DEPARTMENT OF MAINTENANCE

Cracks in Asphalt Resurfacing Affected by Cracks in Rigid Bases

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● IT has been observed that where old concrete pavements have been resurfaced with asphaltic concrete many of the cracks and joints in the old pavement reappear as cracks in the asphalt surface. These are commonly called reflection cracks.

Usually such cracks appear in the resurfacing during the first few years of service. In themselves the cracks present a maintenance problem; potentially, they are the starting point for destructive forces which can materially shorten the service life of the resurfacing.

This investigation of reflection cracks in asphalt surfaces was begun in Iowa in 1948. At that time three test sections were established to provide information concerning the growth of reflection cracking and its effect on the service life of the resurfacing. In 1949 additional test sections were established for the purpose of evaluating several methods of treating cracks in the concrete before resurfacing.

MEASUREMENT OF REFLECTION CRACKING

For this investigation only transverse cracks and joints were considered. In the old concrete pavements these usually extend across the full width of the slab; occasionally they extend only from one edge to the center. However, when base cracks and joints are reflected in the asphalt resurfacing, the full length of the crack may not reappear for some time. Frequently only a few feet of a particular crack will be evident the first year, then after another year or two the reflected crack can be observed across the full width of the pavement.

Because of this the measurement of reflection cracking is based on the total length of transverse joints and cracks, rather than on the number of such joints and cracks. The percent of reflection cracking for any given section of highway is obtained from the following formula:

$$\text{Percent } RC = \frac{R(100)}{B}$$

where

RC = reflection cracking
B = total length of transverse joints and cracks in the base
R = total length of reflected cracks and joints

GROWTH OF REFLECTION CRACKING

Reflection cracking in asphalt resurfacing appears to be a progressive condition. Some of the cracks existing in the base at the time of resurfacing will reappear in the asphalt surface during the first year of service. In each succeeding year more of the base cracks will be reflected. This growth is probably affected by numerous variables, such as, the condition of the old concrete pavement and the design of the asphalt resurfacing.

During this investigation the growth of reflection cracking was observed in three test sections on US 69 between Ames and Des Moines. No general curve of growth has been derived, since the development of reflection cracking appears to be quite different for each of the three sections. The individual figures are shown in Table 1.

It may be observed that in Section A, 34 percent of the cracks in the old concrete pavement were reflected in the asphalt surface at the end of a year of service; for Section B this figure was 59 percent. At the end of 4 years, however, the reflection cracking in both sections had increased to 74 percent. In contrast to this, the reflection cracking in

TABLE 1
REFLECTION CRACKING
Sections on US 69

Section	Length of Section (Feet)	Percent Reflection Cracking After Months in Service								Amount of Base Cracking (Ft. per 100 Ft.)
		6	8	9	18	21	30	51	61	
A	5000	23			45		59		83	149
B	5000		54			69		74		125
C	3500			28		34		37		114

TABLE 2
CONCRETE PAVEMENTS

Item	Route 69			Route 30
	Section A	Section B	Section C	Sect. DEFGH
Date paved	1929	1923	1921	1922
Width	20 ft.	20 ft.	20 ft.	18 ft.
Thickness	10–8–10	8 uniform	7–8–7	7–8–7
Center joint	Mastic	None	None	None
Longitudinal reinforcement	4 bars ⅝ in.	3 bars ½ in.	3 bars ½ in.	3 bars ½ in.
Transverse joints	Expansion 94–99 ft. apart	Const. only	Const. only	Const. only
Concrete Proportions	By Weight 1:1.97: 2.88	By Weight 1:1.93: 2.91	By Volume 1:2: 3.5	By Volume 1: 4.84
Coarse Aggregate	Limestone	Gravel	Gravel	Gravel

Section C was 30 percent at the end of a year of service, and only 36 percent at the end of 4 years.

CONCRETE BASE

The resurfacing in all of the test sections was laid over old concrete pavements which vary in age and design. Detailed data concerning these pavements is contained in Table 2. No correlation has been discovered between any of the design features of the base and the amount of reflection cracking evident in the asphalt surface.

All test sections, except Section A, were originally paved with concrete containing dependable gravel aggregates. Section A was paved in 1929 with concrete containing a limestone aggregate which has since displayed a very-poor service record as an aggregate for concrete pavements.

Section A is also the only test section in which the old concrete pavement contains expansion joints. These were placed at intervals of 94 feet and 99 feet. By the time this section was resurfaced in 1948, almost all of the joints had been removed and had been replaced with concrete patches. This patching had been necessary because of the extensive deterioration of the concrete adjacent to the joints. The few joints remaining when the pavement was resurfaced have now reappeared as reflected cracks in the asphalt surface, and some break-up of the asphaltic concrete has been noted along the edges of these cracks.

TREATMENT OF BASE CRACKS

The treatment of cracks in the old concrete pavement has an influence on the amount and seriousness of reflection cracking in the asphalt surface. Common practice is to clean and refill the cracks a short time before the resurfacing is laid, but even this simple treatment is subject to variation.

On some of the earlier resurfacing projects in Iowa, cracks in the base which were open ½ inch or more were cleaned and then filled with material produced from the binder course material by raking out the larger particles. This method was used for the test sections on US 69. When the first evidence of reflection cracking was observed, the treatment of base cracks was given much consideration, and the test sections on US 30 near Clinton were established to compare several proposed treatments.

The five test sections on highway US 30

TABLE 3
REFLECTION CRACKING
Sections on US 30

Section	Length of Section (Feet)	Crack Treatment	Percent Reflection Cracking			Amount of Base Cracking (Ft. per 100 Ft.)
			Base Cracks Open 1 in. or More	Base Cracks Open Less Than 1 in.	All Base Cracks	
D	5000	Cleaned Filler-Binder Mix	72	44	49	82
E	5000	Cleaned Filler-Asphalt Mortar	62	29	35	97
F	2000	None	65	34	40	95
G	1470	None Extra 1½ in. Course SC-5	81	30	42	87
H	485 South	None Extra 1½ in. Course SC-5	63	12	34	46
	North	AC	62	32	49	39

total approximately 2.6 miles. Detailed crack surveys were made of the old concrete pavement throughout all of these test sections, and all cracks open an inch or more were specifically noted. Shortly before the resurfacing was laid, those cracks open an inch or more were outlined on the pavement with yellow paint, and only the cracks so marked were cleaned and filled.

In Section D the cracks open an inch or more were cleaned to a depth of 1 to 1½ inches with hand tools and compressed air. They were then filled with material produced from the binder course material by raking out the larger particles. Three years after the resurfacing was placed in Section D, 72 percent of the treated base cracks appeared as reflected cracks in the asphalt surface.

The cracks open an inch or more in Section E received the same cleaning treatment as those in Section D, but they were filled with hot-mixed asphalt mortar containing only the finer aggregate from the regular binder mix. All of this aggregate would pass a No. 4 sieve. When Section E was surveyed 3 years later, 62 percent of the treated base cracks had been reflected in the asphalt surface.

In Section F the base cracks were not cleaned nor filled. In this section 65 percent of the base cracks open one inch or more at the time of resurfacing reappeared in the asphalt surface after three years.

In Sections G and H the base cracks were not treated, but an extra 1½ inches of resurfacing was used. A discussion of the thickness of resurfacing in relation to reflection cracking is contained in this report.

ASPHALT RESURFACING

All of the test sections involved in this investigation were resurfaced with hot-mixed, hot-laid, asphaltic concrete. Average figures for grading of the aggregate, asphalt content, and stability are shown in Table 4. These figures were obtained from samples of the asphaltic concrete actually placed in the test sections.

The binder course in all sections is a dense-graded asphaltic concrete. It is possible that reflection cracking might have been reduced had an open-graded mix been used for the binder course. Such a mix was not used because of the danger of stripping. The movement of water through cracks in asphalt surface has been observed, and it is thought that such water will produce stripping more readily in an open-graded than in a dense-graded mix.

TABLE 4
ASPHALT RESURFACING

Item	Route 69						Route 30		
	Section A		Section B		Section C		Sec. DEFGH		Sect. G & H
	Bin.	Sur.	Bin.	Sur.	Bin.	Sur.	Bin.	Sur.	Sp. Bin.
% Asphalt[a]	5.04	5.82	5.44	6.08	5.70	5.81	5.45	6.08	4.73
Grading % Passing									
1	100	100	100	100	100	100	100	100	100
¾	89	99	99	100	93	100	89	99	97
½	77	95	89	93	84	94	74	91	83
⅜	64	84	74	79	72	83	61	75	68
4	54	64	50	55	52	59	46	52	49
8	42	50	40	46	44	48	35	39	36
16	30	36	30	36	32	36	28	32	—
30	18	24	21	25	21	23	22	25	22
50	12	18	16	18	16	16	17	19	17
100	8.6	10	10	10	10	9.6	13	14	12
200	7.0	6.4	6.9	6.6	6.2	7.2	10	11	8.7
Hveem Stability[b]	—	55	42	40	45	46	41	52	43
Sp. gr.—Design	—	2.27	2.27	2.28	2.29	2.28	2.36	2.39	2.32
Sp. gr.—Field	2.29	—	2.21	2.21	2.29	2.27	2.27	2.32	—
% Voids—Field	—	—	6.9	6.1	2.7	2.6	—	—	—
Asphalt Penetration	71	80	74	79	79	115	78	74	—

[a] By extraction.
[b] Side pressure, psi, at vertical load of 400 psi.

THICKNESS OF ASPHALT RESURFACING

Reflection cracking as affected by the thickness of resurfacing was studied on test Sections G and H on US 30. All base cracks in both sections were left untreated. The resurfacing in both sections is 4½ inches of hot mixed, hot-laid, asphaltic concrete placed in three courses each 1½ inches thick.

The first course in Section G contains the regular binder aggregate combined with an SC-5 cutback asphalt in place of the usual asphalt cement. The second course and the surface course contain asphalt cement. Three years after this resurfacing was laid, 81 percent of the base cracks an inch or more in width were reflected in the asphalt surface.

In Section H the first course on the south half of the highway contains SC-5, and the first course on the north side contains asphalt cement. The second binder course and the surface course on both sides of the road contain asphalt cement. On the south side 63 percent of the base cracks open an inch or more have been transmitted to the surface; on the north side the figure is 62 percent.

ASPHALT

In Section C on US 69, the surface course contains an asphaltic cement which had an average penetration of 115. The binder and surface courses in all other test sections contain asphalt cement which had a penetration of 70 to 85.

Sections B and C on US 69 were resurfaced during the same season, by the same contractor, using the same materials and equipment. The amount of base cracking in Section B was 125 feet per 100 feet of highway. In Section C this figure was 114 feet per 100 feet of highway. The reflection cracking observed in the two sections 4 years after resurfacing was 74 percent for Section B, where 75–80-penetration asphalt was used, and 36 percent for Section C where the 115-penetration asphalt was used.

This wide difference in the reflection cracking found in the two sections which are otherwise similar may possibly be explained by the penetration grade of asphalt used in the two sections.

This idea is also suggested by the fact that Section C on US 69 is the only section in which self-healing of the cracks in the asphalt surface has been observed in the wheel tracks.

AGGREGATE USED IN ASPHALT RESURFACING

The binder course laid in Section A on US 69 contains a crushed gravel aggregate. The surface course for this section and both binder and surface courses for all other test sections contain limestone aggregate. Consequently, in this investigation it is impossible to trace any difference in reflection cracking to a difference in the aggregate.

Such a comparison was reported by the Missouri State Highway Department (*1*). That report shows that during the first year of service a greater percent of base cracks was reflected in the asphalt concrete containing gravel aggregate than was reflected in that containing a dolomitic aggregate. After 4 years of service, however, the dolomitic section contained as many or more reflected cracks as did the gravel section.

SUMMARY

The following comments are based on observations made during this investigation.

In those sections where the base cracks were cleaned and refilled before resurfacing, the results indicate that an asphalt mortar is more satisfactory as a crack filler than is material from the regular binder course.

Where the cracks were not cleaned nor filled, the use of an additional 1½ inches of resurfacing apparently did not result in a significant reduction of reflection cracking.

In comparison with other test sections, the resurfacing containing SC-5 in the first course was not effective in preventing reflection cracking. However, there are some indications that reflection cracking was affected by the penetration grade of asphalt used in the surface course.

Observations will continue to be made on the test sections already established. Additional information is needed to aid in forming an accurate appraisal of the seriousness of reflection cracking and its effect on the useful life of the asphalt resurfacing.

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Control of Reflection Cracking in Bituminous Resurfacing over Old Cement-Concrete Pavements

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THIS paper describes the causes of reflection cracking and several experimental techniques for its control. Particular emphasis is placed on the strains imposed in bituminous-concrete surfaces by the horizontal movement of concrete slabs at joints and cracks due to temperature changes. Measurements were made of joint openings and closings in concrete pavements to determine the magnitude of strains imposed upon the resurfacing. Constant-strain and constant-stress tension-test procedures were developed to determine the strength and elongation characteristics of three types of bituminous concrete at winter temperatures.

Test-road sections are described in which several methods of joint treatment and reinforcing were incorporated. These experimental devices included plugging certain expansion joints with cement grout or a stabilized-soil mix, breaking the bond between bituminous concrete and cement concrete at joints, placing metal plates on concrete, and reinforcing the bituminous concrete with various types of metal placed either on the concrete or between binder and surface courses of bituminous mix.

The paper concludes that reflection cracking can be eliminated only by the development of new techniques for handling joints in resurfacing. Preliminary conclusions are drawn as to the effectiveness of the experimental techniques described.

● IN recent years many miles of old concrete pavements have been resurfaced with bituminous concrete. On the whole this has proven to be a satisfactory and economical method of restoring and enhancing the traffic service of older highways. After a short period of time, however, cracks usually begin to appear over the joints and cracks in the underlying concrete pavement; this phenomenon is commonly referred to as "crack reflection." It is undesirable for a number of reasons. Water is admitted through the cracks to the pavement below, often causing disintegration of the concrete, or softening of the subgrade. The cracks not only produce an unsightly road for the motoring public but frequently widen and deepen sufficiently to cause thumping under traffic. Their maintenance presents a special and difficult problem.

CAUSES OF CRACKING

Reflection cracking apparently results from differential vertical or horizontal movements at joints, cracks, and edges of the underlying slabs. The vertical movements may be caused by excessive deflections under loads such as