

Tests on Treatments for Reflective Cracking

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Eighteen test sections with a thin overlay either of 31.8 mm (1.25 in) of asphalt concrete or of 12.7 mm (0.5 in) of asphalt concrete finishing course were built in 1971 and 1972 to determine to what extent they prevented reflective cracking. Of these 18, 5 treatments were found to significantly reduce reflective cracking—heater scarification plus Petroset, asphalt rubber membrane interlayer, fiberglass, heater scarification plus Reclamite, and 200/300 penetration asphalt. Other performance aspects, such as roughness, rutting, deflection, and asphalt properties are reported, and costs in terms of construction and actual maintenance are given. Each treatment's failure or success is reviewed and considered before determining the conclusions and recommendations.

The primary object of any pavement design is not simply to provide a roadway of safe and desirable ride performance but also to extend these characteristics over a maximum useful life with minimum maintenance. However, because of the highly complex nature of flexible pavement structures, cracking, rutting, and other surface failures do occur and are influenced by environmental, traffic, and original design factors. Restoration to extend the useful life of deteriorating roadways typically involves the application of a thin asphalt overlay on the old pavement.

Historically, however, application of these thin overlays, which are generally of 10.2 cm (4 in) or less, results in a new and complex problem known as "reflective cracking" that is defined as the migration of a subsurface cracking pattern into and through the overlay. Once the overlay fractures, general erosion occurs and severely affects performance and requires further costly maintenance.

In an attempt to better understand the mechanism of reflective cracking and to pursue the development of new methods and materials to prevent it, a case study was conducted by the Arizona Department of Transportation, in conjunction with the federal National Experimental and Evaluation Program (NEEP) project on reducing reflective cracking in bituminous overlays (1). The NEEP project objective was to improve and develop materials, methods, and technologies to prevent or greatly minimize the occurrence of reflective cracks in overlays placed over previously cracked bituminous pavements.

This paper describes the Arizona test program, a case study of 18 selected roadway test sections, each evaluated by a carefully chosen set of parameters, materials, and application methods. The following is a summary of the test criteria and our results and recommendations (2).

Our preliminary activities involved extensively researching material and treatment, selecting and evaluating test site conditions, and finding an effective means for data accumulation and reduction. Eighteen individual roadway test sections were chosen to accommodate the range of desired test parameters. Beside each test section was a control section that served as a normalizing base for comparative measurement. This allowed engineers to observe and accumulate qualitative results from each test section, contrast them, and predict the influence of individual parameters. From these results, recommendations were made based on the effectiveness of crack prevention, cost, and other factors.

TEST PROGRAM

The test program was conducted on a 14.4-km (9-mile) section of highway (Minnetonka-East) near Winslow, Arizona, on I-40. Winslow is considered a high desert region, at an elevation of 1524 m (5000 ft), and has less than 20.3 cm (8 in) of rainfall annually. Temperature variations range from -18°C (0°F) during the winter to 38°C (100°F) during the summer. Minnetonka-East provided moderate to heavy average daily traffic (10 000 ADT), a fairly severe climate, and a history of extreme cracking problems. This section of highway was eligible for overlay during 1967 and was selected for use in the NEEP test program in 1970, the year the program was initiated.

Preparatory to designing the test, the nature and degree of distress were extensively evaluated. This involved core sampling, structural support testing, visual surveys, rut depth measurements, Benkelman beam tests, and traffic surveys. Rutting and Benkelman beam conditions are given below (1 mm = 0.039 in).

Test	Maximum	Minimum	Average
Rutting, mm	38.1	0.0	14.3
Benkelman beam, mm	1.9	0.05	0.9

Survey of the road conditions revealed extensive cracking, including block (flexural) and shrinkage (thermal) cracks. Spalling and rutting were also noted. The photographs in Figure 1 show the highway condition in 1969.

Federal participation was limited to an overlay thickness of 31.8 mm (1.25 in) of asphalt concrete (AC) and 12.7 mm (0.5 in) of asphalt concrete finishing course (ACFC) (3). Design engineers considered this thickness inadequate for the structural support necessary for long-term performance. However, as will be seen from the test conclusions, rather significant and impressive results were obtained with this relatively thin overlay.

The 18 test sections were unique in design, treatment, and materials used. The following table briefly describes each individual treatment by test section number (1 cm = 0.39 in).

Test Section Number	Description
1	Asphalt rubber plus precoated chips
2	Heater scarification plus Petroset
3	Asphalt rubber membrane interlayer placed over AC and under ACFC
4	Asphalt rubber membrane interlayer placed over AC and under ACFC
5	Asbestos fortified AC mix
6	No ACFC, 5 cm AC
7	Los Angeles Basin 120/150 penetration asphalt
8	Los Angeles Basin 40/50 penetration asphalt
9	Four corners 120/150 penetration asphalt
10	Los Angeles Basin 200/300 penetration asphalt
11	Emulsion-treated base in place of AC
12	Petromat placed under overlay
13	Fiberglass placed under overlay
14	Petroset flush of overlay before ACFC placed
15	Petroset placed in cracks
16	Reclamite placed in cracks

17	Reclamite flush with old AC
18A, B, C	Heater scarification of old AC plus Reclamite flush and varying AC overlay thickness
Controls	Conventional (standard) overlay

Although various test sections were opened to traffic

Figure 1. Typical roadway cracking on Minnetonka-East, February 1969.



as they were completed, construction was finished in June 1972 and the sections exposed to unrestricted traffic. It should be noted that in the 3½ years after the 1972 completion of overlaying, the highway has been subjected to loads equivalent to the first 9 years of original service. That is, 1975 ADT was 10 600 [i.e., the number of equivalent 80-kN (18 000 lbf) loads was 159 213] as compared to the 1958 ADT of 3342 (i.e., the number of 80-kN loads was 39 486).

Climatic variations were rather severe during the test period and rainfall was above average. Also, the test region has a freezing index of 700, which is quite high.

ANALYSIS

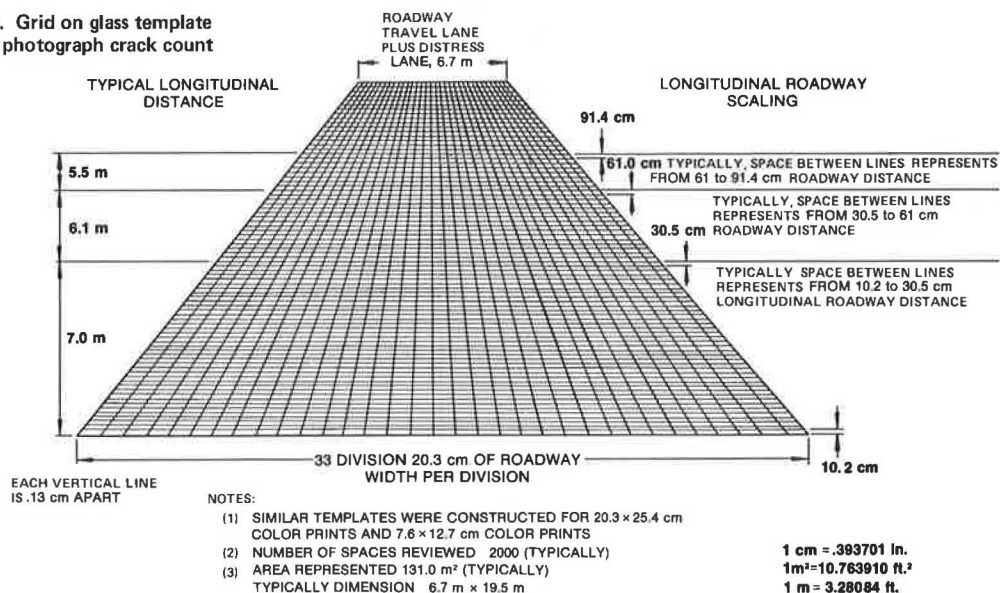
The Minnetonka project was designed to select the materials and treatments that significantly reduce reflective cracking. We therefore used a special photographic technique and an optical grid to accurately determine the extent and type of cracking before and after overlay. We used 35-mm color film to photograph 7.6-m (25-ft) highway panel sections from a mobile camera platform (Figure 2). Only the most severely cracked areas in the travel and distress lanes for each test section were photographed.

In addition, the highway was divided into 152.4-m

Figure 2. Mobile photography van.



Figure 3. Grid on glass template used for photograph crack count survey.



(500-ft) lengths, and one 7.6-m (25-ft) panel per 152.4-m length was randomly selected for photographing. Eighty-eight locations were photographed in March 1971.

The initial check of each print's quality led to the development of a glass template (Figure 3) to aid in our analysis. This template, designed to compensate for the distortion resulting from photographing at an oblique angle, divided each photo into several thousand parts.

We scanned each part line by line and coded each crack onto a computer form to indicate exact location. Coded forms were keypunched and processed by a special computer program that counted cracked and uncracked areas and computed the percentage of area cracked. The program also put each grid line into proper perspective by comparing the photos with the actual field cracking. We found that distortion did occur with distance, however, so we calculated the distance between each grid line up to the point where clarity was lost. Generally this point corresponded to a distance between grid lines of 0.9 m (3 ft) or more. As a result, 0.9 m was incorporated into the program as the logical end point after which no further grid lines would be counted for cracking.

The above procedure, although initially somewhat cumbersome because the cracked area was so large, proved efficient for measuring the magnitude of the original cracked area. It was also possible to differentiate to some degree between fatigue, or flexural cracking, and shrinkage cracking. Each photo location was photographed throughout 1975. The five photographs in Figure 4 provide the typical cracking history given below.

Photo-graph	Date	Cracking Before Overlay (%)	Cracking After Overlay (%)	Reflective Cracking After Overlay (%)
A	3/25/71	23.1	—	—
B	3/24/72	23.7	—	—
C	2/6/73	—	2.9	12.2
D	2/26/74	—	3.6	15.2
E	3/13/75	—	8.7	36.7

RESULTS

The percentage rankings presented in the table below are a true representation of cracking after overlay (1 mm = 0.039 in).

Test Section Number	Treatment	Percentage of Reflective Cracking Appearing by 1975
	31.8 mm AC overlay and 12.7 mm ACFC overlay and	
2	Heater scarification with Petroset	3
3 and 4	Asphalt rubber under ACFC	4
13	Fiberglass	5
18A	Heater scarification with Reclamite	6
10	200/300 penetration	8
12	Petromat	12
15	Petroset in cracks	12
5	Asbestos	13
7	120/150 penetration Los Angeles Basin	14
11	Emulsion-treated AC	14
17	Reclamite flush	15
14	Petroset flush	16
	Control sections	17
9	120/150 penetration four corners	18
16	Reclamite in cracks	20
8	40/50 penetration Los Angeles Basin	20
1	Rubberized asphalt seal coat	19
6	50.8 mm AC, no ACFC	64

The percentage of area cracked after overlay was divided by the percentage of area cracked before overlay. This section ranking, one of the most important parts of this

study, clearly reveals those five treatments that were capable of significantly reducing reflective cracking when used in conjunction with an ACFC or other suitable open-textured surface. These percentages are particularly significant when a very thin overlay is used.

Generally, ridability is one of the key design criteria for both new pavements and rehabilitated old ones. Mays-Meter testing was performed before and after overlay treatment as shown below.

Test Section Number	Treatment	Percentage of Original Roughness
10	200/300 penetration	21
12	Petromat	26
13	Fiberglass	43
17	Reclamite flush	45
7	120/150 penetration Los Angeles Basin	48
9	120/150 penetration four corners	50
15	Petroset in cracks	50
—	Control section	57
14	Petroset flush	59
2	Heater scarification with Petroset	61
5	Asbestos	62
16	Reclamite in cracks	65
3	ACFC over rubberized seal coat	85
8	40/50 penetration	85
4	ACFC over rubberized seal coat	91
6	No ACFC	91
11	Emulsion-treated base	99
1	Rubberized seal coat	107

It was found that those sections constructed without ACFC (sections 1 and 6) or blade laid (section 11) gave the poorest performance. Test sections with ACFC over a chip seal (3 and 4) or with asphalt of a higher viscosity (8) performed slightly better. And, test sections with asphalt of lower viscosity (7, 9, and 10) or matting (12 and 13) performed the best.

We also found that basic asphalt properties influenced the reduction of reflective cracking more than any other property. The 400 kPa·s (4 million poise) at 25°C (77°F) viscosity [equivalent penetration about 45, absolute unaged viscosity of 0.3 kPa·s (3000 poise) at 60°C (140°F)] was critical to crack initiation. That is, the longer an asphalt can maintain a viscosity below 400 kPa·s, the less likely it is that reflective cracks will appear. Actual crack formation is triggered and intensified by cold temperatures. So once the asphalt reaches the 400-kPa·s level, it becomes highly susceptible to cracking. All system designs, then, should use asphalt of the lowest possible viscosity allowed by strength requirements and should use it in such a way that aging is retarded as much as possible.

CONCLUSION

This report, the culmination of over 4 years of careful planning, construction, and objective data analysis, provided much meaningful information that should be of value to federal, state, and local agencies restoring existing roadways and constructing new ones.

Our recommendations refer to overlays, in particular thin overlays of 10.2 cm (4 in) or less placed over badly cracked, rutted, or otherwise distorted bituminous pavements. Overlaying can also improve skid resistance and ridability. One should bear in mind, however, that no one treatment is a cure-all for bad roadway conditions. The following recommended crack-preventing treatments should rather be integrated into a total overlay design and carefully tailored to the nature of the distress.

Five treatments found to have significantly reduced reflective cracking are

Figure 4. Typical history of cracking on control section.

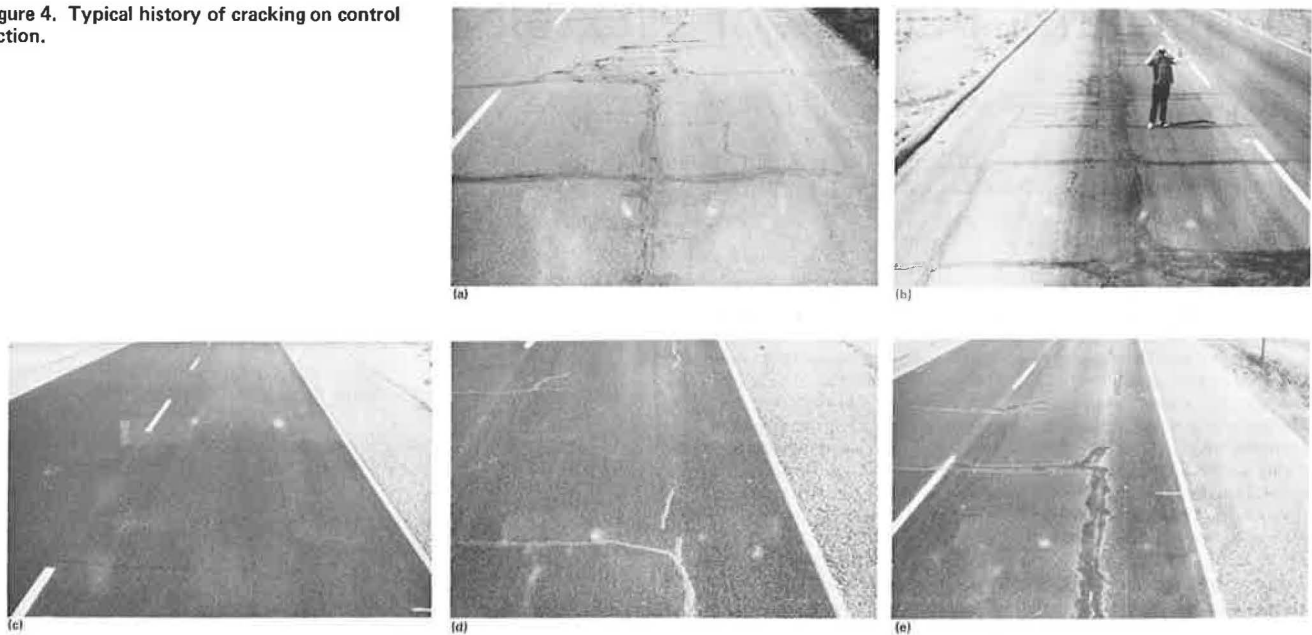


Table 1. Initial versus long-term costs of cracking treatments.

Treatment	Percentage of Reflective Cracking in 3 Years	Initial Cost per m ²	Cumulative 3-Year Maintenance Cost per m ²	Total Cost
50.8 mm AC, no ACFC	64	1.89	1.11	3.00
31.8 mm AC plus 12.7 mm open graded ACFC	17	1.87	0.75	2.62
31.8 mm AC plus 12.7 mm open graded ACFC plus treatment 200/300 penetration asphalt	8	1.87	0.14	2.00
Heater scarification plus Reclamite	6	2.28	0.10	2.38
Fiberglass	5	2.93	0.07	3.00
Asphalt rubber under ACFC	4	2.77	0.05	2.82
Heater scarification plus Petroset	3	2.28	0.05	2.33

Note: 1 mm = 0.039 in and 1 m² = 1.196 yd².

1. Heater scarification with Petroset,
2. Asphalt rubber membrane seal coat under ACFC,
3. Fiberglass membrane,
4. Heater scarification with Reclamite, and
5. 200/300 penetration asphalt.

As can be seen from the tables, some crack-preventing treatments compare quite favorably in price with cumulative maintenance cost figures. Application considerations are

1. One or more of the above treatments in combination should be used for all thin overlays of 10.2 cm (4 in) or less;
2. Heater scarification should always be to a depth of at least 19.1 mm (0.75 in);
3. AC asphalt of the lowest possible viscosity and the slowest aging characteristics should be used;
4. Applications using an asphalt rubber membrane seal coat under the AC or ACFC should be used with chips to provide direct transfer of vertical loads;
5. Fiberglass membrane material, although somewhat cumbersome to use during construction, could possibly be utilized during maintenance as a pre-overlay treatment on selected small areas;

6. Existing roadways being considered for overlay should be carefully investigated for possible stripping tendencies. Should stripping appear likely, efforts should be made either to give no structural value to the existing AC or to reconstruct the existing surface; and
7. Open-textured surfaces should be placed on top of densely graded overlays. This provides not only good skid resistance but improved appearance by hiding narrow reflective cracks.

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