:

P_1 = proportion of longitudinal cracks reflected through pavement in 22A-23A gravel cushion areas = 10.2 percent

P_2 = proportion of longitudinal cracks reflected through pavement in asphalt-stabilized gravel cushion areas = 0.0 percent.

P_3 = proportion of longitudinal cracks reflected through pavement where bituminous surface was placed directly on concrete = 40.8 percent

Null hypothesis: no significant difference in longitudinal reflection cracking exists between cushioned and non-cushioned areas; i.e. $P_1 = P_2 = P_3$

<u>Test $P_1 = P_3$</u>

$$\text{Pooled } P = \frac{N_1P_1 + N_3P_3}{N_1 + N_3} = \frac{158 + 6,368}{1,556 + 15,584} = \frac{6,526}{17,140} = 0.38$$

where

N_1 = linear feet of longitudinal reflection cracking in original rigid pavement in 22A-23A gravel cushion areas

N_3 = linear feet of longitudinal reflection cracking in original rigid pavement in non-cushioned test areas

$$\sigma_{P_3 - P_1} = \sqrt{P\,(1-P)\left(\frac{1}{N_1} + \frac{1}{N_3}\right)} = \sqrt{0.38 \times 0.62 \times \left(\frac{1}{1,556} + \frac{1}{15,584}\right)}$$

$$= \sqrt{0.236\,(0.00064 + 0.00006)} = \sqrt{0.236 \times 0.00070}$$

$$= \sqrt{0.000165} = 0.013$$

$$Z^* = \frac{0.41-0.10}{0.013} = \frac{0.31}{0.013} \doteq 24$$

Thus, the difference between P_1 and P_3 is highly significant.

<u>Test $P_1 = P_2$</u>

$$\text{Pooled } P = \frac{N_1P_1 + N_2P_2}{N_1 + N_2} = \frac{158 + 0}{1,556 + 540} = \frac{158}{2,096} = 0.075$$

where

N_2 = linear feet of longitudinal cracking in original rigid pavement in asphalt-stabilized gravel cushion areas.

$$\sigma_{P_1-P_2} = \sqrt{0.075 \times 0.925\left(\frac{1}{1,556} + \frac{1}{540}\right)} = \sqrt{0.070\ (0.00064 + 0.00185)}$$

$$= \sqrt{0.070 \times 0.00249} = \sqrt{0.00017} = 0.013$$

$$Z = \frac{P_1-P_2}{\sigma_{P_1-P_2}} = \frac{0.102-0.000}{0.013} = \frac{0.102}{0.013} = 7.8$$

Thus, the difference between P_1 and P_2 is highly significant.

---

*When the value of Z, the standard variable, equals or exceeds 2, the probability is only about 5 percent or less that the null hypothesis is true. Thus, at this level, there is considered to be a significant difference between the two variables being compared. When the value of Z equals or exceeds 3, the probability is only about 0.3 percent or less that the null hypothesis is true. Thus, at this level, there is considered to be a highly significant difference between the two variables being compared.